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Vaccine 41 (2023) 2466–2475

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Using the precaution adoption process model to understand decision-making about the COVID-19 booster vaccine in England

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ARTICLE INFO

Article history:
Received 7 February 2022
Received in revised form 21 December 2022
Accepted 13 February 2023
Available online 17 February 2023

Keywords:
Coronavirus
Vaccine hesitancy
Booster vaccination
Precaution adoption process model
Health belief model
Theory of planned behaviour

ABSTRACT

Background: COVID-19 continues to pose a threat to public health. Booster vaccine programmes are critical to maintain population-level immunity. Stage theory models of health behaviour can help our understanding of vaccine decision-making in the context of perceived threats of COVID-19.
Purpose: To use the Precaution Adoption Process Model (PAPM) to understand decision-making about the COVID-19 booster vaccine (CBV) in England.
Methods: An online, cross-sectional survey informed by the PAPM, the extended Theory of Planned Behaviour and Health Belief Model administered to people over the age of 50 residing in England, UK in October 2021. A multivariate, multinomial logistic regression model was used to examine associations with the different stages of CBV decision-making.
Results: Of the total 2,004 participants: 135 (6.7%) were unengaged with the CBV programme; 262 (13.1%) were undecided as to whether to have a CBV; 31 (1.5%) had decided not to have a CBV; 1,415 (70.6%) had decided to have a CBV; and 161 (8.0%) had already had their CBV. Being unengaged was *positively* associated with beliefs in their immune system to protect against COVID-19, being employed, and low household income; and *negatively* associated with CBV knowledge, a positive COVID-19 vaccine experience, subjective norms, anticipated regret of not having a CBV, and higher academic qualifications. Being undecided was *positively* associated with beliefs in their immune system and having previously received the Oxford/AstraZeneca (as opposed to Pfizer/BioNTech) vaccine; and *negatively* associated with CBV knowledge, positive attitudes regarding CBV, a positive COVID-19 vaccine experience, anticipated regret of not having a CBV, white British ethnicity, and living in East Midlands (vs London).
Conclusions: Public health interventions promoting CBV may improve uptake through tailored messaging directed towards the specific decision stage relating to having a COVID-19 booster.

1. Introduction

With the emergence of new variants [1] and concerns over waning immunity against COVID-19 in the months following the second dose of a COVID-19 vaccine [2,3], COVID-19 continues to pose a threat to public health in countries where vaccination coverage for COVID-19 is high. Booster vaccines have been shown to be safe and effective [4] and deemed by governments globally to be a critical component in the ongoing public health efforts to protect their populations from serious illness or death [5]. On 14 September 2021, the Joint Committee on Vaccination and Immunisation (JCVI) provided independent guidance to UK governmental health authorities on the administration of the booster vaccine [6] which has since been updated to include all people over the age of 18 who received their vaccine a minimum of three months prior [7]. In England, COVID-19 vaccination is centrally organised through the Department of Health and Social Care in collaboration with NHS England, NHS Improvement, and the UK Health Security Agency and is available for free at the point of access. The success of the booster programme relies on people having the vaccine once offered. In the first three months of the booster programme (September 16 – December 12, 2021), 79.4% of adults in England

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https://doi.org/10.1016/j.vaccine.2023.02.047
0264-410X/

over the age of 50 who had received two doses of the COVID-19 vaccine had received a third dose [8]. Estimations of the vaccine coverage required to achieve and sustain herd immunity vary depending on levels of natural infection, vaccine effectiveness against new variants, and waning immunity [9]; however, modelling suggests that 72% of a highly-vaccinated population (where $\geq$ 59% of the population are fully vaccinated) need to receive a booster vaccine to sustain population-level immunity against COVID-19, accounting for waning immunity [10].

COVID-19 booster vaccines are likely to be administered annually whilst COVID-19 continues to circulate [11]. Therefore, to optimise future booster vaccine uptake, health officials and policymakers need to understand why some people may be reluctant to receive the booster vaccine. The (extended) Theory of Planned Behaviour (TPB) [12,13] and Health Belief Model (HBM) [14] have been used extensively to understand determinants of COVID-19 vaccine intention [15–18]. Factors found to be associated with the intention to receive a COVID-19 vaccine vary across studies, though those that have most consistently been shown to significantly influence intention include more perceived benefits [16,18], more positive beliefs and attitudes towards COVID-19 vaccination [15,18,19], greater perceived knowledge about vaccination [18,19], and stronger subjective norms [16,18]. Other factors associated with COVID-19 vaccine intention include previous influenza vaccination [16,18–20], trust [15,18], and socio-demographic characteristics including age, ethnicity, education, sex, and relative affluence [16,19,20]. It is not yet known if these factors will be associated with intentions to have a COVID-19 booster vaccine, particularly as to be eligible, one must have already received the primary course of an approved COVID-19 vaccine.

Importantly, the views of those individuals who are hesitant to have a COVID-19 booster vaccine are unlikely to be homogenous [21,22]. One way to model these differences is to reference stage theory, which postulates that people within the same stage of decision making may face similar barriers to stage transition, whereas people in different stages face different barriers [23,24]. Therefore, it is important that we understand what factors differentiate people at different stages of decision-making about the booster vaccine so that Government and public health officials can tailor their interventions accordingly to optimise uptake [25]. The Precaution Adoption Process Model (PAPM) was developed to facilitate our understanding of decision-making in the context of a novel threat to health [23,24] and has been used to understand decision making about human papillomavirus (HPV) vaccination [26,27]. The PAPM conceptualises seven unique stages of decision-making that one might move through, including being unaware of a precautionary action (not heard of COVID-19 booster vaccination) (Stage 1), being aware but unengaged in the decision to act or not (not thought about having the booster vaccine) (Stage 2), being undecided about whether or not to act (undecided about having the booster vaccine) (Stage 3), deciding not to act (deciding not to have booster vaccine) (Stage 4), deciding to act (deciding to have booster vaccine) (Stage 5), taking action (having a booster vaccine) (Stage 6) and maintaining action (routine vaccination) (Stage 7) [23,24]. Unlike other stage theories, the PAPM does not specify a time period for behaviour change to occur and acknowledges that people who have no intention to change their behaviour may have never heard of the precautionary action, not thought about taking action, or decided not to act [23].

The aim of the present study was to (1) use the PAPM to profile the general public's decision-making about having a COVID-19 booster vaccine (CBV); and (2) examine associations between PAPM stage and individuals' experiences of receiving their first and second COVID-19 vaccines, attitudes and beliefs about CBV, personal health characteristics, and socio-demographic characteristics.

2. Method

2.1. Design

An online, cross-sectional, population-based survey was administered to the general public residing in England between October 11–20, 2021, approximately 4 weeks after the JCVI published their initial guidance [6]. We obtained ethical approval for the study from Newcastle University Research, Policy, Intelligence and Ethics Team (Reference: 13754/2020).

2.2. Participants

Individuals were eligible to participate in this study if: they resided in England, UK; were fully vaccinated against COVID-19 (i.e., received two doses of the Oxford/AstraZeneca, Pfizer/BioNTech, or Moderna vaccine (or combination of vaccines); or one dose of the Janssen vaccine); and over the age of 50. These criteria were consistent with the age-based eligibility criteria for CBV at the time we administered the survey. Quotas were used to ensure national representativeness with respect to gender and region. All participants were recruited using Qualtrics, a market research company.

2.3. Materials

The questionnaire was adapted from one we administered previously to capture psychological determinants of COVID-19 vaccine intention in people who were either undecided or had decided not to have the vaccine [18] and was administered using Qualtrics.

2.3.1. PAPM stage for COVID-19 booster vaccination

To categorise participants by PAPM stage, participants were asked "Which of the following best describes your thoughts about having a COVID-19 booster vaccine, once Public Health authorities recommend you have one?" and were asked to select one of six options that represented Stages 2 to 6 (see Appendix A). We did not include options that related to Stage 1 (unaware) because COVID-19 booster vaccination was well publicised; or Stage 7 (maintenance) because the booster vaccine programme had only just commenced.

2.3.2. Previous vaccine experience

Questions focused on individuals' overall experiences of receiving their first and second vaccine (5 items), the quality of the healthcare environment (6 items) and patient-provider connection (4 items) when they received their second COVID-19 vaccine (adapted from the HEAL short form items [28]), vaccine access (3 items), and the perceived benefits from COVID-19 vaccination (3 items) (see Appendix A). All items were measured on a 5-point Likert scale, with higher scores representing more positive experiences. Items pertaining to each of the 5 subscales had good internal consistency (Cronbach's alpha 0.68–0.91) and so subscale scores are reported as a single mean score.

2.3.3. Beliefs and attitudes about COVID-19 and COVID-19 booster vaccination

The extended TPB [12,13] and HBM [14] were used to understand individuals' beliefs and attitudes about COVID-19 and COVID-19 booster vaccination. Regarding the extended TPB, we captured vaccine attitudes (2 items), vaccine subjective norms (4 items), vaccine perceived control (1 item), and anticipated regret (3 items). Regarding the HBM, we captured perceived severity (1 item), perceived susceptibility (3 items), perceived benefits (6 items), and perceived vaccine safety (2 items). Other factors deemed relevant included knowledge about vaccine effectiveness,

vaccine safety, and transmissibility of COVID-19 post-vaccination (3 items) [29]; trust in Government (1 item; adapted from [30]); and fear of needles (1 item; [13]). Items were based on items used in similar studies that have examined the psychological determinants of vaccine intention [13,19,31,32] and are presented in Appendix A. All items (except 'fear of needles') were measured on a 5-point Likert scale, with higher scores representing higher levels of agreement / more anticipated regret. Except for 'perceived susceptibility', all constructs had good internal consistency (Cronbach's alpha 0.70–0.97) and thus each were represented as a single mean score.

2.3.4. Personal health characteristics and socio-demographic characteristics

Participants were asked to rate their general health, if they had been asked to shield from COVID-19, or had previously had COVID-19. Socio-demographic and socio-economic questions asked for participants' age, gender, region, ethnicity, education status, employment status, keyworker status, and household income.

2.3.5. Patient and public involvement

Our dedicated patient and public involvement team (N = 6, five aged 50 + years consistent with target population) reviewed the survey on two occasions to (1) ensure the survey items were relevant and easily interpretable and (2) the online survey was easy to navigate.

2.4. Data analysis

All analyses were conducted using STATA (version 16). We examined univariate associations between PAPM stage, and 6 factors related to previous COVID-19 vaccine experiences, 13 psychological factors, 3 personal health characteristics, and 6 socio-demographic and 3 socio-economic factors, using a series of univariate regression models. Only significant variables ($p < 0.10$) were considered for inclusion in the multivariate model. Pairwise correlations were computed between all significant ($p < 0.10$) continuous variables; the variable 'healthcare environment' was dropped because it was highly correlated with 'patient-provider connection' ($r = 0.74$). All other correlations were<0.7. Multicollinearity was checked and all variation inflation factor (VIF) values were<5.0. A multivariate, multinomial logistic regression model was fitted to the data using backward stepwise selection based on p-values ($p < 0.10$). Participants in PAPM Stage 5 (decided to act) were compared to participants in Stage 2 (unengaged) and Stage 3 (undecided). Participants in PAPM Stage 4 (decided not to act) were excluded because the sample size was too small; and participants in PAPM Stage 6 (vaccinated) were excluded because not all people were eligible to have the booster vaccine at the time we conducted the study. The relative risk ratios (RRR) and 95 % confidence intervals are reported; RRRs < 1 indicate a negative association with PAPM stage and RRRs > 1 indicate a positive association. Studentised residuals were calculated to identify possible outliers. No outliers were identified (all residuals < ±2.58). The pseudo r^2 value is reported to indicate goodness of fit.

3. Results

Overall, 2,004 participants completed the survey (see Table 1 for a summary of sample characteristics). Of these, 135 (6.7%) participants indicated they were in Stage 2 (unengaged), 262 (13.1%) participants were in Stage 3 (undecided), 31 (1.5%) participants were in Stage 4 (decided not to act), 1,415 (70.6%) participants were in Stage 5 (decided to act), and 161 (8.0%) participants were in Stage 6 (had booster vaccine). Descriptive statistics are presented for each of the potential explanatory variables, pertaining to socio-demographic, socio-economic, and health information (see Table 2) and previous COVID-19 vaccine experiences and psychological constructs (see Table 3), by PAPM stage.

Table 1
Sample characteristics (N = 2,004).

Variable		
Age – M (SD)	63.61	(8.45)
Gender – N (%)		
- Female	1,022	(51.00)
- Male	981	(48.95)
- Other	1	(0.05)
Region – N (%)		
- East Midlands	181	(9.03)
- East of England	220	(10.98)
- London	297	(14.82)
- North East	104	(5.19)
- North West	259	(12.92)
- South East	320	(15.97)
- South West	200	(9.98)
- West Midlands	223	(11.13)
- Yorkshire and the Humber	200	(9.98)
Ethnicity – N (%)		
- White British	1,843	(91.97)
- Not white British	155	(7.73)
Education status – N (%)		
- No formal qualification	148	(7.39)
- High school qualification (e.g., BTEC, GCSE, A-levels)	883	(44.06)
- University diploma/degree	512	(25.55)
- Other qualification	453	(22.60)
Employment status – N (%)		
- Employed	751	(37.48)
- Not employed	1,245	(62.13)
Household income – N (%)		
- Less than £30,000	988	(49.30)
- More than £30,000	852	(42.51)
- Prefer not to say	164	(8.18)
Asked to shield – N (%)		
- Yes	397	(19.81)
- No	1,599	(79.79)
Previous COVID-19 infection – N (%)		
- Yes	216	(10.78)
- No	1,786	(89.12)

The multivariate model is presented in Table 4. Of the 30 potential explanatory variables, 28 were considered for inclusion in the multivariate model. The final model (log likelihood = -782.78, LR χ^2 (28) = 518.71, pseudo r^2 = 0.249, $p < 0.0001$) was based on 1,637 participants and revealed 12 significant predictors of PAPM stage (adjusted $p < 0.05$). Factors *positively* associated with being 'unengaged' included stronger beliefs that their immune system was strong enough to protect against COVID-19, being employed, and having a household income < £30,000; factors *negatively* associated with being 'unengaged' included greater booster vaccine knowledge, a better experience with their previous COVID-19 vaccine, stronger subjective norms, more anticipated regret, and having a high school qualification, University diploma or degree, or other qualification (vs no qualification). Factors *positively* associated with being 'undecided' included stronger beliefs that their immune system was strong enough to protect against COVID-19 and having received the Oxford/AstraZeneca previously (vs Pfizer/BioNTech); factors negatively associated with being 'undecided' included greater booster vaccine knowledge, positive attitudes towards the booster vaccine, a better experience with their previous COVID-19 vaccine, more anticipated regret, white British ethnicity, and living in East Midlands (vs London).

4. Discussion

Our results indicated that approximately 20 % of those eligible had not yet decided to have a CBV in the early stages of the booster

Table 2
Socio-demographic, socio-economic, and health information for participants, by PAPM stage of decision-making.

	Unengaged		Undecided		Decided NOT to have booster		Decided to have booster		Had booster		†Univariate analyses	
	(N = 135)		(N = 262)		(N = 31)		(N = 1,415)		(N = 161)		N	pseudo r^2
Age – M (SD)	59.21	(6.93)	60.33	(7.71)	62.03	(9.96)	63.87	(7.90)	70.58	(10.09)	1,812	0.033***
Gender – N (%)											1,812	0.002*
- Female or Other	70	(6.84)	152	(14.86)	17	(1.66)	711	(69.50)	73	(7.14)		
- Male	65	(6.63)	110	(11.21)	14	(1.43)	704	(71.76)	88	(8.97)		
Region – N (%)											1,812	0.013**
- East of England	12	(5.45)	35	(15.91)	5	(2.27)	158	(71.82)	10	(4.55)		
- East Midlands	11	(6.08)	13	(7.18)	2	(1.10)	145	(80.11)	10	(5.52)		
- London	28	(9.43)	42	(14.14)	7	(2.36)	183	(61.62)	37	(12.46)		
- North East	10	(9.62)	13	(12.50)	1	(0.96)	71	(68.27)	9	(8.65)		
- North West	14	(5.41)	28	(10.81)	4	(1.54)	190	(73.36)	23	(8.88)		
- South East	21	(6.56)	49	(15.31)	2	(0.63)	221	(69.06)	27	(8.44)		
- South West	6	(3.00)	21	(10.50)	1	(0.50)	158	(79.00)	14	(7.00)		
- West Midlands	20	(8.97)	33	(14.80)	2	(0.90)	151	(67.71)	17	(7.62)		
- Yorkshire & the Humber	13	(6.50)	28	(14.00)	7	(3.50)	138	(69.00)	14	(7.00)		
Ethnicity – N (%)											1,807	0.009***
- White British	115	(6.24)	225	(12.21)	25	(1.36)	1,328	(72.06)	150	(8.14)		
- Not white British	19	(12.26)	35	(22.58)	6	(3.87)	85	(54.84)	10	(6.45)		
Education status – N (%)											1,806	0.007**
- No formal qualification	19	(12.84)	16	(10.81)	3	(2.03)	95	(64.19)	15	(10.14)		
- High school qualification	58	(6.57)	136	(15.40)	14	(1.59)	618	(69.99)	57	(6.46)		
- University diploma/degree	34	(6.64)	54	(10.55)	8	(1.56)	375	(73.24)	41	(8.01)		
- Other qualification	24	(5.30)	53	(11.70)	5	(1.10)	324	(71.52)	47	(10.38)		
Employment status – N (%)											1,806	0.013***
- Employed	75	(9.99)	120	(15.98)	11	(1.46)	496	(66.05)	49	(6.52)		
- Not employed	58	(4.66)	141	(11.33)	19	(1.53)	916	(73.57)	111	(8.92)		
Key worker status – N (%)											1,812	0.008***
- Yes	32	(10.36)	56	(18.12)	4	(1.29)	186	(60.19)	31	(10.03)		
- No	103	(6.08)	206	(12.15)	27	(1.59)	1,229	(72.51)	130	(7.67)		
Health or social care worker – N (%)											1,812	0.001
- Yes	5	(5.62)	14	(15.73)	2	(2.25)	42	(47.19)	26	(29.21)		
- No	130	(6.79)	248	(12.95)	29	(1.51)	1,373	(71.70)	135	(7.05)		
Household income – N (%)											1,812	0.004**
- Less than £30,000	47	(5.52)	101	(11.85)	6	(0.70)	624	(73.24)	74	(8.69)		
- More than £30,000	78	(7.89)	144	(14.57)	18	(1.82)	670	(67.81)	78	(7.89)		
- Prefer not to say	10	(6.10)	17	(10.37)	7	(4.27)	121	(73.78)	9	(5.49)		
General health – M (SD)	2.39	(0.86)	2.38	(0.95)	2.77	(0.96)	2.44	(0.83)	2.56	(0.96)	1,808	0.001
Asked to shield – N (%)											1,806	0.002*
- Yes	19	(4.79)	40	(10.08)	4	(1.01)	278	(70.03)	56	(14.11)		
- No	115	(7.19)	221	(13.82)	26	(1.63)	1,133	(70.86)	104	(6.50)		
Previous COVID-19 infection – N (%)											1,811	0.003**
- Yes	17	(7.87)	40	(18.52)	8	(3.70)	137	(63.43)	14	(6.48)		
- No	118	(6.61)	222	(12.43)	23	(1.29)	1,277	(71.50)	146	(8.17)		

Note. PAPM = precaution adoption process model. † based on univariate multinomial regression model, with reference category 'Stage 5: Decided to have booster'; stages 4 (decided NOT to have booster) and 6 (had booster) were excluded from regression analyses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

programme in England. A variety of factors related to individuals' previous vaccine experiences, their attitudes and beliefs towards COVID-19 booster vaccination, and socio-demographic and socio-economic factors differentiated people who were 'unengaged' and 'undecided', from people who had made the decision to have the booster vaccine. People were considered 'unengaged' if they had not yet thought about having the booster vaccine; and 'undecided' if they had considered taking action but remained uncertain [23]. Some factors were consistent across both stages; however, differences also emerged highlighting the utility of applying the PAPM model to understand decision-making about the COVID-19 booster vaccine.

The most important factors that differentiated people in both the 'unengaged' and 'undecided' groups from people who had decided to have the booster vaccine, included knowledge about the safety and effectiveness of the booster vaccine and the perception that the immune system was strong enough to protect against COVID-19 (perceived susceptibility). Knowledge gaps were identified as a significant predictor of COVID-19 vaccine intention earlier in the pandemic prior to the approval of a COVID-19 vaccine [18,19] and the fact that it remains a strong predictor indicates that public education about the safety and effectiveness of the booster vaccine needs to be a priority. Public understanding of COVID-19 vaccination has likely changed over the course of the pandemic, as more becomes known about vaccine side effects [33–35] and their effectiveness against new variants of the virus [36,37]. In contrast to knowledge, perceived susceptibility has not previously been shown to predict COVID-19 vaccine intention or behaviour, like it has for other illnesses such as HPV and seasonal flu [27,38]. Our results indicate that perceived susceptibility might have shifted during the pandemic now that there are high levels of immunity among the community, either from vaccination or natural infection. This might have translated into beliefs that the immune system is sufficiently strong to protect against COVID-19 without need for further protection from a booster vaccine.

More negative experiences with the primary course of the COVID-19 vaccine were associated with being both 'unengaged' and 'undecided' about the booster vaccine, and is consistent with previous research showing that people who have experienced vaccine-related side-effects in the past are more hesitant to have vaccines in adulthood [39]; and conversely, positive past experiences are associated with greater vaccine uptake [40]. This suggests that more needs to be done to understand and address concerns in those that experienced unpleasant side effects from previous doses of the COVID-19 vaccine as a specific subgroup of the population who may be vaccine hesitant.

Table 3
Experiences, attitudes, and beliefs about COVID-19 (booster) vaccination, by PAPM stage of decision-making.

	Unengaged (N = 135)		Undecided (N = 262)		Decided NOT to have booster (N = 31)		Decided to have booster (N = 1,415)		Had booster (N = 161)		†Univariate analyses N	pseudo r^2
Previous COVID-19 vaccine experience												
Previous vaccine – N (%)											1,791	0.008***
- Pfizer/BioNTech	23	(3.99)	45	(7.80)	7	(1.21)	393	(68.11)	109	(18.89)		
- Oxford/AstraZeneca	107	(7.62)	215	(15.31)	23	(1.64)	1,008	(71.79)	51	(3.63)		
Overall experience – M (SD)	4.18	(0.75)	4.21	(0.65)	3.35	(0.95)	4.60	(0.49)	4.72	(0.47)	1,811	0.056***
Healthcare environment – M (SD)	4.65	(0.54)	4.59	(0.56)	4.42	(0.87)	4.77	(0.43)	4.84	(0.36)	1,812	0.013***
Patient-provider connection – M (SD)	4.56	(0.64)	4.47	(0.70)	4.14	(1.04)	4.75	(0.53)	4.85	(0.38)	1,812	0.023***
Access – M (SD)	4.46	(0.74)	4.43	(0.72)	4.60	(0.55)	4.63	(0.59)	4.77	(0.45)	1,812	0.011***
Perceived benefits – M (SD)	4.09	(0.75)	4.04	(0.64)	3.45	(0.97)	4.45	(0.57)	4.59	(0.53)	1,694	0.049***
Psychological constructs												
Perceived severity – M (SD)	3.05	(1.05)	3.17	(1.02)	3.16	(0.97)	3.38	(1.02)	3.50	(1.06)	1,812	0.008***
Perceived susceptibility – M (SD)												
- likelihood coming into contact with person with COVID-19	3.14	(0.92)	3.30	(1.01)	2.94	(1.12)	3.44	(0.93)	3.52	(0.96)	1,812	0.007***
- good immunity to COVID-19	3.66	(0.79)	3.55	(0.81)	3.52	(1.03)	3.85	(0.80)	4.12	(0.84)	1,812	0.015***
- immune system strong enough	3.49	(0.87)	3.30	(0.97)	3.68	(0.79)	3.17	(1.05)	3.57	(1.16)	1,812	0.006***
Perceived benefits – M (SD)	3.76	(0.74)	3.77	(0.61)	2.62	(0.93)	4.26	(0.56)	4.26	(0.57)	1,812	0.084***
Perceived safety – M (SD)	3.60	(0.87)	3.44	(0.84)	2.21	(1.10)	4.20	(0.69)	4.46	(0.61)	1,812	0.104***
Booster vaccine attitudes – M (SD)	3.92	(0.71)	3.86	(0.62)	2.58	(0.95)	4.58	(0.50)	4.74	(0.42)	1,812	0.167***
Subjective norms – M (SD)	3.58	(0.78)	3.64	(0.65)	2.94	(0.81)	4.21	(0.63)	4.46	(0.62)	1,812	0.098***
Perceived control – M (SD)	3.91	(0.95)	3.83	(0.89)	3.94	(1.03)	4.49	(0.70)	4.71	(0.53)	1,812	0.076***
Anticipated regret – M (SD)	4.02	(1.34)	4.15	(1.22)	2.72	(1.23)	4.69	(0.92)	4.62	(1.05)	1,812	0.035***
Booster vaccine knowledge – M (SD)	3.32	(1.02)	3.38	(0.90)	2.92	(0.99)	4.21	(0.70)	4.53	(0.53)	1,812	0.132***
Trust – M (SD)	3.53	(0.90)	3.47	(0.86)	2.10	(1.22)	4.09	(0.84)	4.29	(0.80)	1,812	0.057***
Fear of needles – N (%)											1,781	0.004***
- Yes	28	(9.18)	53	(17.38)	8	(2.62)	196	(64.26)	20	(6.56)		
- No	102	(6.13)	203	(12.19)	21	(1.26)	1,199	(72.01)	140	(8.41)		

Note. PAPM = precaution adoption process model. † based on univariate multinomial regression model, with reference category 'Stage 5: Decided to have booster'; stages 4 (decided NOT to have booster) and 6 (had booster) were excluded from regression analyses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4
Multivariate, multinomial backward stepwise logistic regression model for different stages of decision making about getting the COVID-19 booster vaccine, represented by PAPM stage, displaying adjusted relative risk ratios and 95 % CIs (N = 1,637).

	Decided to have the booster vaccine (n = 1,300) vs			
	Unengaged (n = 106)		Undecided (n = 231)	
First vaccine Oxford/AstraZeneca *(vs Pfizer/BioNTech)*	1.461	[0.840,2.542]	1.638*	[1.085,2.472]
Previous COVID-19 vaccine: Overall experience	0.574**	[0.391,0.843]	0.692*	[0.516,0.928]
Booster vaccine knowledge	0.384***	[0.275,0.537]	0.510***	[0.391,0.665]
Booster vaccine attitudes	0.689	[0.415,1.144]	0.284***	[0.193,0.418]
Subjective norms	0.556**	[0.373,0.829]	0.750	[0.550,1.022]
Anticipated regret	0.799*	[0.662,0.966]	0.843*	[0.727,0.977]
Perceived susceptibility: believe my immune system is strong enough to protect me against COVID-19	1.927***	[1.472,2.522]	1.383***	[1.142,1.676]
White British (vs *not White British)*	0.533	[0.262,1.082]	0.518*	[0.292,0.920]
Currently employed (vs *not employed*)	2.508***	[1.565,4.020]	1.295	[0.912,1.837]
Household income less than £30,000 (vs *more than £30,000*)	1.644*	[1.037,2.605]	1.380	[0.979,1.944]
Education				
- No qualification	(reference)		(reference)	
- High school qualification	0.363**	[0.177,0.743]	1.470	[0.741,2.915]
- University diploma/degree	0.406*	[0.182,0.906]	1.138	[0.537,2.414]
- Other qualification	0.365*	[0.162,0.824]	1.337	[0.639,2.797]
Live in East Midlands (vs London)	0.453	[0.194,1.060]	0.362**	[0.183,0.715]

Note. PAPM = precaution adoption process model. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. pseudo $R^2 = 0.249$.

Attitudes towards the booster vaccine was uniquely associated with being undecided about having the vaccine once available to them, as was having had the Oxford/AstraZeneca vaccine previously as opposed to the Pfizer/ BioNTech vaccine. Attitudes have consistently been identified as a strong predictor of COVID-19 vaccine intention [15,18,19]; however, the fact that vaccine type is associated with vaccine hesitancy is a novel finding. This latter finding might reflect some apprehension about combining vaccines, given that JCVI recommended that the Pfizer/BioNTech or Moderna vaccine be administered as the booster vaccine in England [6]. Alternatively, it might reflect the high level of media coverage of the rare but serious adverse effects from the Oxford/AstraZeneca vaccine [41]. This finding requires further investigation.

Disparities in protection from COVID-19 have widened during the UK vaccine roll out as minority ethnic groups are less likely to take up vaccination than the majority white population [42–44]. The present results indicate that this may worsen during the booster vaccine rollout given that people of minority ethnic heritage were more likely to be undecided about having a booster vaccine than those from a white British background. Indeed, recent reports indicate that booster vaccine uptake is consistently highest among people of white ethnicity and lowest amongst people who are Black or South Asian [45,46]. It might also help explain the finding that people who live in East Midlands were less likely than people in London to be "undecided" about having the booster vaccine; there was a higher proportion of ethnic diversity among

participants living in London, with about one-quarter reporting an ethnicity other than white British, compared to 3 % living in East Midlands. This finding should be interpreted with caution, however, given that sample sizes became small when the data were categorised into one of nine regions in England and no other regional comparisons with London were significant. All considered, it will be important to continue public health efforts that have been implemented successfully over the course of the pandemic to improve booster vaccine uptake among people from minority ethnic groups in order to prevent existing disparities from widening [44].

A combination of socio-economic factors also uniquely differentiated people who were 'unengaged' from people who had decided to have the vaccine, including a greater likelihood of being in the workforce and having a household income less than £30,000, as well as a lower likelihood of having a formal qualification. In addition, people who had not yet engaged in the decision-making process were exposed to weaker social pressure (subjective norms) to have the booster vaccine [16,18]. Given that subjective norms are strongly influenced by exposure to the attitudes and behaviours of family, friends and colleagues within a community, it is important that efforts are made to engage, understand and work with the specific barriers to booster vaccination uptake in more deprived communities. For example, despite UK Government guidance recommending employers support vaccination by allowing time off to get vaccinated and to review their sick leave policies [47], some workplaces do not allow their employees to receive the booster vaccine during working hours or may not provide paid leave in the event of negative side effects [48].

4.1. Policy recommendations

Overall, our results suggest that public health interventions for COVID-19 booster vaccination need to incorporate a combination of general and more targeted approaches to achieve maximum impact. Efforts to educate the public about the safety and effectiveness of booster vaccines needs to continue, particularly as new variants emerge that pose new threats to public health, and likewise, the public need to be informed that a strong immune system is not sufficient to protect them from contracting COVID-19. To support booster vaccine uptake in people currently unengaged in the decision-making process, more research is needed to understand the additional barriers faced by people with less financial security so that the necessary support can be made available. For example, some workplaces may require on-site vaccination access or the Government may need to provide paid sick leave to those who are not well enough to work after having their booster vaccine. To help increase perceived social norms, role models could be used to deliver messages about social acceptance of booster vaccination, which has been shown to be effective at increasing vaccine intention for hepatitis B [49]. In light of our findings which indicate that people from minority ethnic backgrounds are more likely to be undecided about having a COVID-19 booster vaccine, it will be important that public health efforts aimed at supporting vaccine uptake in these populations are continued. This could involve working with local communities to build trust in health systems, providing culturally appropriate educational materials, listening to and addressing specific fears and concerns, addressing misinformation, and making booster vaccines available in religious venues and other community venues [44,50–52].

4.2. Methodological limitations and future directions

The following limitations need to be taken into consideration when interpreting our findings. Firstly, data were collected at the beginning of the booster vaccine rollout and therefore it is possible that some people may not have been aware of the COVID-19 booster program at the time of the study and were incorrectly assigned to PAPM Stage 2 (instead of Stage 1). Likewise, the number of people who had already decided they would not have a booster vaccine was too small to allow for any further analyses, meaning we need to learn more about why previously vaccinated people do not want a booster vaccine. Secondly, the study was conducted prior to the emergence of the Omicron variant in November 2021 [1]. Despite our study being based on stable and well-validated theoretical constructs, it is not certain if these findings would reflect current decision-making about the COVID-19 booster vaccine. Thirdly, we only captured data for people who were eligible for the booster vaccine at the time of data collection, and therefore we do not know if the findings would generalise to people aged<50 years. Lastly, our sample was a predominantly white British sample and therefore more research is needed to better understand the reasons for vaccine hesitancy among people from ethnic minority groups. Future research should draw on behavioural science models and frameworks such as the Behaviour Change Wheel [53] to design and evaluate public health measures to promote vaccine uptake among those who have not yet decided to have a COVID-19 booster vaccine. More research is needed to understand individuals' past experiences with COVID-19 vaccination among people who are vaccine hesitant, to see if and how there is scope to intervene to support future vaccination. Likewise, the association between COVID-19 vaccine type and vaccine decision-making warrants further investigation so that public health interventions can appropriately address the underlying reason/s for this association.

5. Conclusion

Our results demonstrate the usefulness of applying the PAPM to understand decision-making about the CBV, and subsequently propose policy recommendations to increase booster vaccine uptake among people who are 'unengaged' or 'undecided'. Given that being 'unengaged' and 'undecided' was associated with less perceived knowledge about the safety and effectiveness of the booster vaccine and less perceived susceptibility, we propose that public health policy prioritise educating the public about the safety and efficacy of booster vaccination and dispel beliefs that a healthy immune system alone will protect against COVID-19. Being 'unengaged' was uniquely associated with a combination of socio-economic factors, as well as weaker subjective norms, highlighting the need to understand the additional barriers faced by people who have less financial security, and to understand the social processes facilitating CBV uptake among these people. Attitude towards the booster vaccine was uniquely associated with being undecided about having the vaccine once available to them, as was not being of white British ethnicity. Therefore, public health efforts aimed at shifting attitudes and supporting vaccine uptake in minority ethnic groups should continue. Future research should draw on behavioural science models and frameworks such as the Behaviour Change Wheel to design and evaluate public health measures to promote CBV uptake.

Funding

This paper is independent research commissioned and funded by the National Institute for Health Research Policy Research Programme. The views expressed in this publication are those of the author(s) and not necessarily those of the NHS, the National Institute for Health Research, the Department of Health and Social Care or its arm's length bodies, and other Government Departments. This project is funded by the National Institute for Health Research

(NIHR) [Policy Research Unit in Behavioural Science (project reference PR-PRU1217-20501).

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Falko F Sniehotta reports financial support was provided by National Institute of Health and Medical Research.

Acknowledgements

We would like to thank the participants for taking the time to participate in this study. We would also like to thank Louise Letley (Nurse Manager Research, PHE) and our dedicated PPI group for their input into survey design, including Dave Green, Stu Edwards, Caroline Kemp, Maisie McKenzie, Sudhir Shah, and Irene Soulsby.

Appendix A. Overview of subscale items included in the analysis

Subscale and included items	Scale / response options	Cronbach's alpha
PAPM STAGE		n/a
Which of the following best describes your thoughts about having a COVID-19 booster vaccine, once Public Health authorities recommend you have one?	"I've not yet thought about having a booster vaccine" (Stage 2); "I'm not yet sure about having a booster vaccine, but will probably (not) have it" (Stage 3); "I've decided I don't want to have a booster vaccine" (Stage 4); "I've decided I do want to have a booster vaccine" (Stage 5); and "I have had the booster vaccine" (Stage 6)	
PREVIOUS COVID-19 VACCINE EXPERIENCE		
Previous COVID-19 vaccine: Overall experience	5-point scale	0.70
Having the vaccine was … *painful / tolerable*		
I believe the vaccine was … *worthless / valuable*		
After having the first COVID-19 vaccine, I experienced … *strong side effects / no side effects*		
After having the second COVID-19 vaccine, I experienced … *strong side effects / no side effects*		
Overall, I found having the vaccine was … *a terrible experience / a good experience*		
Previous COVID-19 vaccine: Healthcare environment	5-point scale (*not at all – very much*)	0.87
The staff were respectful		
The staff were friendly		
The staff were helpful		
My care was well organized		
My privacy was respected		
The waiting area was comfortable		
Previous COVID-19 vaccine: Patient-provider connection	5-point scale (*not at all – very much*)	0.91
I trusted them		
They paid attention to my individual needs		
They gave me enough information		
They gave me support and encouragement		
Previous COVID-19 vaccine: Access	5-point scale (*strongly disagree – strongly agree*)	0.79
Booking my second COVID-19 vaccine was easy		
Getting to the place where I had my second COVID-19 vaccine was easy		
I was happy with the venue where I received my second dose		
Previous COVID-19 vaccine: Perceived benefits	5-point scale (*strongly disagree – strongly agree*)	0.68
My health is better protected now that I have been vaccinated		
I have done all I can to protect my family and friends now that I have been vaccinated		
I am less nervous, anxious, or on edge now that I have been vaccinated		

Overview of subscale items included in the analysis (*continued*)

Subscale and included items	Scale / response options	Cronbach's alpha
PSYCHOLOGICAL CONSTRUCTS		
HEALTH BELIEF MODEL		
Perceived severity	5-point scale (*strongly disagree – strongly agree*)	n/a
Despite already being fully vaccinated (have received at least two doses), I believe I would be very sick if I got COVID-19		
Perceived susceptibility	5-point scale (*strongly disagree – strongly agree*)	†0.33
There is a high chance I will come into contact with a person with COVID-19 over the next few weeks		
I believe I will still have good immunity to COVID-19, six months after having the vaccine		
I believe my immune system is strong enough to protect me against COVID-19		
Perceived benefits	5-point scale (*strongly disagree – strongly agree*)	0.87
A COVID-19 booster vaccine will protect me against catching COVID-19		
A COVID-19 booster vaccine would reduce the severity of a possible future COVID-19 infection		
If I have a COVID-19 booster vaccine, I would be less likely to spread COVID-19 to others		
A mass COVID-19 booster vaccine programme will protect the vulnerable from catching COVID-19		
A mass COVID-19 booster vaccine programme, will help protect the NHS		
A mass COVID-19 booster vaccine programme could prevent the re-introduction of protection measures such as social distancing		
Perceived safety	5-point scale (*strongly disagree – strongly agree*)	0.70
I believe that an approved COVID-19 booster vaccine will be very safe		
I'm NOT concerned about the possible side effects of a COVID-19 booster vaccine		
THEORY OF PLANNED BEHAVIOUR		
Vaccine attitudes	5-point scale (*strongly disagree – strongly agree*)	0.78
Having a COVID-19 booster vaccine would be beneficial		
Having a COVID-19 booster vaccine would be tolerable		
Subjective norms	5-point scale (*strongly disagree – strongly agree*)	0.75 (3 items) / 0.79 (4 items)
My family would expect me to have a COVID-19 booster vaccine		
My GP would expect me to have a COVID-19 booster vaccine		
‡My employer would expect me to have a COVID-19 booster vaccine		
My family and friends have said they would get the COVID-19 booster vaccine once it's available to them		
Perceived control	5-point scale (*strongly disagree – strongly agree*)	n/a
I feel in total control as to whether I will have a COVID-19 booster vaccine		
Anticipated regret	5-point scale (*not at all – a great deal*)	0.97
How much would you regret that you did not get a COVID-19 booster vaccine if it was recommended you have one?		
You were hospitalised and admitted to the intensive care unit as a result of a COVID-19 infection		
You caught COVID-19 and passed it on to a friend		

(*continued on next page*)

Overview of subscale items included in the analysis (*continued*)

Subscale and included items	Scale / response options	Cronbach's alpha
You caught COVID-19 and passed it on to a family member		
OTHER FACTORS		
Vaccine knowledge	5-point scale (*strongly disagree – strongly agree*)	0.89
I know enough about the safety of a COVID-19 booster vaccine, to make an informed decision about whether or not to get the vaccine booster		
I know enough about how the COVID-19 booster vaccine will help reduce the spread of the virus		
I know enough about how effective the COVID-19 booster vaccine will be, to make an informed decision about whether or not to get the vaccine booster		
Trust	5-point scale (*strongly disagree – strongly agree*)	n/a
Information from the Government about the COVID-19 booster vaccine can be trusted		
Fear of needles	Yes / no / don't know	n/a
I am scared of needles		

Note. †each item represented separately in analyses due to low internal consistency; ‡only asked to people who reported they were employed.

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