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Cross-sectional analyses of online appointment booking and repeat prescription ordering user characteristics in general practices of England in the years 2018–2020

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ABSTRACT

Objectives To explore the characteristics of the General Practice Patient Survey (GPPS) respondents using the different functionalities of the online services in the context of England's National Health Service General Practices. We hypothesised that respondents who are older, with lower socioeconomic status and non-white ethnicity would be less likely to use online services, while long-term conditions might increase their usage.

Design Cross-sectional study using respondent-level data from the GPPS in England of the years 2018, 2019 and 2020. We assessed the association between online services use and respondent characteristics using two-level mixed-effects logistic regression.

Participants Survey respondents of the GPPS 2018–2020.

Primary outcome measures Online appointment booking and online repeat prescription ordering.

Results 1 807 049 survey respondents were included in this study. 15% (n=263 938) used online appointment booking in the previous 12 months, and 19% (n=339 449) had ordered a repeat prescription in the previous 12 months. Respondents with a long-term condition, on regular multiple medications, who have deafness or hearing loss and who are from the lowest deprivation quintile were more likely to have used online services. Male respondents (compared with females) and respondents with black and other ethnicity compared with white ethnicity were less likely to use online services. Respondents over 85 years old were less likely to use online appointment booking and online repeat prescription ordering compared with the younger age groups.

Conclusions Specific groups of respondents were more likely to use online services such as patients with long-term conditions or those with deafness or hearing loss. While online services could provide efficiency to patients and practices it is essential that alternatives continue to be provided to those that cannot use or choose not to use online services. Understanding the different patients' needs could inform solutions to increase the uptake and use of the services.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study used a sample from a major national survey which has developed a robust methodology in its data collection to explore the characteristics of online services users, a service which has been highly advocated in the National Health Service and in other healthcare systems of the world.
⇒ Given the clustered nature of the data (where patients are registered to different general practices) and to account for the clustering, we used multilevel logistic regression analysis.
⇒ The study used only complete-case data in the analyses, which risked sample bias.
⇒ The study relied on self-reported data for online service use due to data unavailability which can lead to response bias.

BACKGROUND

Online services such as online appointment booking or repeat prescription ordering are offered in 99.7% of General Practitioner (GP) practices in England,[1] but patients have to request access to the service and adoption remains low (about 50% in May 2023).[1] According to previous literature, online services, also referred to as patient portals, have the potential to promote patients' involvement in their care, reduce emergency visits and hospitalisation[2] and may improve some health outcomes through improving medication adherence[2 3] patients' knowledge about health and patient efficacy (eg, patient's confidence in adhering to health instructions or treatment).[4] Few studies have examined the characteristics of patients using online services and the inequalities that might exist based on patient characteristics in the context of the National Health Service (NHS) of England such as ethnicity and deprivation inequalities.[5–7] Understanding patient characteristics associated with online service use may reveal barriers to use and may

inform service planning to increase the uptake of these services.

Studies from other countries, and a limited number of studies from the UK, suggest that[7–10] patients with low income, and with non-white ethnicity may be less likely to use patient portals due to reduced access to the internet, computers and smartphones.[8 10] This is the first study to look at online services user characteristics for both online appointment booking and repeat prescription ordering explicitly in England, where the NHS have invested in a nation-wide digital transformation programme.[11]

Healthcare systems are characterised as complex systems and healthcare innovations often face multifaceted challenges in diffusion ('passive spread') and adoption due to the nature of complex systems.[12] A major theory considered in healthcare innovation adoption is the digital divide theory which highlights the inequality that arises when people without access to technology (that is physical access but also access to the knowledge and skills to use the technology) are excluded from the benefits that technology has to offer.[13–15] In consideration of the digital divide theory,[13–15] we formulated several hypotheses based on respondent characteristics and knowledge from previous literature. We hypothesised that:

1. The younger age group (younger than 35 years old) to be more likely to use online services due to the high adoption of technology in this age group and their familiarity with the use of the internet.[16]
2. Individuals of lower socioeconomic status and minority ethnicities to be less likely to use online services as this has been reported in several studies looking into the use of patient portals and patient characteristics.[8 17–19]
3. In consideration of individuals' health status, we hypothesised that respondents with long-term or chronic conditions (but not those who are very ill) may be more likely to use online services because of their increased need to access and use the services such as appointment booking and repeat prescription. Additionally, people with long-term conditions have certain physical limitations and socioeconomic circumstances that could be associated with their ability to access healthcare services in person.

Thus, we aimed to examine which respondent characteristics were associated with online appointment booking and repeat prescription service ordering and test the hypotheses that we formulated.

METHODS

Patient and public involvement

This study had limited involvement from the National Institute for Health Research Applied Research Collaboration of Northwest London Public Advisors, whom were consulted during the study write-up and were involved appropriately in the drafting.

Study design

Cross-sectional analyses of respondent-level data obtained from the General Practice Patient Survey (GPPS) of 2018, 2019 and 2020 in England. The respondent-level data were pseudonymised. The researchers did not have access to the respondents' identifies: name, address, NHS number and date of birth. Respondent-level data are only presented aggregately to protect respondents' privacy as agreed in the ethical approval of the study. Data collection for each survey was between January and March for the years 2018 and 2019 and between January and April for 2020. Respondents in the survey had the right to withdraw their consent before their data were processed.[20]

Variables

Outcome variables

The outcome variables (online appointment booking use and online repeat prescription use) were based on the responses to the GPPS question: 'Which of the following general practice online services have you used in the past 12 months?'[21] in which the answers 'Booking appointments online', and 'Ordering repeat prescriptions online' were used for this study. We compared the characteristics of those who replied 'yes' to the question to those who replied 'no' to the question. The answers 'yes' and 'no' were provided by the GPPS for each of the options: 'Booking appointments online', and 'Ordering repeat prescriptions online'. The GPPS also records the use of online record viewing. However, we did not include it in this study due to the limited number of respondents reporting the use of the functionality (about 5% in 2020 and lower proportions in 2019 and 2018).

Explanatory variables

Ten different covariates (explanatory variables) were included in the models as listed in table 1. Variables were selected based on:

1. Factors that have been identified in the literature as being associated with patient portal use, such as long-term condition status, deafness or hearing loss and parent and carer status, and
2. Data availability such as taking five or more medications regularly (another indicator for healthcare status).

Data source

The GPPS is a national, postal survey commissioned by NHS England. GPPS uses random sampling, proportionately stratified by GP practice, age and gender. Eligibility for GPPS includes having a valid NHS number, being 16 years or older and being registered with a GP practice for at least 6 months. Response rates of previous surveys are considered, sending more surveys to low-response practices and fewer surveys to high-response practices.[22–24] The survey was sent to 2 221 068, 2 328 560, 2 329 590 respondents in the years 2018, 2019 and 2020, with response rates of 34%, 33% and 32%, respectively.[22–24]

Table 1 The list of variables included in the two-level regression models of the study and their definitions

Variable	Categories and definition
Gender	Male, female
Age (bands)	16–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, 85 or over (as categorised by the survey)
Ethnicity	White, mixed, Asian, black, other (five broad groups derived from 18 ethnicity categories published by the Office of National Statistics (ONS) categories[50])
Survey year	2018, 2019 or 2020 (created based on the year of the survey)
Long-term conditions	Yes, no or 'I don't know/Can't answer' answers to the question: 'Do you have any long-term physical or mental health conditions, disabilities or illnesses?'[21]
Deafness or hearing loss	Yes or no answer to the question: 'Which, if any, of the following long-term conditions do you have?… Deafness or hearing loss'[21]
Taking five or more medications on a regular basis	Yes or no answer to the question: 'Do you take 5 or more medications on a regular basis?'[21]
Parent status	Yes or no answer to the question: 'Are you a parent or a legal guardian for any children aged under 16 living in your home?'[21]
Carer status	Yes or no answer derived from the answers to the question: 'Do you look after, or give any help or support to family members, friends, neighbours or others because of either: long-term physical or mental ill health / disability, or problems related to old age?' [21]
Index of Multiple Deprivation (IMD) quintiles	The GPPS provided a variable called deprivation rank for all respondents included in the survey which was defined as: ONS IMD score—deprivation banding based on respondents' postcode. We converted the ONS IMD scores provided by GPPS to IMD quintiles using the English indices of deprivation 2019 guidance.[51] We chose the deprivation quintile instead of deciles or IMD ranking to reduce the number of categories in the model while accounting for a potential predictor of online services use (deprivation)[52] and to duplicate the same categories used in previous GPPS analyses.[5 6 52]
Rurality of the General Practice	A variable provided by GPPS based on the GP practice's postcode categorised as rural or urban as defined by the ONS[53] rural or urban as defined by the ONS.[53]

GP, General Practitioner; GPPS, General Practice Patient Survey.

In March 2020, social restrictions were announced in England due to the COVID-19 pandemic.[25] The last data collected for the GPPS was in April 2020, however, only a small number of surveys were received post March 2020 with the GPPS indicating it was highly unlikely that the survey results were affected by the pandemic.[23]

Study population

We obtained data from respondents who completed the GPPS surveys in 2018, 2019 and 2020 and only included the respondents who answered either 'yes' or 'no' to using online appointment booking and/or online repeat prescription ordering as described in the variables section above. We then removed respondents who did not have complete data for the variables of interest.

Statistical analyses

We first reported descriptive statistics of the respondents based on their online appointment booking and repeat prescription use. All of the included variables in this study were categorical. We first tabulated each exploratory variable by the outcome variables and compared them using χ^2 test. We then performed univariate analysis between each of the explanatory variables and the outcome variable to check if they converge and to examine the coefficients. Collinearity was avoided by using the same set of variables used in previous studies analysing online services use using GPPS data,[5] and checking for collinearity after the analysis was completed. To perform multilevel mixed-effects logistic regression models: First, we created null models with only the outcome variables and random intercepts (GP practices) to understand if there was clustering due to the random intercepts. We then added all respondent level covariates to the models (model 2) (most of the variables in the final models were respondent level variables). We checked the Intraclass Correlation Coefficient (ICC) and intercepted all models to examine the effect of clustering. We then added the GP practice level variable (GP practice rurality) in the final models (model 3).[26] After completing all analyses, we also performed model diagnostics to check the best fit model and checked for multicollinearity by calculating the variable inflation factor (VIF). Model diagnostics was performed by calculating Bayesian information criterion (BIC) and comparing the BIC of the different versions of the models. The model with the lowest BIC was considered the best fit model.[27] VIF values greater than 5 indicated collinearity.[28] The statistical analyses were performed using RStudio software V.1.4.1717.

Sensitivity analyses

The methods used in the sensitivity analyses are described in online supplemental table 1. Because this study included only complete case participants, we ran a sensitivity analysis to predict the outcome this decision may have had on the main analyses. To do this, we first categorised GP practices, according to the proportion of complete case participants available, into three groups: highest missing data group (75% of the participants in these practices had missing data), middle-range missing data group (26–74% of the participants in these practices had missing data) and lowest missing data group (25% or less of the participants in these practices had missing data). We next categorised the complete-case participants according to the proportion of missing data in their GP practices using the three categories (highest, middle-range and lowest missing data groups) and then ran the same analyses described in the statistical analyses subsection above.

We completed the Strengthening the Reporting of Observational Studies in Epidemiology checklist to review the methods of the study[29] (online supplemental table 2).

RESULTS

Some of the results of this study were presented in a conference abstract.[30]

Sample size

We received data from 2 246 109 respondents who completed the GPPS surveys in 2018, 2019 or 2020. After removing respondents that did not have complete data for the variables of interest (n=439 060), 1 807 049 (80.5%) respondents were included.

Summary statistics

1 807 049 respondents were included of which 15% (n=263 938) used online appointment booking (used at least once in the previous 12 months), and 19% (n=339 449) used online repeat prescription (used at least once in the previous 12 months). Of the respondents, 55.1% were women, 22% in the 65–74 years age group, 86.8% self-identified as having white ethnicity, 83.1% were registered at GP practices in an urban area and half (51.1%) had a self-reported long-term condition (table 2).

About 19.5% of the total population sample received from GPPS was excluded due to missing data. The proportion of respondents by category in the excluded respondents were different to the complete case data set in the proportions for age, ethnicity (most respondents were from the mixed ethnicity), survey year, long-term condition, taking five or more medications, reporting of deafness or hearing loss and slight difference in deprivation fifths proportions (online supplemental table 3). However, when comparing the complete case sample to the total sample received, the differences in proportions between the two categories are very small and vary between 1 and −2% (online supplemental table 3).

Descriptive statistics of the sensitivity analysis groups are displayed in online supplemental table 4. GP practices with the highest proportion of missing data (practices with 75% or more of respondents with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a higher proportion of respondents with black, Asian and other ethnicities, as well as higher proportion or respondents from the most deprived group compared with the GP practices with lower missing data.

Respondent and GP practice characteristics associated with online services' use

The results of the univariate analysis are in the online supplemental table 5.

Online appointment booking

Results of the two-level mixed-effects logistic regression for the online appointment booking outcome are presented in table 3. Respondents with a long-term condition, taking five or more medications on a regular basis and who have deafness or hearing loss were more likely to use online appointment booking compared with respondents without these characteristics. In the fully adjusted model for respondent and GP practice characteristics, respondents with a long-term condition had 67% greater odds of using online appointment booking (OR: 1.67, 95% CI: 1.66 to 1.69) compared with respondents without a long-term condition.

Respondents with black and 'other' ethnicity had lower odds than those with white ethnicity for using online appointment booking, whereas respondents with Asian ethnicity had 11% (OR: 1.11, 95% CI: 1.09 to 1.13) greater odds of using online appointment booking.

There was an inverse association between deprivation quintile and online appointment booking. The odds for using online appointment booking increased with reducing deprivation from the second to fifth (least deprived) quintiles compared with the most deprived quintile. Respondents in the least deprived quintile had 54% greater odds of booking appointments online (OR: 1.54, 95% CI: 1.51 to 1.57) compared with those in the most deprived quintile. Respondents from the survey year 2020 were the most likely to use online appointment booking compared with respondents from the survey year 2018 and 2019.

Respondents from GP practices located in an urban setting had 11% greater odds of booking appointments online compared with respondents from GP practices in a rural setting (OR: 1.11, 96% CI: 1.07 to 1.16).

Model comparison: The ICC of 0.13 indicates that there is a slight similarity between values from the same group (in this case from the same GP practice) although the difference is not large because the value is close to zero.

Table 2 Descriptive statistics of the number and proportion of respondent characteristics in the total population included in the analyses (n=1 807 049), categorised by online services use

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1 807 049)	No (N=1 543 111)	Yes (N=263938)	P value*	No (N=1 467 600)	Yes (N=339 449)	P value†
Gender				<0.001			0.97
Female	996544 (55.1%)	843422 (54.7%)	153122 (58.0%)		809337 (55.1%)	187207 (55.2%)	
Male	810505 (44.9%)	699689 (45.3%)	110816 (42.0%)		658263 (44.9%)	152242 (44.8%)	
Age (bands)				<0.001			<0.001
16–24	74381 (4.1%)	64513 (4.2%)	9868 (3.7%)		67069 (4.6%)	7312 (2.2%)	
25–34	159806 (8.8%)	132951 (8.6%)	26855 (10.2%)		141376 (9.6%)	18430 (5.4%)	
35–44	217687 (12.0%)	181290 (11.7%)	36397 (13.8%)		186112 (12.7%)	31575 (9.3%)	
45–54	302285 (16.7%)	253145 (16.4%)	49140 (18.6%)		243458 (16.6%)	58827 (17.3%)	
55–64	381808 (21.1%)	321902 (20.9%)	59906 (22.7%)		295168 (20.1%)	86640 (25.5%)	
65–74	397999 (22.0%)	340484 (22.1%)	57515 (21.8%)		303875 (20.7%)	94124 (27.7%)	
75–84	211586 (11.7%)	191217 (12.4%)	20369 (7.7%)		176214 (12.0%)	35372 (10.4%)	
85+	61497 (3.4%)	57609 (3.7%)	3888 (1.5%)		54328 (3.7%)	7169 (2.1%)	
Ethnicity				<0.001			<0.001
White	1567690 (86.8%)	1340202 (86.9%)	227488 (86.2%)		1258828 (85.8%)	308862 (91.0%)	
Black	52950 (2.9%)	46120 (3.0%)	6830 (2.6%)		47195 (3.2%)	5755 (1.7%)	
Asian	137026 (7.6%)	115015 (7.5%)	22011 (8.3%)		118728 (8.1%)	18298 (5.4%)	
Other	29168 (1.6%)	24993 (1.6%)	4175 (1.6%)		25773 (1.8%)	3395 (1.0%)	
Mixed	20215 (1.1%)	16781 (1.1%)	3434 (1.3%)		17076 (1.2%)	3139 (0.9%)	
Survey year				<0.001			<0.001
2018	612084 (33.9%)	536349 (34.8%)	75735 (28.7%)		512184 (34.9%)	99900 (29.4%)	
2019	623358 (34.5%)	534321 (34.6%)	89037 (33.7%)		507522 (34.6%)	115836 (34.1%)	
2020	571607 (31.6%)	472441 (30.6%)	99166 (37.6%)		447894 (30.5%)	123713 (36.4%)	
Long-term condition				<0.001			<0.001
No	833523 (46.1%)	730177 (47.3%)	103346 (39.2%)		736861 (50.2%)	96662 (28.5%)	
I do not know/cannot answer	49746 (2.8%)	43186 (2.8%)	6560 (2.5%)		43212 (2.9%)	6534 (1.9%)	
Yes	923780 (51.1%)	769748 (49.9%)	154032 (58.4%)		687527 (46.8%)	236253 (69.6%)	
Taking five or more medications on a regular basis				<0.001			<0.001
No	1343735 (74.4%)	1151312 (74.6%)	192423 (72.9%)		1118704 (76.2%)	225031 (66.3%)	
Yes	463314 (25.6%)	391799 (25.4%)	71515 (27.1%)		348896 (23.8%)	114418 (33.7%)	

Continued

Table 2 Continued

Characteristics	Total	Online appointment booking in the previous 12 months			Online repeat prescription ordering in the previous 12 months		
	Total (N=1 807 049)	No (N=1 543 111)	Yes (N=263938)	P value*	No (N=1 467 600)	Yes (N=339 449)	P value†
Deafness or hearing loss				<0.001			<0.001
No	1 652 099 (91.4%)	1 409 236 (91.3%)	242 863 (92.0%)		1 344 856 (91.6%)	307 243 (90.5%)	
Yes	154 950 (8.6%)	133 875 (8.7%)	21 075 (8.0%)		122 744 (8.4%)	32 206 (9.5%)	
Parent or legal guardian to a 16-year-old or younger				<0.001			<0.001
No	1 466 017 (81.1%)	1 254 880 (81.3%)	211 137 (80.0%)		1 177 272 (80.2%)	288 745 (85.1%)	
Yes	341 032 (18.9%)	288 231 (18.7%)	52 801 (20.0%)		290 328 (19.8%)	50 704 (14.9%)	
Carer				<0.001			<0.001
No	1 462 467 (80.9%)	1 254 985 (81.3%)	207 482 (78.6%)		1 200 653 (81.8%)	261 814 (77.1%)	
Yes	344 582 (19.1%)	288 126 (18.7%)	56 456 (21.4%)		266 947 (18.2%)	77 635 (22.9%)	
Deprivation quintile				<0.001			<0.001
1 (most deprived)	338 728 (18.7%)	298 412 (19.3%)	40 316 (15.3%)		292 405 (19.9%)	46 323 (13.6%)	
2	353 580 (19.6%)	304 870 (19.8%)	48 710 (18.5%)		296 229 (20.2%)	57 351 (16.9%)	
3	376 042 (20.8%)	322 081 (20.9%)	53 961 (20.4%)		304 048 (20.7%)	71 994 (21.2%)	
4	378 002 (20.9%)	319 100 (20.7%)	58 902 (22.3%)		297 096 (20.2%)	80 906 (23.8%)	
5 (least deprived)	360 697 (20.0%)	298 648 (19.4%)	62 049 (23.5%)		277 822 (18.9%)	82 875 (24.4%)	
General practice rurality				<0.001			<0.001
Rural	306 200 (16.9%)	263 405 (17.1%)	42 795 (16.2%)		238 353 (16.2%)	67 847 (20.0%)	
Urban	1 500 849 (83.1%)	1 279 706 (82.9%)	221 143 (83.8%)		1 229 247 (83.8%)	271 602 (80.0%)	

*P value derived from χ^2 test comparing online appointment booking users and non-users.
†P value derived from χ^2 test comparing online repeat prescription users and non-users.

Table 3 Two-level mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on online appointment booking use in the previous 12 months (level 1, N=1 807 049 respondents; level 2, N=7256 general practices)

	Respondent characteristics + GP practice characteristics (model 3)	
Predictors	**ORs**	**95% CI**
Long-term condition (REF=no)		
Long-term condition—I do not know/cannot say	1.15***	(1.12 to 1.19)
Long-term condition—yes	1.67***	(1.66 to 1.69)
Taking five or more medications on a regular basis—yes (REF=no)	1.19***	(1.18 to 1.20)
Deafness or hearing loss—yes (REF=no)	1.13***	(1.11 to 1.15)
Gender—male (REF=female)	0.89***	(0.88 to 0.90)
Age (bands) (REF: 85+)		
16–24	3.63***	(3.48 to 3.78)
25–34	4.96***	(4.78 to 5.14)
35–44	4.85***	(4.68 to 5.03)
45–54	4.26***	(4.12 to 4.42)
55–64	3.69***	(3.57 to 3.82)
65–74	3.09***	(2.99 to 3.20)
75–84	1.74***	(1.68 to 1.80)
Ethnicity (REF: white)		
Black	0.84***	(0.81 to 0.86)
Asian	1.11***	(1.09 to 1.13)
Other	0.96**	(0.92 to 0.99)
Mixed	1.04	(1.00 to 1.08)
Parent or legal guardian to a 16-year-old or younger—yes (REF=no)	0.92***	(0.90 to 0.93)
Carer—yes (REF=no)	1.14***	(1.13 to 1.16)
Deprivation quintile (REF: 1—most deprived)		
2	1.15***	(1.13 to 1.17)
3	1.27***	(1.25 to 1.29)
4	1.40***	(1.37 to 1.42)
5 (least deprived)	1.54***	(1.51 to 1.57)
Survey year (REF=2018)		
2019	1.19***	(1.18 to 1.20)
2020	1.52***	(1.50 to 1.54)
General practice rurality—urban (REF=rural)	1.11***	(1.07 to 1.16)
Model summary		
ICC	0.13	

*p value=0.05, **p value≤0.01, ***p value≤0.001.
GP, General Practitioner; ICC, Intraclass Correlation Coefficient.

Sensitivity analyses

Results of the sensitivity analysis for online appointment booking are in the online supplemental table 6. Most of the predictor variables in online supplemental table 6 had similar ORs and/or overlapping CIs when comparing the respondents from the practices with the different proportion of missing data. The difference in ORs when comparing respondents from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality. The differences between the ORs based on the deprivation quintile for online repeat prescription were also bigger than online appointment booking in all the categories of GP practices. Most of the ORs that were statistically significant remained significant for the different analyses by practice size, except for the ethnicity groups including: Asian, other and mixed categories which may reflect the differences in ethnic representation in each of the sensitivity analyses categories.

Online repeat prescription ordering

Results of the two-level mixed-effects logistic regression for the online repeat prescription ordering outcome are presented in table 4. Respondents with a long-term condition, users of five or more medications on a regular basis and respondents with deafness or hearing loss were all more likely to use online repeat prescription ordering compared with respondents without these characteristics. The odds of using online repeat prescription ordering were 2.58 times greater (OR: 2.58, 95% CI: 2.55 to 2.60) for respondents with a long-term condition compared with those without a condition.

Black, Asian and mixed ethnicities had lower odds of using online repeat prescription ordering compared with the white ethnicity.

Respondents in the deprivation quintiles 4 and 5 (least deprived) had the highest odds of using online repeat prescription ordering compared with the most deprived group (OR: 1.62, 95% CI: 1.59, 1.64) and (OR: 1.77, 95% CI: 1.74, 1.80), respectively.

Respondents who completed the survey in the years 2019 and 2020 had greater odds of using online repeat prescription ordering compared with respondents from the survey year 2018. Respondents from GP practices located in an urban setting had lower odds of ordering repeat prescriptions online compared with respondents from GP practices in a rural setting.

Model comparison

The ICC was 0.08 for model 3 in table 4, which also showed that there is slight evidence that respondents from the same GP practices may have more similar results compared with respondents from other GP practices.

Table 4 Two-level mixed-effects multivariable logistic regression of General Practice Patient Survey respondent characteristics on online repeat prescription ordering use in the previous 12 months (level 1, N=1 807 049 respondents; level 2, N=7256 general practices)

	+GP practice characteristics (model 3)	
Predictors	**ORs**	**95% CI**
Long-term condition (REF=no)		
Long-term condition—I do not know/cannot say	1.25***	(1.22 to 1.29)
Long-term condition—yes	2.58***	(2.55 to 2.60)
Taking five or more medications on a regular basis—yes (REF=no)	1.26***	(1.25 to 1.28)
Deafness or hearing loss—yes (REF=no)	1.02**	(1.00 to 1.03)
Gender—male (REF=female)	0.96***	(0.96 to 0.97)
Age (bands) (REF: 85+)		
16–24	1.71***	(1.64 to 1.77)
25–34	2.17***	(2.10 to 2.23)
35–44	2.69***	(2.61 to 2.77)
45–54	3.18***	(3.10 to 3.28)
55–64	3.28***	(3.20 to 3.37)
65–74	3.01***	(2.93 to 3.09)
75–84	1.68***	(1.64 to 1.73)
Ethnicity (REF: white)		
Black	0.76***	(0.74 to 0.78)
Asian	0.94***	(0.93 to 0.96)
Other	0.78***	(0.75 to 0.81)
Mixed	0.98	(0.94 to 1.02)
Parent or legal guardian to a 16-year-old or younger—yes (REF=no)	0.95***	(0.94 to 0.96)
Carer—yes (REF=no)	1.16***	(1.15 to 1.17)
Deprivation quintile (REF: 1—most deprived)		
2	1.23***	(1.21 to 1.25)
3	1.44***	(1.42 to 1.46)
4	1.62***	(1.59 to 1.64)
5 (least deprived)	1.77***	(1.74 to 1.80)
Survey year (REF=2018)		
2019	1.18***	(1.17 to 1.19)
2020	1.46***	(1.44 to 1.47)
General practice rurality—urban (REF=rural)	0.88***	(0.85 to 0.91)
Model summary		
ICC	0.08	

*p value=0.05, **p value≤0.01, ***p value≤0.001.
GP, General Practitioner; ICC, Intraclass Correlation Coefficient.

Sensitivity analyses

Results of the sensitivity analysis for the repeat prescription outcome are in online supplemental table 7. Differences (compared with the main analysis) in ORs were seen for the long-term condition (answering yes), age groups, ethnicity, being a parent, being a carer and for the deprivation quintile. Among respondents from practices with 75% or more respondents with missing data, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82 to 1.97) higher odds of online repeat prescription use compared with respondents from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59 to 1.71) in the lowest missing data GP practice respondents. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile was associated with bigger differences in the odds associated with the outcome for respondents from the highest missing data GP practices compared with the other GP practices.

Model diagnostics

The VIF values for all explanatory variables in our fixed-effects logistic regression models for both outcomes (online appointment booking and online repeat prescription ordering) were below the threshold of 5 (ranging from 1 to 1.8) indicating that there is no evidence of multicollinearity among the explanatory variables. In terms of model diagnostics, BIC values of each of the models (null model, model 2 and model 3) were compared with each other to make sure that the model presented is the best fit model (the model with the lowest BIC). The values of BIC for all the models for each outcome are summarised in table 5 below.

DISCUSSION

Principal findings

Overall, the findings of the study indicate that indicators of increased healthcare need and socioeconomic disadvantage predicted variations in the use of two types of online services and use of these services increased over the 3 years studied. Contrary to our hypothesis about age, we observed different variability in the relationship between age and online services use. Respondents younger than 35 years old were not the only highest users of online services as respondents of the age groups 35–84 were all more likely to use online services compared with

Table 5 Model diagnostics results (namely BIC, Bayesian information criterion) for both outcomes and for each of the models (null model, model 2 and model 3)

Model	Value of BIC for the online appointment booking outcome models	Value of BIC for the online repeat prescription ordering outcome models
Null model	1 434 808	1 692 919
Model 2	1 398 822	1 601 232
Model 3	1 398 807	1 601 182

respondents of the age group 85 years old and older. Our findings partially confirmed our hypotheses regarding lower socioeconomic status and minority ethnicities aligning with our expectations that these respondent groups were less likely to use online services. A notable alignment with our hypothesis was observed in the relationship between online services use and long-term conditions. Respondents with long-term conditions were more likely to use online services both online appointment booking and repeat prescription ordering.

Strengths and weaknesses of the study

Strengths

This study used a major national survey which uses robust research methodology in its data collection process and used suitable analysis methodology for processing the data (accounting for GP practice variation in the models and accounting for missing data in the sensitivity analyses). The study explored online services user characteristics in England which can inform service planning and can identify patient groups who may need support using these services.

We accounted for clustering in our data presenting respondent level data in which respondents' belonged to different GP practices, by using multilevel logistic regression model which is an analysis methodology that takes into account the hierarchy in the data.[31] Clustering by GP practice was important not only because respondents from the same GP practice may be more similar to each other, but patient portal functionalities and promotion of online services (such as providing training, posters, emails and reminders) to use online services may vary from one GP practice to another.[32]

Limitations

A limitation of the study was using only complete-case data in the analyses, which risked sample bias. Respondents excluded from the analyses due to missing data presented differences in the breakdown of respondent characteristics. Therefore, we performed sensitivity to explore what kind of differences might have been observed if there were no exclusions. Comparing summary statistics of the excluded sample and the sensitivity analyses showed that GP practices with more missing data were more likely to have younger age groups, greater deprivation groups and ethnically diverse groups, all of which were associated with relatively lower odds of using online services. This introduces the possibility that some of the ORs presented in the main analysis may be overestimated in the population due to missing data bias.

However, although most of the estimates of effect were slightly different in the sensitivity analyses compared with the main analyses, there was no change in terms of the direction of the effects. For example, ORs that were larger than one in the main analyses remained larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that differences in online services use between the three categories of GP practices were bigger for online repeat prescription use compared with the online appointment booking use.

As with all survey-based studies, a major potential limitation of the GPPS is non-response bias. However, a study on the methodology of the GPPS, did not find evidence of non-response bias.[33] We tried to alleviate non-response bias by controlling for deprivation, ethnicity, age and gender (which can often be associated with low-response rates as reported in a study examining GPPS non-response characteristics[33]).

Strengths and weaknesses in relation to other studies

This study relied on self-reported online service usage which could introduce response bias.[34] A potentially better way to measure use of online appointment booking and repeat prescription ordering could be via the electronic patient portal log files. The log files automatically record patient portal activity and can serve as an objective method to examine patient portal use because these are not subject to recall bias and record the exposure prior to the outcome.[3] However, due to data unavailability of patient-level data of this kind at the time of the study, the GPPS records of online services use were used in this study in other England-based studies exploring online services' use.[5 6]

Discussing important differences in results

People from more deprived areas, and from ethnic minorities were reported to have lower uptake of patient portals in previous studies.[35] According to previous studies, deprivation and ethnicity play key roles in online services use[36–38] which were confirmed by the main analysis and sensitivity analyses in this study. A survey study from the USA suggested that respondents' ethnicity could be associated with less trust in patient portals.[18] Reduced use of online services by respondents with greater deprivation levels has been reported multiple times in the literature.[19] This may be due to worse access to the internet, smartphone and computers among individuals from more deprived areas.[7 39]

Meaning of the study

There is evidence that online services use in England is increasing every year and it is likely to continue to be an important tool in GP practice settings. Although online services have been offered almost universally in GP practices in England since 2015, there continues to be a lack of research on the use of online services (or patient portals) in primary care.[7 40] Understanding the needs of populations less likely to use online services may help to improve the uptake of these services and to better meet the needs of vulnerable populations which are more likely to have reduced access to healthcare services[41] in addition to online services.

According to the theory of the digital divide,[14 15] using technologies such as patient portals may require more than just having access to a computer. Skills such as digital literacy and eHealth literacy may be essential to enable the

use of these services. Lack of education is also considered a detrimental factor contributing to the digital divide.[42] While our study did not directly investigate the mechanisms of the digital divide, it provides valuable insight into the disparities that may exist in the use of online services. Factors associated with reduced use of online services, like lower socioeconomic status indicators, may relate to challenges such as limited digital skills and inadequate access to technology.[13] Understanding the specific challenges faced by different patient groups in accessing and using online services can help healthcare staff and policymakers to develop tailored strategies to bridge the digital divide[43] and to ensure fair access to online services. Further investigation, employing quantitative and qualitative approaches, can enhance our understanding of the mechanisms influencing individual technology adoption.

We hypothesised that younger populations would be more likely to use and have access to technologies, but we could not see that pattern in the study, possibly because young people are less likely to need the healthcare system and services, such as appointment booking and repeat prescription requests. Additionally, this may be due to the complex mechanisms that may be involved in individuals opting to use online services which may be driven by social factors not included in this study.

Possible explanations and implications for clinicians and policymakers

The adoption of online services by those with long-term conditions is promising and can potentially contribute to improving self-management of long-term conditions.[2] However, there is evidence that people with long-term conditions may generally be more likely to use healthcare services.[44–46] Practices should continue to encourage and support people with long-term conditions to sign up and use online services. However, it is essential that alternatives to online services continue to be provided to people who are unwilling or unable to use these services.[44–46]

This study shows that online services' use is lower among people from more deprived areas and from ethnic minorities, which may increase inequities if in-person services become further out of reach. As an example, the move to telephone consultations and remote triage in GP practices amidst the COVID-19 pandemic made it difficult for homeless people to access care, due to not having a telephone or if having a telephone, not being able to pay for the call.[47] However, the study only interviewed 21 people experiencing homelessness and may not be representative of the experience of all people under similar circumstances in England.[47] In-person access to care is seen as necessary to reach all patient groups, despite using access to technology to support moves to increased remote consultations in the COVID-19 pandemic.[47] For this reason, it is important that practices continue to provide in-person access (eg, for appointment booking and repeat prescriptions) to patients especially those less able to access remote services. Training GP practice staff to promote and to support the increased use of online services is already occurring in some GP practices[32] and we can continue to recommend providing training to increase use.

Unanswered questions and future research

Further research is needed to understand low uptake of online services in some patient groups, and to clarify if this is due to barriers or due to peoples' preference. During the COVID-19 pandemic, when patients are asked to contact their GP practice remotely,[48] variable access and use of the online services may have exacerbated inequities in situations where online services became the only route to access care.[49] Although this study's findings relate to the pre-COVID-19 period, the patterns in disparities may have persisted or worsened in the post-COVID-19 period amidst the move to increasing the delivery of GP services remotely.

Future research could explore how remote services might affect aspects of the healthcare system such as healthcare usage and patients' self-management of their conditions. Our future research aim is to study patient portal use in GP practices in England using electronic health records instead of relying on individuals' self-reporting. We will explore the association between patient portal use and health outcomes and on healthcare usage to better understand its impact on health and the healthcare system.

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Contributors AA, GG, TB and CEC created the study design, formulated the research question and finalised the study methodology. AA performed the analysis of the study. JN contributed to the introduction and discussion sections of the study. AA is responsible for the overall content as the guarantor. All authors reviewed and approved the submitted manuscript.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval This study was approved by the Imperial College Research Ethics Committee, Reference number: 20IC6303. Respondents of the survey provided informed consent to take part in the research by allowing us to use their anonymised survey data, but they had the right to withdraw their consent before these data were processed.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The data that support the findings of this study are available on request from Ipsos Mori but cannot be provided by the authors due to ethical restrictions. However, the aggregate level GPPS data are openly available in the GP Patient Survey webpage at https://www.gp-patient.co.uk/.

of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

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Supplementary material:

Supplementary Table 1**. Methods and results of the sensitivity analysis**

Methods	In the main analyses performed in this study, only complete case respondents (respondents that did not have any missing data for any of the variables included in the analyses) were included. We ran sensitivity analyses to explore the effects of excluding respondents with missing data. We first calculated the proportion of respondents with complete data per practice using the complete dataset (n=2198821) and assigned each practice a new variable indicating the proportion of complete case respondents in the practice. We then separated the complete case respondents (n=1807049) into three categories based on the proportion of complete case respondents in their practice. The three categories were: highest missing data group (≥75%), middle-range missing data group (26-74%), and lowest missing data group (≤25%). We then ran the same two-level mixed-effects models for each of the outcomes (online appointment booking and online repeat prescription use) separately for each of the three categories.
Results	The summary statistics of the sensitivity analysis groups are reported in table Supplementary Table 5. GPs with the highest proportion of missing data (practices with

	75% or more of respondents with missing data) had slightly higher percentage of younger age groups from 16 to 44 and they had a greater proportion of respondents from Black, Asian and Other ethnic backgrounds as well. Greater proportion or respondents from the most deprived group compared to the GPs with lower missing data. Results of the sensitivity mixed-effects regression analyses for the online appointment booking outcome is in table Supplementary Table 6. Most of the predictor variables in Supplementary Table 6 had similar odds ratios and/or overlapping confidence intervals when comparing the respondents from the practices with the different proportion of missing data. The difference in odds ratios when comparing respondents from the three different practice types (based on the proportion of missing data) were seen in the predictors: having a long-term condition (answering yes), age group, ethnicity, parent status, carer status, year of survey and GP rurality. These differences indicate that the characteristics of respondents within each type of the GPs (based on the proportion of missing data) were more similar to each other than the other type of practices. For the repeat prescription outcome (Supplementary Table 7), differences in odds ratios were also seen for the long-term condition (answering yes), age groups, ethnicity, being a parent, being a carer and for the deprivation quintile. Among the highest missing data GP practice respondents, the least deprived group had 89% (OR: 1.89, 95% CI: 1.82-1.97)

	greater odds of online repeat prescription use compared to respondents from the most deprived group where this percentage was only 65% (OR: 1.65, 95% CI: 1.59-1.71) in the lowest missing data GP practice respondents. This indicates that deprivation has a larger impact in practices with the most missing data compared to practices with the least missing data for the online repeat prescription ordering outcome. Sensitivity analyses results reveal that some of the estimates in this study may be attenuated if missing data/non-response respondents were present. However, although most of the estimates of effect were slightly different in the sensitivity analyses compared to the main analyses, there was no change in terms of the direction of the effects. For example, odds ratios that were larger than one in the main analyses remained to be larger than one in all three models of the sensitivity analysis. The sensitivity analysis also revealed that differences in online services between the three categories of GPs use were bigger for online repeat prescription use compared to the online appointment booking use. The differences between the odds ratios based on the deprivation quintile for online repeat prescription was also bigger than online appointment booking in all the categories of GPs indicating that socioeconomic inequities may have a larger influence on online repeat prescription ordering than online appointment booking. At the same time, for the online repeat prescription outcome, the difference in deprivation quintile were associated with

	bigger differences in the odds associated with the outcome for respondents from the highest missing data GPs compared to the other GPs.

Supplementary Table 2 STROBE 2007 checklist [12] of items to be included in reports of observational studies in epidemiology

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	9 & Supplementary Table 1

Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	Supplementary Table 1
		(*c*) Explain how missing data were addressed	Supplementary Table 1
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	Supplementary Table 1
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	10
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-13
		(b) Indicate number of participants with missing data for each variable of interest	13 & Supplementary Table 3
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Data collection times are summarized under study design subsection
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Supplementary Table 3 (check categories of survey year)
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Supplementary Table 3
		Cross-sectional study—Report numbers of outcome events or summary measures	13 & table 3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-18, Supplementary Table 5
		(*b*) Report category boundaries when continuous variables were categorized	Table 1

		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary Table 1, Supplementary Table 6-7
Discussion			
Key results	18	Summarise key results with reference to study objectives	20
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	21-22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	23-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	23-24
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	26

Supplementary Table 3 The breakdown of respondents by characteristics in the total sample received (n=2,198,821), in the complete case dataset used for the analyses in this study (n=1,806,977) and in the excluded sample (n=439,060)

Characteristics	**Total in the sample received (n=2,246,109)**	**Total in the complete case dataset (n=1807049)**	**Total in the excluded sample (n=439,060)**
Online appointment booking in the previous 12 months			
No	1892841 (84.3%)	1543111 (85.4%)	349730 (79.7%)
Yes	305980 (13.6%)	263938 (14.6%)	42042 (9.6%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Online repeat prescription ordering in the previous 12 months			
No	1807863 (80.5%)	1467600 (81.2%)	340263 (77.5%)
Yes	390958 (17.4%)	339449 (18.8%)	51509 (11.7%)
(Missing)	47288 (2.1%)	0 (0.0%)	47288 (10.8%)
Gender			

Female	1229473 (54.7%)	996544 (55.1%)	232929 (53.1%)
Male	967079 (43.1%)	810505 (44.9%)	156574 (35.7%)
(Missing)	49557 (2.2%)	0 (0.0%)	49557 (11.3%)
Age			
16-24	87081 (3.9%)	74381 (4.1%)	12700 (2.9%)
25-34	185580 (8.3%)	159806 (8.8%)	25774 (5.9%)
35-44	256766 (11.4%)	217687 (12.0%)	39079 (8.9%)
45-54	360011 (16.0%)	302285 (16.7%)	57726 (13.1%)
55-64	454900 (20.3%)	381808 (21.1%)	73092 (16.6%)
65-74	487171 (21.7%)	397999 (22.0%)	89172 (20.3%)
75-84	287533 (12.8%)	211586 (11.7%)	75947 (17.3%)
85+	91083 (4.1%)	61497 (3.4%)	29586 (6.7%)
(Missing)	35984 (1.6%)	0 (0.0%)	35984 (8.2%)
Ethnicity			
White	1895473 (84.4%)	1567690 (86.8%)	15862 (3.6%)
Black	68812 (3.1%)	52950 (2.9%)	33583 (7.6%)
Asian	170609 (7.6%)	137026 (7.6%)	10257 (2.3%)
Other	39425 (1.8%)	29168 (1.6%)	4558 (1.0%)
Mixed	24773 (1.1%)	20215 (1.1%)	327783 (74.7%)
(Missing)	47017 (2.1%)	0 (0.0%)	47017 (10.7%)
Survey year			
2018	750619 (33.4%)	612084 (33.9%)	138535 (31.6%)
2019	763244 (34.0%)	623358 (34.5%)	139886 (31.9%)
2020	732246 (32.6%)	571607 (31.6%)	160639 (36.6%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Long term condition			
No	1022671 (45.5%)	833523 (46.1%)	189148 (43.1%)
Yes	1050129 (46.8%)	923780 (51.1%)	126349 (28.8%)
Don’t know/Can’t say	61802 (2.8%)	49746 (2.8%)	12056 (2.7%)
Prefer not to say	38879 (1.7%)	0 (0.0%)	38879 (8.9%)
(Missing)	72628 (3.2%)	0 (0.0%)	72628 (16.5%)
Taking five or more medication on a regular basis			
No	1632850 (72.7%)	1343735 (74.4%)	289115 (65.8%)

Yes	574749 (25.6%)	463314 (25.6%)	111435 (25.4%)
(Missing)	38510 (1.7%)	0 (0.0%)	38510 (8.8%)
Deafness or hearing loss			
No	1799633 (80.1%)	1652099 (91.4%)	147534 (33.6%)
Yes	179304 (8.0%)	154950 (8.6%)	24354 (5.5%)
(Missing)	267172 (11.9%)	0 (0.0%)	267172 (60.9%)
Parent or legal guardian to a 16 year old or younger			
No	1782911 (79.4%)	1466017 (81.1%)	316894 (72.2%)
Yes	407923 (18.2%)	341032 (18.9%)	66891 (15.2%)
(Missing)	55275 (2.5%)	0 (0.0%)	55275 (12.6%)
Carer			
No	1741536 (77.5%)	1462467 (80.9%)	279069 (63.6%)
Yes	410450 (18.3%)	344582 (19.1%)	65868 (15.0%)
(Missing)	94123 (4.2%)	0 (0.0%)	94123 (21.4%)
Deprivation fifth			
1- least deprived	437189 (19.5%)	338728 (18.7%)	98461 (22.4%)
2	444869 (19.8%)	353580 (19.6%)	91289 (20.8%)
3	464884 (20.7%)	376042 (20.8%)	88842 (20.2%)
4	461586 (20.6%)	378002 (20.9%)	83584 (19.0%)
5 - most deprived	435997 (19.4%)	360697 (20.0%)	75300 (17.2%)
(Missing)	1584 (0.1%)	0 (0.0%)	1584 (0.4%)
General practice rurality			
Rural	374466 (16.7%)	306200 (16.9%)	68266 (15.5%)
Urban	1871643 (83.3%)	1500849 (83.1%)	370794 (84.5%)
(Missing)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Supplementary Table 4 Breakdown of the number and proportion of respondent characteristics based on the categories of the proportion of missing data in the GP practice

Characteristics	Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices	Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices	Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices
Online services use			
Online appointment booking in the previous 12 months	75194(15.9%)	176193(19.4%)	55937(13.1%)
Online repeat prescription use in the previous 12 months	102332(21.6%)	176193(19.4%)	60924(14.4%)
Gender			
Female	265428 (56.0%)	503040 (55.3%)	228076 (53.8%)
Male	208654 (44.0%)	406112 (44.7%)	195739 (46.2%)
Age			
16-24	18750 (4.0%)	34473 (3.8%)	21158 (5.0%)
25-34	39537 (8.3%)	75142 (8.3%)	45127 (10.6%)
35-44	55609 (11.7%)	103244 (11.4%)	58834 (13.9%)
45-54	79934 (16.9%)	149707 (16.5%)	72644 (17.1%)
55-64	100332 (21.2%)	194450 (21.4%)	87026 (20.5%)
65-74	106927 (22.6%)	208741 (23.0%)	82331 (19.4%)

Characteristics	**Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**	**Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**	**Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**
75-84	56564 (11.9%)	111123 (12.2%)	43899 (10.4%)
85+	16429 (3.5%)	32272 (3.5%)	12796 (3.0%)
Ethnicity			
White	5027 (1.1%)	17758 (2.0%)	30165 (7.1%)
Black	16190 (3.4%)	49142 (5.4%)	71694 (16.9%)
Asian	3729 (0.8%)	10722 (1.2%)	14717 (3.5%)
Other	4175 (0.9%)	8704 (1.0%)	7336 (1.7%)
Mixed	444961 (93.9%)	822826 (90.5%)	299903 (70.8%)
Survey year			
2018	166729 (35.2%)	305514 (33.6%)	139841 (33.0%)
2019	162214 (34.2%)	315671 (34.7%)	145473 (34.3%)
2020	145139 (30.6%)	287967 (31.7%)	138501 (32.7%)
Long-term condition			
No	11725 (2.5%)	24207 (2.7%)	13814 (3.3%)
I don’t know/ Can’t answer	220575 (46.5%)	411974 (45.3%)	200974 (47.4%)
Yes	241782 (51.0%)	472971 (52.0%)	209027 (49.3%)

Characteristics	**Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**	**Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**	**Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**
Taking five or more medication on a regular basis			
No	363720 (76.7%)	674880 (74.2%)	305135 (72.0%)
Yes	110362 (23.3%)	234272 (25.8%)	118680 (28.0%)
Deafness or hearing loss			
No	433463 (91.4%)	827757 (91.0%)	390879 (92.2%)
Yes	40619 (8.6%)	81395 (9.0%)	32936 (7.8%)
Parent or legal guardian to a 16 year old or younger			
No	385230 (81.3%)	746422 (82.1%)	334365 (78.9%)
Yes	88852 (18.7%)	162730 (17.9%)	89450 (21.1%)
Carer			
No	382112 (80.6%)	732193 (80.5%)	348162 (82.1%)
Yes	91970 (19.4%)	176959 (19.5%)	75653 (17.9%)
Deprivation quintile			
1 (Most deprived)	38111 (8.0%)	146156 (16.1%)	154461 (36.4%)

Characteristics	**Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**	**Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**	**Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**
2	64792 (13.7%)	174694 (19.2%)	114094 (26.9%)
3	99792 (21.0%)	199586 (22.0%)	76664 (18.1%)
4	124261 (26.2%)	203142 (22.3%)	50599 (11.9%)
5 (Least deprived)	147126 (31.0%)	185574 (20.4%)	27997 (6.6%)
General practice rurality			
Rural	116101 (24.5%)	165787 (18.2%)	24312 (5.7%)
Urban	357981 (75.5%)	743365 (81.8%)	399503 (94.3%)

Supplementary Table 5. Table presenting summaries of the univariate analyses for each of the outcomes:

Summary of univariate analysis for the online appointment booking outcome univariate analysis with each of the predictors (1807049 respondents in 7256 practices)

Predictors	*Odds Ratios*	*SE*	*CI*	*p*
Long term condition (REF= No)				
Long term condition- I don't know/ Can't say	1.10	0.02	1.07 - 1.13	**<0.001**
Long term condition- Yes	1.50	0.01	1.48 - 1.51	**<0.001**
Taking five or more medication on a regular basis-Yes (REF= No)	1.16	0.01	1.15 - 1.17	**<0.001**
Deafness or hearing loss-Yes (REF= No)	0.94	0.01	0.92 - 0.95	**<0.001**
Gender-Male (REF= Female)	0.88	0.00	0.87 - 0.89	**<0.001**
Age bands (REF: 85+)				
16-24	2.32	0.05	2.24 - 2.41	**<0.001**
25-34	3.05	0.05	2.94 - 3.15	**<0.001**
35-44	3.00	0.05	2.9 - 3.11	**<0.001**
45-54	2.96	0.05	2.87 - 3.06	**<0.001**
55-64	2.88	0.05	2.79 - 2.98	**<0.001**
65-74	2.62	0.04	2.53 - 2.71	**<0.001**
	1.61	0.03	1.56 - 1.67	**<0.001**
Ethnicity (REF: White)				

Black	0.81	0.01	0.79 - 0.84	**<0.001**
Asian	1.10	0.01	1.08 - 1.12	**<0.001**
Other	0.94	0.02	0.91 - 0.97	**<0.001**
Mixed	1.11	0.02	1.07 - 1.16	**<0.001**
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	1.06	0.01	1.05 - 1.07	**<0.001**
Carer-Yes (REF= No)	1.21	0.01	1.2 - 1.22	**<0.001**
Deprivation quintile (REF: 1- Most deprived)				
2	1.11	0.01	1.1 - 1.13	**<0.001**
3	1.19	0.01	1.18 - 1.21	**<0.001**
4	1.28	0.01	1.26 - 1.3	**<0.001**
5 (least deprived)	1.38	0.01	1.36 - 1.41	**<0.001**
Survey year (REF= 2018)				
2019	1.18	0.01	1.17 - 1.2	**<0.001**
2020	1.50	0.01	1.48 - 1.51	**<0.001**
General practice rurality-urban (REF= rural)	1.07	0.02	1.03 - 1.11	**<0.001**

Summary of univariate analysis for the repeat prescription ordering outcome univariate analysis with each of the predictors (1807049 respondents in 7256 practices)

Predictors	*Odds Ratios*	*SE*	*CI*	*p*
Long term condition (REF= No)				
Long term condition- I don't know/ Can't say	1.21	0.02	1.18 - 1.24	**<0.001**
Long term condition- Yes	2.70	0.01	2.68 - 2.73	**<0.001**
Taking five or more medication on a regular basis-Yes (REF= No)	1.72	0.01	1.71 - 1.74	**<0.001**
Deafness or hearing loss-Yes (REF= No)	1.13	0.01	1.11 - 1.14	**<0.001**
Gender-Male (REF= Female)	1.01	0.00	1 - 1.02	**0.007**
Age bands (REF: 85+)				
16-24	0.87	0.02	0.84 - 0.9	**<0.001**
25-34	1.06	0.02	1.03 - 1.09	**<0.001**
35-44	1.37	0.02	1.33 - 1.4	**<0.001**
45-54	1.91	0.03	1.86 - 1.96	**<0.001**
55-64	2.31	0.03	2.25 - 2.37	**<0.001**
65-74	2.41	0.03	2.35 - 2.47	**<0.001**
Ethnicity (REF: White)				
Black	0.66	0.01	0.64 - 0.68	**<0.001**
Asian	0.77	0.01	0.76 - 0.78	**<0.001**

Other	0.66	0.01	0.63 - 0.68	**<0.001**
Mixed	0.84	0.02	0.81 - 0.87	**<0.001**
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.73	0.00	0.72 - 0.73	**<0.001**
Carer-Yes (REF= No)	1.32	0.01	1.3 - 1.33	**<0.001**
Deprivation quintile (REF: 1- Most deprived)				
2	1.18	0.01	1.16 - 1.2	**<0.001**
3	1.35	0.01	1.33 - 1.37	**<0.001**
4	1.50	0.01	1.48 - 1.52	**<0.001**
5 (least deprived)	1.60	0.01	1.58 - 1.63	**<0.001**
Survey year (REF= 2018)				
2019	1.18	0.01	1.17 - 1.19	**<0.001**
2020	1.43	0.01	1.42 - 1.44	**<0.001**
General practice rurality-urban (REF= rural)	0.78	0.01	0.76 - 0.8	**<0.001**

Supplementary Table 6 Results of model 3 of the sensitivity analysis of the online appointment booking in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	**Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**		**Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**		**Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**	
	Odds Ratios	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.16***	(1.10, 1.23)	1.14***	(1.10, 1.19)	1.16***	(1.10, 1.22)
Long term condition- Yes	1.78***	(1.75, 1.81)	1.69***	(1.67, 1.72)	1.49***	(1.46, 1.53)
Taking five or more medication on a regular basis-Yes (REF= No)	1.19***	(1.17, 1.22)	1.20***	(1.18, 1.22)	1.20***	(1.17, 1.23)
Deafness or hearing loss-Yes (REF= No)	1.15***	(1.11, 1.19)	1.12***	(1.09, 1.14)	1.12***	(1.08, 1.16)
Gender-Male (REF= Female)	0.88***	(0.86, 0.89)	0.88***	(0.87, 0.89)	0.91***	(0.89, 0.93)
Age (REF: 85+)						

Predictors	**Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**		**Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**		**Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**	
	Odds Ratios	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**
16-24	3.39***	(3.14, 3.66)	3.76***	(3.55, 3.98)	3.50***	(3.21, 3.82)
25-34	4.69***	(4.37, 5.03)	5.17***	(4.91, 5.45)	4.66***	(4.30, 5.06)
35-44	4.63***	(4.32, 4.96)	5.13***	(4.87, 5.40)	4.46***	(4.11, 4.83)
45-54	4.28***	(4.01, 4.57)	4.51***	(4.29, 4.74)	3.75***	(3.46, 4.06)
55-64	3.80***	(3.56, 4.05)	3.94***	(3.75, 4.13)	3.07***	(2.84, 3.32)
65-74	3.27***	(3.07, 3.49)	3.32***	(3.16, 3.48)	2.35***	(2.18, 2.54)
75-84	1.81***	(1.69, 1.93)	1.83***	(1.74, 1.93)	1.43***	(1.32, 1.55)
Ethnicity (REF: White)						
Black	0.75***	(0.69, 0.81)	0.83***	(0.79, 0.87)	0.87***	(0.83, 0.90)
Asian	1.04	(1.00, 1.09)	1.10***	(1.07, 1.14)	1.14***	(1.10, 1.17)
Other	0.86**	(0.79, 0.95)	0.92**	(0.87, 0.98)	1.01	(0.96, 1.06)
Mixed	1.01	(0.93, 1.10)	1.01	(0.95, 1.07)	1.09**	(1.02, 1.16)
Parent or legal guardian to a 16-year-old or younger-Yes (REF= No)	0.91***	(0.89, 0.93)	0.90***	(0.88, 0.92)	0.96***	(0.93, 0.98)
Carer-Yes (REF= No)	1.11***	(1.09, 1.13)	1.15***	(1.13, 1.17)	1.17***	(1.14, 1.19)
Deprivation quintile (REF: 1-Most deprived)						
2	1.15***	(1.11, 1.20)	1.14***	(1.12, 1.17)	1.16***	(1.13, 1.19)

Predictors	**Model 3, Respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**		**Model 3, Respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**		**Model 3, Respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**	
	Odds Ratios	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**
3	1.23***	(1.19, 1.28)	1.29***	(1.26, 1.32)	1.27***	(1.23, 1.30)
4	1.38***	(1.33, 1.44)	1.40***	(1.37, 1.43)	1.36***	(1.31, 1.41)
5 (least deprived)	1.54***	(1.48, 1.60)	1.52***	(1.49, 1.56)	1.53***	(1.46, 1.60)
Survey year (REF= 2018)						
2019	1.16***	(1.14, 1.18)	1.18***	(1.17, 1.20)	1.25***	(1.22, 1.28)
2020	1.46***	(1.43, 1.49)	1.52***	(1.50, 1.54)	1.61***	(1.57, 1.65)
General practice rurality-Urban (REF= Rural)	1.22***	(1.10, 1.23)	1.11***	(1.10, 1.19)	1.10	(0.97, 1.24)
Model summary						
Interclass correlation coefficient (ICC)	0.13		0.12		0.13	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001

Supplementary Table 7 Results of model 3 of the sensitivity analysis of the online repeat prescription ordering in the previous 12 months outcome for each of the categories of GPs based on the proportion of missing data in the practice

Predictors	**Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**		**Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**		**Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**	
	Odds Ratios	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**
Long term condition (REF= No)						
Long term condition- I don't know/ Can't say	1.25***	(1.18, 1.32)	1.25***	(1.20, 1.30)	1.24***	(1.17, 1.31)
Long term condition- Yes	2.71***	(2.66, 2.75)	2.56***	(2.52, 2.59)	2.42***	(2.37, 2.47)
Taking five or more medication on a regular basis- Yes (REF= No)	1.26***	(1.24, 1.29)	1.26***	(1.24, 1.28)	1.29***	(1.26, 1.32)
Deafness or hearing loss-Yes (REF= No)	1.02	(1.00, 1.05)	1.02	(1.00, 1.04)	1.01	(0.98, 1.04)
Gender-Male (REF= Female)	0.96***	(0.94, 0.97)	0.96***	(0.95, 0.97)	0.98**	(0.96, 1.00)
Age (REF: 85+)						
16-24	1.64***	(1.53, 1.75)	1.76***	(1.67, 1.85)	1.62***	(1.50, 1.76)
25-34	2.16***	(2.04, 2.29)	2.22***	(2.13, 2.32)	1.98***	(1.85, 2.13)
35-44	2.67***	(2.52, 2.82)	2.82***	(2.70, 2.94)	2.37***	(2.21, 2.54)
45-54	3.25***	(3.09, 3.42)	3.29***	(3.16, 3.42)	2.82***	(2.65, 3.01)
55-64	3.35***	(3.18, 3.52)	3.43***	(3.31, 3.56)	2.81***	(2.64, 3.00)
65-74	3.11***	(2.97, 3.27)	3.15***	(3.03, 3.27)	2.48***	(2.33, 2.64)
75-84	1.73***	(1.65, 1.82)	1.75***	(1.68, 1.82)	1.43***	(1.34, 1.53)
Ethnicity (REF: White)						

Predictors	**Model 3, respondents from practices with 25% or less respondents with missing data n=474082, 1843 practices**		**Model 3, respondents from practices with 26%-74% of respondents with missing data n=909152, 3361 practices**		**Model 3, respondents from practices with 75% or more respondents with missing data. n=423815, 2052 practices**	
	Odds Ratios	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**	**Odds Ratios**	**95% Confidence Interval**
Black	0.77***	(0.71, 0.84)	0.73***	(0.70, 0.77)	0.81***	(0.77, 0.84)
Asian	0.88***	(0.84, 0.92)	0.94***	(0.91, 0.97)	1.01	(0.98, 1.04)
Other	0.79***	(0.71, 0.87)	0.76***	(0.72, 0.81)	0.82***	(0.77, 0.86)
Mixed	0.96	(0.89, 1.05)	0.98	(0.93, 1.05)	0.99	(0.92, 1.07)
Parent or legal guardian to a 16 year old or younger-Yes (REF= No)	0.93***	(0.91, 0.96)	0.94***	(0.92, 0.96)	0.99	(0.96, 1.02)
Carer-Yes (REF= No)	1.13***	(1.11, 1.16)	1.15***	(1.14, 1.17)	1.19***	(1.17, 1.22)
Deprivation quintile (REF: 1-Most deprived)						
2	1.21***	(1.17, 1.26)	1.22***	(1.19, 1.25)	1.22***	(1.19, 1.26)
3	1.37***	(1.32, 1.42)	1.43***	(1.40, 1.46)	1.43***	(1.39, 1.47)
4	1.54***	(1.48, 1.59)	1.59***	(1.55, 1.62)	1.67***	(1.62, 1.73)
5 (least deprived)	1.65***	(1.59, 1.71)	1.74***	(1.70, 1.78)	1.89***	(1.82, 1.97)
Survey year (REF= 2018)						
2019	1.16***	(1.13, 1.18)	1.17***	(1.15, 1.19)	1.26***	(1.24, 1.29)
2020	1.40***	(1.38, 1.43)	1.46***	(1.44, 1.48)	1.54***	(1.51, 1.58)
General practice rurality-Urban (REF= Rural)	0.94**	(0.89, 0.99)	0.90***	(0.87, 0.94)	0.97	(0.88, 1.07)
Model summary						
Interclass correlation coefficient (ICC)	0.07		0.07		0.08	

* p-value= 0.05, ** p-value= ≤ 0.01, *** p-value= ≤ 0.001