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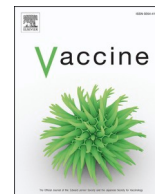
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Analyzing the 7C psychological antecedents of vaccine acceptance throughout the COVID-19 pandemic among healthcare sector workers in France: A repeated cross-sectional study (CappVac-Cov)

Lucia Araujo-Chaveron^{a,b}, Cyril Olivier^c, Gérard Pellissier^c, Elisabeth Bouvet^c, Judith E. Mueller^{a,b,d,*}

^a EHESP French School of Public Health, Paris, France

^b Institut Pasteur, Paris, France

^c Research Group for the Prevention of Occupational Infections in Healthcare Workers (GERES), Paris, France

^d Univ. Rennes, EHESP, CNRS, Inserm, Arènes - UMR 6051, RSMS (Recherche sur les Services et Management en Santé) - U 1309, F-35000 Rennes, France

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ABSTRACT

Background: Across various stages of the COVID-19 pandemic and related vaccine recommendations in France, we assessed the association of the 7C-psychological antecedents with vaccine uptake/intention for booster vaccination among healthcare-sector workers (HCSWs). We also assessed whether 7C-antecedent profiles changed over time.

Methodology: The Research Group for the Prevention of Occupational Infections in Healthcare Workers (GERES) conducted three repeated web-surveys which were disseminated by email chain-referral among HCSWs throughout France. The questionnaires waves took place: July-November 2021, February-March 2022 and January-March 2023 (P2, P3 and P4). We also reanalysed data from a prior similar study conducted late 2020-early 2021 (Moirangthem et al. (2022)) (P1). To evaluate the association of 7C-items with vaccine uptake-intention for future vaccination, we estimated adjusted prevalence ratios (aPR) using robust variance Poisson regression. We report the 7C-item population attributable loss in vaccine intention.

Results: The four surveys (P1-P4) encompassed 5234, 339, 351 and 437 participants. At earlier stages of the vaccine campaign, the principal antecedents of vaccine intention were favorable perception of vaccination benefit-risk-balance (BRB) (vs. unfavorable, aPR: 2.32), reactance to employer encouragement for vaccination (motivates vs. dissuades-me, aPR:2.23), vaccine confidence (vs. not-being-confident, aPR: 1.71) and social conformism towards vaccination (favorable vs. skeptical opinion in private environment, aPR: 1.33). Under a vaccine mandate for HCSWs, only perceiving vaccination as a collective action was associated with current vaccine status (agree vs. disagree, aPR: 2.19). At later stages of the epidemic, hypothetical booster vaccine intentions were strongly associated with BRB perception (favorable vs. unfavorable, aPR: 2.07) and perceiving vaccination as a collective action (agree vs. disagree, aPR: 1.69). Fearing a severe side effect from vaccination decreased population vaccine intention by 26.2%.

Conclusion: Our results suggest that both 7C-antecedents and their association with vaccine behaviour can change over time, and underscore the importance of assuring confidence in vaccine safety.

1. Introduction

Vaccine acceptance appears as a variable state that depends on the specific vaccine [1,2]. The World Health Organization asks countries to monitor vaccine hesitancy in their annual joint reporting form to identify changes and trends over time and detect vaccine concerns at the

early stages [3,4]. To better understand vaccine acceptance, a 3C-model was developed which encompassed the main drivers of vaccine acceptance, referred to as the psychological antecedents of vaccination [5]. This model comprises Complacency (not perceiving diseases as high risk and vaccination as necessary), Convenience (perception of access barriers) and Confidence (lack of trust in safety and effectiveness of

* Corresponding author at: Institut Pasteur, 25-28 rue du Dr Roux, 75724 Paris cedex 15, France.

E-mail address: judith.mueller@ehesp.fr (J.E. Mueller).

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vaccines). Betsch et al. (2018) [6] extended the original model to a 5C-model integrating Calculation (deliberation between benefits and risks of the vaccine) and Collective responsibility (willingness to protect others by one's own vaccination). During the COVID-19 pandemic, Moirangthem et al. (2022) [7] and Oudin Doglioni et al. (2023) [8] proposed and validated an extended version of the psychological antecedents' model including 7 dimensions, which explained well Health Care Sector Workers' (HCSWs) vaccine acceptance during the pandemic. Confidence was split into *Confidence in the vaccine safety* and *Confidence in systems (capacity for reactance)*, and *Social conformism* (influence of the social environment) added as an additional item.

HCSWs have a strong influence in vaccine decisions of the general population [9–12] and the COVID-19 crisis has illustrated the importance of their commitment to health recommendations, through care practice and own health protection. However, vaccine hesitancy repeatedly has been reported in HCSWs [10,13–15] and uptake of the influenza vaccine remains low in France among HCSWs [16]. The COVID-19 vaccine campaign was characterized by an initial low uptake in HCSWs, until vaccine mandates were implemented [17]. The enactment of this mandate raised important ethical concerns between professional obligation of HCSWs to protect others and the individual autonomy of the HCSW on its own medical decision [18]. Due to these evolutions over the course of the COVID-19 vaccine campaign in HCSWs, understanding the drivers of vaccine acceptance among HCSWs requires repeated assessment over time.

To our knowledge, no study has monitored HCSWs' psychological antecedents of vaccination over time. This lack of evidence makes it difficult to anticipate vaccine uptake during crises such as COVID-19 pandemic. In addition, it remains unclear in how far individual attitudes about vaccination vary or can be influenced.

This study aimed to evaluate, among HCSWs in France and across evolving vaccine recommendations made by the French government at different stages of the COVID-19 pandemic, i) the association between the 7C-psychological antecedents of vaccination and vaccine intentions, and ii) changes of 7C-psychological antecedents overtime.

2. Methodology

2.1. Study design and participant inclusion

We conducted a series of three repeated cross-sectional studies. The Research Group for the Prevention of Occupational Infections in Healthcare Workers (GERES) implemented repeated online surveys via the Sphinx (two first surveys) and RedCap (third survey) survey platforms. Study invitations were disseminated by email to a group of HCSWs throughout France who previously had signalled interest to participate in a longitudinal study. Participants were encouraged to chain-refer the invitation email for the first, but not the following surveys. The questionnaire waves took place between 13 July to 30 November 2021 (study period P2), 11 February and 28 March 2022 (study period P3) and 12 January to 13 March 2023 (study period P4). Any ≥ 18 -year-old health professional working in mainland France was eligible for participation.

We also used data from a prior study conducted between December 18 2020, and February 1 2021 [7]. In this study, the GERES also published an online questionnaire on the Sphinx online survey platform, which was disseminated throughout France through chain referral. Several formal and informal networks of hospital-based and private practice HCSWs and of nursing home directors contributed to its dissemination. This study had comprised any ≥ 18 -year-old professional in healthcare- or welfare-related careers, including physicians, nurses, nurse assistants, other paramedical professionals and social workers, administrative and logistic staff.

We labelled the Moirangthem et al. (2022) [7] study as the "first study-period" and subsequent studies as the "second", "third" and "fourth" study periods.

For all study periods, since each participant could forward the survey across its own networks, we did not estimate a response rate. We did not count visits to the survey website, neither.

The planning, conduct and reporting of the study were in line with the Declaration of Helsinki (2013) and the GDPR regulation. The study protocol was approved by the Institut Pasteur IRB on 8 July 2021. Because the data collection was anonymous without risk of indirect identification and did not collect any sensitive information, only self-declared biomedical information, no informed consent or full ethical review was required according to French regulation.

2.2. Data collection

Each survey questionnaire, P1-P4, contained three parts: (1) socio-demographic characteristics, (2) perceived health status, perceptions related to the COVID-19 epidemic and information on the intention to accept COVID-19 vaccination, (3) attitudes and knowledge related to COVID-19 vaccination, based on a short list of 7C psychological antecedents of vaccination, which has been previously published [7]. As the evidence of COVID-19 epidemiology and COVID-19 vaccines evolved during the pandemic, we decided not to explore knowledge items of the 7C-model at P4. Each 7C-dimension was evaluated by at least one attitude and one knowledge, in total, the short version of the 7C questionnaire included 10 questions associated with attitudes towards vaccination and 9 associated with knowledge about the vaccine. The 7C-knowledge items were presented either as a statement to which participants could answer 'True', 'Do not know' or 'False' or requested a single choice answer to a question from several options which included 'Do not know' (Supplementary Table 1). The 7C-attitudes were explored through 5-point Likert-scale which is a psychometric response method where respondents can state their level of agreement in five points: (1) strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, (5) strongly agree. For analyses, 7C-items were grouped into 3 categories: i) strongly disagree and disagree, ii) undecided, iii) strongly agree and agree.

2.2.1. Monitoring of COVID-19 vaccine intentions and uptake

P1 explored vaccine intention through the question "If a vaccine was available now against Coronavirus (COVID-19), would you get vaccinated?" (**Current Vaccine Intention December 2020-February 2021**).

P2 occurred between July and November 2021, when daily COVID-19 incidence rate ranged between 43 and 370 per 100,000 persons [19] and COVID-19 vaccination was mandatory for HCSWs. During P2, participants' vaccine intentions were explored through the question "currently, what is your vaccination intention (summer-fall 2021)?" (**Current Vaccine Uptake summer-fall 2021**), and on hypothetical booster intention to get COVID-19 vaccine "Would you accept a booster of this vaccine (outside of any obligation)?" (**Hypothetical booster vaccine intention**).

P3 occurred between February and March 2022, when daily COVID-19 incidence ranged between 540 and 1 500 per 100 000 persons [19] and booster vaccination was mandatory for HCSWs. P3 explored booster vaccine uptake (**Current booster vaccine uptake**) and among those vaccinated with it, we explored hypothetical vaccine intention for a second booster "Currently, what is your vaccination intention regarding a booster in the fall of 2022, if it was recommended (outside of any obligation)?" (**Hypothetical 2nd booster vaccine intention**).

P4 occurred between January and March 2023, when daily COVID-19 incidence ranged between 33 and 70 per 100 000 persons [19]. Booster was still mandatory for HCSWs during the survey, but the mandate was lifted soon after, on 13 May 2023 [20]. At P4 the question "Today, would you accept vaccination against COVID-19, if it was recommended to you by your general practitioner (GP) (outside of any obligation)?" was asked to the full sample (**Hypothetical 3rd booster vaccine intention**). The last study-period focused on further booster

vaccine intention and did not explore any vaccine uptake, in the context of the COVID-19 vaccination mandate enacted by the French government in July 2021 [21,22].

2.2.2. Covariables: Examining Socio-demographic, and psychological factors in COVID-19 vaccination Intention and Uptake

Socio-demographic information comprised gender, age, region of residence, professional category.

7C antecedents of vaccination (7C-model): Confidence in the vaccine was evaluated as perceived vaccination safety, Confidence in systems as reliability on entities that give vaccine recommendations, Complacency referred to the perceived risks of vaccine-preventable diseases, Calculation referred to the perception of the benefit-risk balance (BRB) of vaccination; Collective responsibility, referred to perceiving vaccination as a collective action to stop the pandemic; Social conformism, to the majority opinion on COVID-19 vaccination in the social environment, and Convenience the perceived accessibility of vaccination. 7C-items were adapted during each study period to the current vaccine recommendation: questions in P1 related to hypothetical primo-vaccination, P2 to hypothetical first booster vaccine, P3 to a hypothetical second booster, P4 to a hypothetical third booster dose.

2.3. Statistical analyses

Due to the evolution of biomedical evidence on COVID-19 vaccines during the pandemic, we opted not to explore the association between 7C-knowledge items and vaccine acceptance, and only described frequencies of knowledge items.

We used robust variance Poisson regression models to estimate the unadjusted and adjusted prevalence ratios (aPR) and 95%-confidence intervals (95%-CI) to explore the association of participant characteristics and individual 7C-items with vaccine status and future vaccine intention at each period. To identify socio-demographic and health-related determinants of vaccine intention, we included independent variables that had a p-value < 0.20 in bivariable models. Essential potential confounders (age, gender and profession category) were forced into the full multivariable models. In France, most professional categories in the healthcare and welfare sector correspond to educational trajectories [23,24], we therefore did not add educational level to the models.

In the multivariable analysis, the 5-point Likert-scale of the 7C-attitudes were grouped; categories 1 and 2 as disagree, and 4 and 5 as agree.

Also, to assess the impact of 7C-items on vaccine intention at the population level, we estimated the loss in vaccine intention attributable to each 7C-attitude (population attributable risk):

$$\Delta CV_{\text{pop}} = CV_{\text{RF}+} * (aPR_{\text{RF}} - 1) * Pr_{\text{RF}+}$$

$CV_{\text{RF}+}$: frequency of no vaccine intention among those having a negative attitude towards the C-item.

aPR_{RF} = adjusted prevalence ratio of C-item with vaccine intention/uptake.

$Pr_{\text{RF}+}$ = frequency of the negative C-attitude in the sample.

3. Results

P1 encompassed the largest sample with 5 234 participants; mainly females (78.4 %). Participants were aged 18–34 years (23.2 %), 35–49 years (40.0 %) and 50 years or older (36.8 %). Nurses (22.9 %), nurse assistants (9.4 %) and biomedical professionals (including physicians, midwives, pharmacists and biologists) (27.7 %), were among the largest groups (Table 1).

Subsequent surveys (P2, P3 and P4) included 339, 351, and 437 participants, respectively. Participants characteristics remained similar to those in P1, with predominantly female participants (76.1 %, 74.6 % and 76.1 %, respectively) and balanced age representation (Table 1).

Contribution by nurses increased from 22.9 % at P1 to 34.7 % at P4 and by biomedical professions from 27.7 % (P1) to 30.3 % (P4). Nurse assistants' contribution decreased from 9.4 % to 1.9 %, and contribution by administrative and technical staff from 24.4 % to 21.1 %. The proportion of hospital workers remained stable (around 65%).

3.1. Evolution of self-reported vaccine intentions/ uptake among participants (Supplementary Fig. 1)

Primary intended vaccination (uptake or intention) increased from 58.1 % (winter 2020–2021) to 91.2 % (summer-fall 2021) (P2), and vaccine refusal decreased from 22.0 % to 8.8 %. At P2, only 8.8 % of 339 remained unvaccinated and 9 of 339 (2.7 %) participants cited vaccination mandate as a main reason for getting vaccinated against COVID-19.

Hypothetical future booster vaccine intentions were assessed at P2 and P3 vaccinated participants or those with intention to do so. In summer-fall 2021 (P2), while 91.2 % of the 339 participants were vaccinated in the context of the mandate, only 78.1 % were willing to accept a hypothetical booster vaccine if recommended by their General Practitioner (GP), and 11.4 % were undecided. Similarly, in winter-spring 2022 (P3), while 93.7 % of the 351 participants were vaccinated in the context of the mandate, only 76.9 % were willing to accept a hypothetical second booster dose, and 11.2 % were undecided. Similarly, in winter 2023 (P4), 73.1 % of participants were willing to accept a hypothetical third dose of booster if recommended by their GP.

3.2. Description of 7C-attitudes

Several items of 7C-antecedents of vaccination showed substantial evolution across surveys, with particularly pronounced differences between P1 and P2, i.e., between winter 2020–21 and summer-fall 2021. The percentage of participants describing a favourable majority opinion about COVID-19 vaccination among family and friends (Social conformism), increased from 34.5 % at P1 to 68.0 % at P2-P3, and remained at 57.2 % at P4. The percentage of participants perceiving more benefits than risks from COVID-19 vaccination (Calculation) increased substantially between P1 (56.0 %) and P2 (72.6 %) and then stabilized with 69.0 % at P3, and 64.0 % at P4 (Table 1). The percentage of participants not expressing fear of getting severe side effects from vaccination (Confidence in the vaccine) substantially increased from P1 (48.6 %) to P2 (65.5 %), and then to P4 (72.5 %) (Table 1). The percentage of participants expressing no difficulties in getting vaccinated (Convenience) increased from 72.9 % at P1 to around 88.0 % thereafter.

Other antecedents remained relatively constant across surveys. The percentage of participants perceiving the employer's incitation for vaccination as motivating or dissuading (Confidence in the system) remained at 30–33 % and 5–8 %, respectively, across all surveys. The percentage of participants who perceived vaccination as a collective action (Collective responsibility) remained relatively stable (around 76.0 % at P1, P3 and P4, with a peak at 81.4 % at P2). The percentage of participants afraid of getting a severe form of COVID-19 (Complacency) increased slightly from 26.4 % to 33.3 %.

Knowledge items of the 7C-model remained constant across P1 to P3, except for 'Serious side effects might occur > 6 months after vaccination' (False; 18.2 % at P1 and 67.2 % at P3) and 'The vaccine blocks transmission of the virus to those around you in case of infection.' (False; 50.2 % at P1 and 18.5 % at P3) (Supplementary Fig. 2).

3.3. Associations between 7C-attitudes dimensions and vaccine intention (Table 2 & Fig. 1)

Calculation (perceived BRB) was the principal antecedent of primary vaccination intention in winter 2020–21 (P1) (favourable vs. unfavourable, aPR: 2.92; p-value < 0.001). Under the vaccine mandate for HCSWs, its association with vaccine uptake was dissipated, but regained

Table 1
Description of the study population. Healthcare sector workers in France. CappVac-Cov study.

	P1 December 2020–February 2021 N = 5 234	P2 July–November 2021 N = 339	P3 February–March 2022 N = 351	P4 January–February 2023 N = 360
Socio-demographic characteristics				
Gender				
Male	1 131 (21.6 %)	81 (23.9 %)	89 (25.4 %)	86 (23.9 %)
Female	4 103 (78.4 %)	258 (76.1 %)	262 (74.6 %)	274 (76.1 %)
Age (in years)				
18–34	1 215 (23.2 %)	58 (17.1 %)	55 (15.7 %)	45 (12.5 %)
35–49	2 092 (40.0 %)	137 (40.4 %)	146 (41.6 %)	152 (42.2 %)
>=50	1 927 (36.8 %)	144 (42.5 %)	150 (42.7 %)	163 (45.3 %)
Region of work				
DROMs and Corsica	23 (0.4 %)	4 (1.2 %)	3 (0.9 %)	2 (0.6 %)
North-Est	1 183 (22.6 %)	83 (24.5 %)	96 (27.4 %)	77 (21.5 %)
North-West	1 301 (24.9 %)	67 (19.8 %)	61 (17.4 %)	65 (18.1 %)
South-Est	1 683 (32.2 %)	65 (19.2 %)	77 (21.9 %)	100 (27.9 %)
South-West	446 (8.5 %)	38 (11.2 %)	53 (15.1 %)	47 (13.1 %)
Paris Region	598 (11.4 %)	82 (24.2 %)	61 (17.4 %)	68 (18.9 %)
Profession				
Biomedical profession	1 449 (27.7 %)	107 (31.6 %)	122 (34.8 %)	109 (30.3 %)
Paramedical professions	818 (15.6 %)	42 (12.4 %)	47 (13.4 %)	43 (11.9 %)
Nurse	1 197 (22.9 %)	104 (30.7 %)	115 (32.8 %)	125 (34.7 %)
Nurse Assistants/Other assistants	491 (9.4 %)	22 (6.5 %)	17 (4.8 %)	7 (1.9 %)
Administrative/Technical staff	1 279 (24.4 %)	64 (18.9 %)	50 (14.3 %)	76 (21.1 %)
Direct contact with patients				
No		94 (27.7 %)	78 (22.2 %)	101 (28.1 %)
Yes		245 (72.3 %)	273 (77.8 %)	259 (71.9 %)
Work in Hospitals				
No	1 971 (37.7 %)	103 (30.4 %)	117 (33.3 %)	112 (31.1 %)
Yes	3 263 (62.3 %)	236 (69.6 %)	234 (66.7 %)	248 (68.9 %)
Work in Nursing Home				
No	4 429 (84.6 %)	294 (86.7 %)	319 (90.9 %)	317 (88.1 %)
Yes	805 (15.4 %)	45 (13.3 %)	32 (9.1 %)	43 (11.9 %)
Off-site				
No	4 502 (86.0 %)	277 (81.7 %)	268 (76.4 %)	284 (78.9 %)
Yes	732 (14.0 %)	62 (18.3 %)	83 (23.7 %)	76 (21.1 %)
Behavioral characteristics				
Level of confidence in authorities * (N = 6 217)				
Low	956 (18.5 %)	111 (32.7 %)	84 (23.9 %)	74 (20.6 %)
Moderate	1 954 (37.8 %)	106 (31.3 %)	127 (36.2 %)	124 (34.4 %)
High	2 255 (43.7 %)	122 (36.0 %)	140 (40.0 %)	162 (45.0 %)
Vaccinated because of the mandate (as one of the 3 main reasons) (N = 690)				
No	<i>Mandate not yet enacted</i>	330 (97.4 %)	326 (92.9 %)	<i>Question not included in the questionnaire</i>
Yes		9 (2.7 %)	25 (7.1 %)	
Opinion on vaccination in general				
Very favourable/Favourable		310 (91.5 %)	338 (96.3 %)	343 (95.3 %)
Undecided		14 (4.1 %)	3 (0.9 %)	8 (2.2 %)
Very skeptical/skeptical		15 (4.4 %)	10 (2.9 %)	9 (2.5 %)
Current vaccine intention, winter 2020–2021				
With intention	3 043 (58.1 %)			
Do not know	1 038 (19.8 %)			
With no intention	1 153 (22.0 %)			
Current vaccine uptake, summer–fall 2021				
Vaccinated		309 (91.2 %)		
Unvaccinated		30 (8.8 %)		
Hypothetical booster vaccine intention, winter–spring 2022				
With intention		239 (78.1 %)		
Do not know		35 (11.4 %)		
With no intention		32 (10.5 %)		
Current booster vaccine uptake, winter–spring 2022				
Vaccinated with booster			329 (93.7 %)	
Vaccinated without booster			8 (2.3 %)	
Unvaccinated			14 (4.0 %)	
Hypothetical 2nd booster vaccine intention, fall 2022				
With intention			253 (76.9 %)	
Do not know			37 (11.2 %)	
With no intention			39 (11.9 %)	

(continued on next page)

Table 1 (continued)

	P1 December 2020–February 2021 N = 5 234	P2 July–November 2021 N = 339	P3 February–March 2022 N = 351	P4 January–February 2023 N = 360
Hypothetical 3rd booster vaccine intention, winter 2023				
With intention				263 (73.1 %)
Do not know				34 (9.4 %)
With no intention				63 (17.5 %)
7C-items				
Calculation 'I think that vaccination against COVID-19 will have more benefits than risks for me.'				
Agree	2 932 (56.0 %)	246 (72.6 %)	242 (69.0 %)	230 (64.0 %)
Undecided	1 136 (21.7 %)	37 (10.9 %)	57 (16.2 %)	46 (12.7 %)
Disagree	1 166 (22.3 %)	56 (16.5 %)	52 (14.8 %)	84 (23.3 %)
Convenience				
'In practice, it will be difficult for me to get vaccinated.'				
Agree	654 (12.5 %)	14 (4.1 %)	15 (4.3 %)	22 (6.1 %)
Undecided	765 (14.6 %)	24 (7.1 %)	18 (5.1 %)	26 (7.2 %)
Disagree	3 815 (72.9 %)	301 (88.8 %)	318 (90.6 %)	312 (86.7 %)
Collective Responsibility				
'Getting vaccinated will also be a collective action to stop the crisis caused by the epidemic.'				
Agree	3 977 (76.0 %)	276 (81.4 %)	268 (76.4 %)	272 (75.6 %)
Undecided	686 (13.1 %)	19 (5.6 %)	36 (10.3 %)	27 (7.5 %)
Disagree	571 (11.0 %)	44 (13.0 %)	47 (13.4 %)	61 (16.9 %)
Social Conformism				
'Among your family and friends, how would you describe the majority opinion towards COVID-19 vaccination?'				
Favorable	1 808 (34.5 %)	230 (67.9 %)	240 (68.4 %)	206 (57.2 %)
Both skeptical and favorable	1 653 (31.6 %)	62 (18.3 %)	68 (19.4 %)	97 (26.9 %)
Skeptical	1 773 (33.9 %)	47 (13.9 %)	43 (12.3 %)	57 (15.8 %)
Complacency				
'I am afraid of getting a severe form of COVID-19.'				
Agree	1 379 (26.4 %)	95 (28.0 %)	104 (29.6 %)	120 (33.3 %)
Undecided	1 222 (23.4 %)	69 (20.4 %)	84 (23.9 %)	40 (11.1 %)
Disagree	2 633 (50.3 %)	175 (51.6 %)	163 (46.4 %)	200 (55.6 %)
Confidence in COVID-19 vaccine				
'I am afraid of having a severe side effect of vaccination.'				
Agree	1731 (33.1 %)	67 (19.8 %)	54 (15.4 %)	63 (17.5 %)
Undecided	959 (18.3 %)	50 (14.8 %)	55 (15.7 %)	36 (10.0 %)
Disagree	2 544 (48.6 %)	222 (65.5 %)	242 (69.0 %)	261 (72.5 %)
Confidence in systems				
'If my employer encourages me to get vaccinated, this...'				
Dissuades me	274 (5.2 %)	28 (8.3 %)	22 (6.3 %)	18 (5.0 %)
Has no effect	3 409 (65.1 %)	209 (61.7 %)	212 (60.4 %)	222 (61.7 %)
Motivates me	1 551 (29.6 %)	102 (30.1 %)	117 (33.3 %)	120 (33.3 %)

* Level of confidence in authorities to manage the health and economic crisis related to the COVID-19 pandemic.

importance for the intention of a hypothetical first (P2), second (P3), and third (P4) booster dose (aPR: 2.29, 2.04, and 2.07, respectively).

Perceiving vaccination as a collective action was the second strongest antecedent of primary vaccination intention in winter 2020–21 (P1) (agree vs. disagree, aPR: 2.84; p -value < 0.001). In summer-fall 2021 (P2), it remained the only psychological antecedent associated with vaccine status (agree vs. disagree, aPR: 2.19; p -value < 0.001) and persisted, albeit more weakly, under the mandate for booster vaccination at P3 (aPR: 1.20). Additionally, it was strongly associated with third and fourth hypothetical booster dose intentions (agree vs. disagree, aPR: 2.18 and 1.69, respectively).

Confidence in the vaccine was positively associated with primary vaccination intention in winter 2020–21 (P1) (agree vs. disagree, aPR: 1.84; p -value < 0.001), its association with vaccine uptake was dissipated in summer-fall 2021 (P2), but regained importance on booster vaccine uptake (agree vs. disagree, aPR: 1.14; p -value = 0.04). Its

association increased for hypothetical booster vaccine intention (agree vs. disagree, aPR: 1.45, 1.67, and 1.43 for the first (P2), second (P3), and third hypothetical booster dose (P4)).

Reactance to employer's encouragement to get vaccinated (Confidence in systems) (motivates vs. dissuades, aPR: 2.15; p -value < 0.001), and Social conformism (favourable vs. skeptical opinion, aPR: 1.33; p -value < 0.001) were significantly associated with primary vaccination intention in winter 2020–21 (P1) but these associations disappeared during the rest of the study periods. Both antecedents were not significantly associated with hypothetical booster dose intention at any survey periods.

When assessing the absolute impact of negative attitudes on vaccine behavior across the observed periods, low confidence in the vaccine (fear of severe side effects from vaccination) was related to the highest population attributable loss in vaccine uptake or intention during any survey (e.g., -26.2 % loss in hypothetical 2nd booster vaccine intention

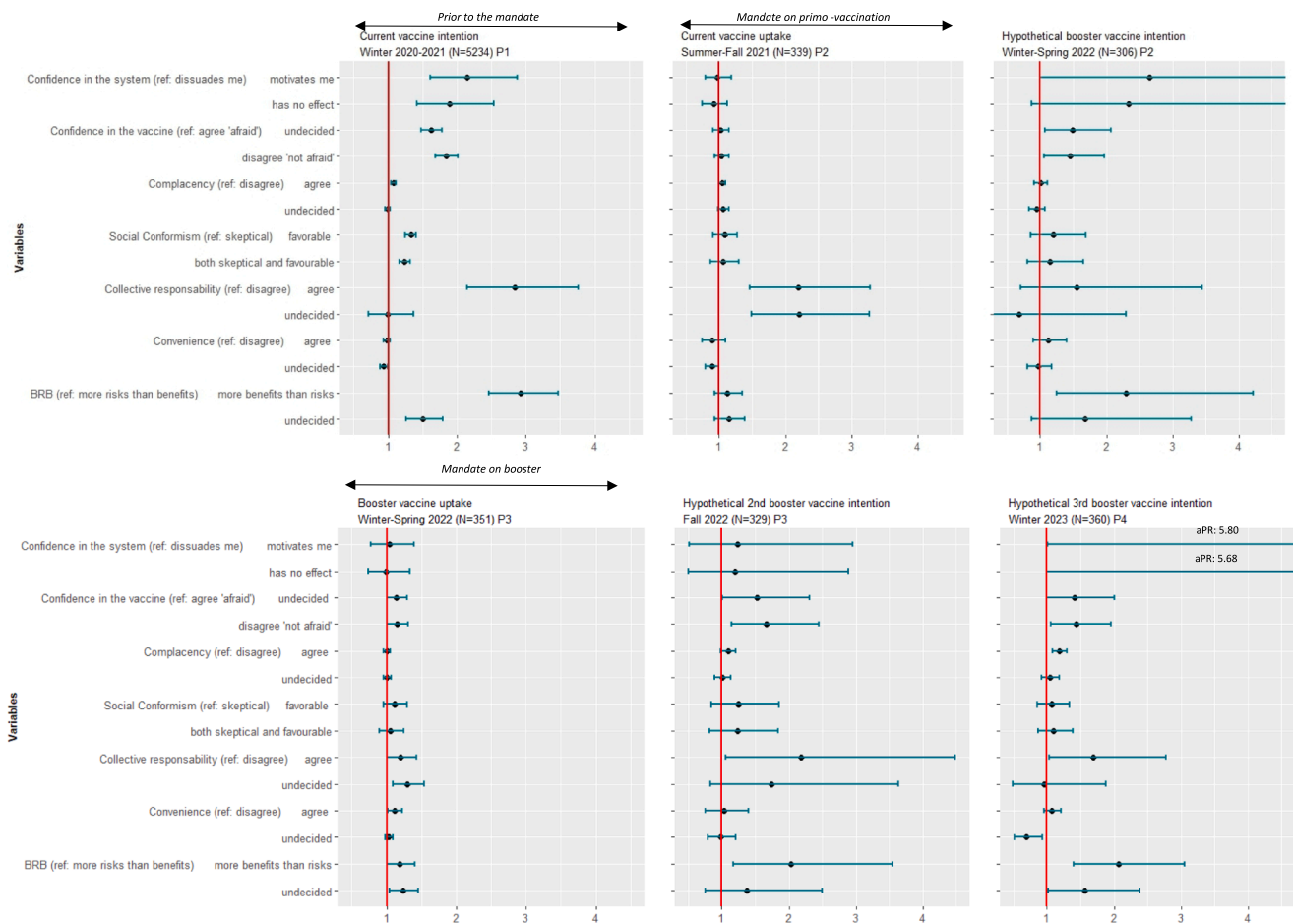


Fig. 1. Association of 7C-attitude items with vaccine intention, vaccine uptake or future vaccine intention (vs. undecided/no intention) during the COVID-19 pandemic among health care sector workers in France. Adjusted prevalence ratio (aPR) obtained from multivariable robust-variance Poisson regression models. CappVac-Cov study. *Detailed results for confidence in the system in the hypothetical 3rd booster vaccine intention (ref: dissuades me): “motivates me”: aPR 5.80, 95%-CI 1.00–33.55. “has no effect”: aPR 5.68, 95%-CI 0.99–32.65. 1st period of study (P1): 18 December 2020 to 1 February 2021. 2nd period of study (P2): 13 July to 30 November 2021. 3rd period of study (P3): 1 February and 28 March 2022. 4th period of study (P4): 12 January to 13 March 2023. Hypothetical Future Vaccine Intention was explored among those vaccinated through the question “Would you accept a booster of this vaccine (outside of any obligation)”.

at P3), with exception to P2 (early mandate) (Table 3). Calculation showed lower, but similarly constant importance.

In longitudinal follow-up of seven participants, relatively stable attitudes were observed only for perceiving vaccination as collective action, and capacity for reactance (Supplementary File 1).

4. Discussion

In this series of surveys during the COVID-19 vaccine campaign among HCSWs in France, we found that the associations between 7C-psychological antecedents and vaccine behaviour changed over time, in particular during the initial phase of the epidemic with a novel vaccine campaign. Furthermore, we found substantial variability of 7C-attitudes over time, specifically description of the majority opinion about the vaccine in the social environment (Social conformism), perception of benefits vs. risks (Calculation), and fear of side effects from vaccination (Confidence in the vaccine). Relatively stable 7C-attitudes were Collective responsibility and capacity for reactance (Confidence in the system). Overall, Calculation and Collective responsibility appeared as strongest determinants in most behaviour contexts during this study, while Confidence in the vaccine was related to the strongest attributable loss in vaccine intention in this HCSWs sample.

In the first survey at the start of the vaccine campaign, Calculation was one of the principal determinants of vaccine intention, and it was in

following surveys a determinant for booster intention and uptake outside mandates. By contrast, under the mandate for primary vaccination for HCSWs (issued in July 2021 [21,22]) when 91.2 % of participants were vaccinated, and for booster vaccination, Calculation was no determinant. In coherence with previous studies conducted among 3870 HCSWs during the beginning of the COVID-19 vaccine campaign [8], these results underpin the importance of the benefit-risk consideration in vaccine decisions and that this prominent role is modified by mandates, albeit only temporally. The perception of benefits vs. risks did not drastically change across surveys in our study, but some changes could indicate that participants perceived less risks after the first year of vaccination, while consequently, benefits were estimated lower, as well. The question arises whether individuals changed from poor to favourable benefit-risk perception following the vaccination under the mandate, which requires a longitudinal study in a larger sample. A previous study among the general population in France in summer 2021 found that intention for future vaccination among persons vaccinated only to obtain a vaccine pass or to satisfy a professional mandate did not depend on a favourable benefit-risk perception [25].

Low confidence in the vaccine (fear of vaccination side-effects) was the antecedent with the strongest absolute impact on hypothetical vaccine intention in most surveys. Despite an only moderate association with vaccine intention, the moderate prevalence of fear of side effects makes a substantial impact on vaccine coverage plausible. The high

Table 2
Association of sociodemographic characteristics and of 7C-attitude items with vaccine intention, vaccine uptake or future vaccine intention (vs. undecided/no intention) during the COVID-19 pandemic among health care sector workers in France. Adjusted Prevalence Ratio (aPR), *p*-value obtained with multivariable robust-variance Poisson regression model. CappVac-Cov study. France.

	Current vaccine intention winter 2020–2021 (N = 5234) P1			Current vaccine uptake summer–fall 2021 (N = 339) P2			Hypothetical booster vaccine intention winter–spring 2022 (N = 306) P2			Current booster vaccine uptake winter–spring 2022 (N = 351) P3			Hypothetical 2nd booster vaccine intention fall 2022 (N = 329) P3			Hypothetical 3rd booster vaccine intention winter 2023 (N = 360) P4		
	With intention (n = 3043, 58.1 %)			Vaccinated (n = 309, 91.2 %)			With intention (n = 239, 78.1 %)			Vaccinated (n = 329, 93.7 %)			With intention (n = 253, 76.9 %)			With intention (n = 263, 73.1 %)		
	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value
<i>Gender</i>																		
Male	302	(13.8)	1	76	(24.6)	1	64	(26.8)	1	87	(26.4)	1	75	(29.6)	1	71	(27.0)	1
Female	1889	(86.2)	0.98	233	(75.4)	0.98	175	(73.2)	0.95	242	(73.6)	0.99	178	(70.4)	1.01	192	(73.0)	0.99
<i>Age (years)</i>																		
18–34	534	(17.6)	1	48	(15.5)	1	33	(13.8)	1	49	(14.9)	1	35	(13.8)	1	31	(11.8)	1
35–49	1160	(38.1)	1.04	126	(40.8)	1.04	95	(39.8)	1.02	137	(41.6)	1.01	108	(42.7)	1.01	104	(39.5)	0.96
>=50	1349	(44.3)	1.08	135	(43.7)	1.03	111	(46.4)	1.01	143	(43.5)	1.01	110	(43.5)	0.95	128	(48.7)	0.97
<i>Profession</i>																		
Admin/ technical staff	725	(23.8)	0.97	62	(20.1)	1.01	51	(21.3)	0.99	46	(14.0)	0.99	36	(14.2)	0.98	51	(19.4)	0.88
Biomedical profession	1162	(38.2)	1	104	(33.7)	1	89	(37.2)	1	117	(35.6)	1	105	(41.5)	1	93	(35.4)	1
Nurse Assistants	150	(4.9)	0.87	19	(6.2)	0.97	9	(3.8)	0.74	15	(4.6)	1.05	8	(3.2)	0.90	3	(1.1)	0.76
Nurses	594	(19.5)	0.96	91	(29.5)	0.96	67	(28.0)	1.02	110	(33.4)	1.06	73	(28.9)	0.88	85	(32.3)	0.90
Other paramedical staff	412	(13.5)	0.92	33	(10.7)	0.94	23	(9.6)	0.97	41	(12.5)	0.99	31	(12.3)	1.01	31	(11.8)	0.95
<i>Calculation</i>																		
<i>'I think that vaccination against COVID-19 will have more benefits than risks for me.'</i>																		
Agree	2622	(86.2)	2.92	244	(79.0)	1.13	216	(90.4)	2.29	238	(72.3)	1.18	218	(86.2)	2.04	218	(82.9)	2.07
Undecided	295	(9.7)	1.50	34	(11.0)	1.14	16	(6.7)	1.68	56	(17.0)	1.23	26	(10.3)	1.37	25	(9.5)	1.56
Disagree	126	(4.1)	1	31	(10.0)	1	7	(2.9)	1	35	(10.6)	1	9	(3.6)	1	20	(7.6)	1
<i>Convenience</i>																		
<i>'In practice, it will be difficult for me to get vaccinated.'</i>																		
Agree	281	(9.2)	1	12	(3.9)	1	10	(4.2)	1	15	(4.6)	1	10	(4.0)	1	19	(7.2)	1
Undecided	329	(10.8)	0.95	20	(6.5)	0.99	15	(6.3)	0.86	18	(5.5)	0.92	14	(5.5)	0.95	11	(4.2)	0.65
Disagree	2433	(80.0)	1.02	277	(89.6)	1.11	214	(89.5)	0.89	296	(90.0)	0.90	229	(90.5)	0.97	233	(88.6)	0.93
<i>Collective Responsibility</i>																		
<i>'Avoiding transmission to others is an important reason for getting vaccinated.'</i>																		
Agree	0.0			268	(86.7)		231	(96.7)		264	(80.2)		220	(87.0)		238	(90.5)	
Undecided	0.0			22	(7.1)		1	(0.4)		38	(11.6)		23	(9.1)		10	(3.8)	
Disagree	0.0			19	(6.2)		7	(2.9)		27	(8.2)		10	(4.0)		15	(5.7)	
<i>'Getting vaccinated will also be a collective action to stop the crisis caused by the epidemic.'</i>																		
Agree	2934	(96.4)	2.84	275	(89.0)	2.19	232	(97.1)	1.56	262	(79.7)	1.20	230	(90.9)	2.18	242	(92.0)	1.69
Undecided	66	(2.2)	0.99	17	(5.5)	2.21	3	(1.3)	0.68	36	(10.9)	1.29	17	(6.7)	1.73	8	(3.0)	0.96

(continued on next page)

Table 2 (continued)

	Current vaccine intention winter 2020–2021 (N = 5234) P1			Current vaccine uptake summer–fall 2021 (N = 339) P2			Hypothetical booster vaccine intention winter–spring 2022 (N = 306) P2			Current booster vaccine uptake winter–spring 2022 (N = 351) P3			Hypothetical 2nd booster vaccine intention fall 2022 (N = 329) P3			Hypothetical 3rd booster vaccine intention winter 2023 (N = 360) P4			
	With intention (n = 3043, 58.1 %)			Vaccinated (n = 309, 91.2 %)			With intention (n = 239, 78.1 %)			Vaccinated (n = 329, 93.7 %)			With intention (n = 253, 76.9 %)			With intention (n = 263, 73.1 %)			
	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value	n (%)	aPR	P-value	
Disagree	43 (1.4)	1		17 (5.5)	1		4 (1.7)	1		31 (9.4)	1		6 (2.4)	1		13 (4.9)	1		
Social Conformism																			
<i>'Among your family and friends, how would you describe the majority opinion towards COVID-19 vaccination?'</i>																			
Favourable	1601 (52.6)	1.33	<0.001	226 (73.1)	1.08	0.385	193 (80.8)	1.20	0.293	235 (71.4)	1.11	0.156	198 (78.3)	1.25	0.272	175 (66.5)	1.07	0.551	
Both skeptical and favourable	952 (31.3)	1.24	<0.001	53 (17.2)	1.06	0.564	35 (14.6)	1.15	0.453	62 (18.8)	1.06	0.516	44 (17.4)	1.23	0.316	66 (25.1)	1.10	0.426	
Skeptical	490 (16.1)	1		30 (9.7)	1		11 (4.6)	1		32 (9.7)	1		11 (4.4)	1		22 (8.4)	1		
Complacency																			
<i>'I am afraid of getting a severe form of COVID-19.'</i>																			
Agree	877 (28.8)	1.08	<0.001	94 (30.4)	1.04	0.103	79 (33.1)	1.00	0.943	101 (30.7)	0.99	0.843	83 (32.8)	1.09	0.095	103 (39.2)	1.18	<0.001	
Undecided	734 (24.1)	0.99	0.677	67 (21.7)	1.06	0.112	49 (20.5)	0.95	0.378	81 (24.6)	0.99	0.783	63 (24.9)	1.01	0.873	30 (11.4)	1.04	0.516	
Disagree	1432 (47.1)	1		148 (47.9)	1		111 (46.4)	1		147 (44.7)	1		107 (42.3)	1		130 (49.2)	1		
Confidence in COVID-19 vaccine																			
<i>'I am afraid of having a severe side effect of vaccination.'</i>																			
Agree	330 (10.8)	1		46 (14.9)	1		17 (7.1)	1		40 (12.2)	1		14 (5.5)	1		18 (6.8)	1		
Undecided	541 (17.8)	1.62	<0.001	45 (14.6)	1.02	0.773	33 (13.8)	1.49	0.019	54 (16.4)	1.14	0.039	35 (13.8)	1.53	0.045	23 (8.8)	1.41	0.058	
Disagree	2172 (71.4)	1.84	<0.001	218 (70.6)	1.03	0.564	189 (79.1)	1.45	0.019	235 (71.4)	1.14	0.040	204 (80.6)	1.67	0.009	223 (84.4)	1.43	0.023	
Confidence in systems																			
<i>'If my employer encourages me to get vaccinated, this...'</i>																			
Dissuades-me	1302 (42.8)	1		19 (6.2)	1		3 (1.3)	1		15 (4.6)	1		3 (1.2)	1		1 (0.4)	1		
Has no effect	27 (0.9)	1.90	<0.001	101 (32.7)	0.91	0.398	91 (38.1)	2.33	0.092	117 (35.6)	0.99	0.953	100 (39.5)	1.20	0.687	154 (58.6)	5.68	0.052	
Motivates-me	1714 (56.3)	2.15	<0.001	189 (61.2)	0.96	0.724	145 (60.7)	2.65	0.051	197 (59.9)	1.04	0.787	150 (59.3)	1.23	0.639	108 (41.1)	5.80	0.050	

Hypothetical booster vaccine intention was explored among those vaccinated through the question “Would you accept a booster of this vaccine (outside of any obligation)”.

1st period of study (P1): 18 December 2020 to 1 February 2021.

2nd period of study (P2): 13 July to 30 November 2021.

3rd period of study (P3): 1 February to 28 March 2022.

4th period of study (P4): 12 January to 13 March 2023.

Table 3
Reduction in vaccination prevalence/intention (%) attributable to 7C-attitude items.

	Current vaccine intention winter 2020–21 (N = 5234) P1	Current vaccine uptake summer–fall 2021 (N = 339) P2	Hypothetical booster Vaccine intention winter–spring 2022 (N = 306) P2	Current booster vaccine uptake winter–spring 2022 (N = 351) P3	Hypothetical 2nd booster Vaccine intention fall 2022 (N = 329) P3	Hypothetical 3rd booster Vaccine intention winter 2023 (N = 360) P4
<i>Calculation: 'I think that vaccination against COVID-19 will have more benefits than risks for me.'</i>						
Disagree	-14.07	NA	-9.02	NA	-7.28	-11.13
<i>Convenience: 'In practice, it will be difficult for me to get vaccinated.'</i>						
Agree	-0.22	NA	NA	0.46	NA	NA
<i>Collective Responsibility: 'Getting vaccinated will also be a collective action to stop the crisis caused by the epidemic.'</i>						
Disagree	-7.03	-6.68	NA	-2.02	-7.08	-6.56
<i>Social Conformism: 'Among your family and friends, how would you describe the majority opinion towards COVID-19 vaccination?'</i>						
Skeptical	-7.06	NA	NA	NA	NA	NA
<i>Complacency: 'I am afraid of getting a severe form of COVID-19.'</i>						
Disagree	-1.97	NA	NA	NA	NA	-4.31
<i>Confidence in COVID-19 vaccine: 'I am afraid of having a severe side effect of vaccination.'</i>						
Agree	-19.79	NA	-18.88	-7.44	-26.16	-2.44
<i>Confidence in system: 'If my employer encourages me to get vaccinated, this...'</i>						
Dissuades-me	-1.59	NA	NA	NA	NA	NA

NA: Not Applicable because C-item not significant in multivariable model.

>10 % point reduction in vaccine intention.

10% to 5% point reduction in vaccine intention.

<5% point reduction in vaccine intention.

prevalence of low confidence in winter 2020–21 (33 %) can be partly explained by the novelty of the vaccine in 2021, with limited safety data and minimal personal experience. In our survey, low confidence in the vaccine among those with no intention to get vaccinated HCSWs was 26.8 % in winter 2020 (P1), and 22.0 % among the general population in spring 2020 [26]. By 2022, this increased to 74.1 % in our survey (P3 fall 2022) and 63.0 % among the general population in summer-fall 2022 [27]. The lower prevalences thereafter (15–20 %), despite emerging evidence on severe side effects such as thrombocytopenic thrombosis and myocarditis, could reflect reassuring personal experience. Studies among mothers suggest that primiparous mothers show more reluctance toward childhood vaccinations than multiparous mothers [11]. This highlights that even during epidemic response vaccination, vaccine delivery needs to yield positive experience with regard to mild and severe side effects, and the way they are handled.

The associations of Collective responsibility (seeing vaccination as a collective action to stop the crisis related to the epidemic) with vaccine uptake and hypothetical intention remained constant during the study period, and the prevalence of agreement with this statement was high across all surveys. Collective responsibility was the only significant determinant of vaccine uptake under the mandate, which means that HCSWs refusing vaccination despite the mandate (with the consequence of job exclusion) refused to see the collective potential in vaccination. Knowledge about Sars-Cov-2 transmission mechanisms have been found to be associated with the sustained or increased adoption of preventive measures [28]. However, detailed (and variable) evidence on the vaccines' effectiveness against infection and transmission became available only later during 2021. We therefore suggest that disagreement with vaccination as a collective action in summer 2021 was rather grounded on ideological attitudes and beliefs. Interestingly, only 9 of the 339 participants in summer 2021 cited the mandate as the reason for vaccination, which suggests that Collective responsibility substantially contributed to the high vaccine uptake observed among our participants.

Previous studies have found that compliance with regulations and recommendations is driven by social norms [28]. Surprisingly, even though there was a trend towards an increase of favourable opinion among family and friends (Social conformism) across surveys, it did not significantly influence vaccine intention at later stages. Social conformism to the private environment appears to have played a role during the initial phase of the vaccine campaign only, when the heuristic of following other people's example had the highest facilitating effect on

decision-making.

Similarly, reactance to employer vaccine encouragement (Confidence in the system) was associated to absence of vaccine intention/uptake only during the initial phase of the vaccine campaign, before the mandate enactment. Social conformism and Confidence in the system are the only 7C-antecedents that are strictly interpersonal and without direct relation to the perception of the vaccine or vaccination. At later stages of the pandemic, a first experience with the COVID-19 vaccine seems to have mitigated the role of these interpersonal antecedents.

Despite previous studies that have shown how compliance with prevention behaviours rely on high perceived vulnerability and fear of severe COVID-19 [28,29], we found that fear of a severe form of COVID-19 (Complacency) was not a substantial determinant of vaccine intention or uptake at any time, while one quarter to one third of participants did express this fear across surveys. This could be related to the fact that other more important reasons for COVID-19 vaccination existed for HCSWs in this study, including Collective responsibility and vaccination against any form of COVID-19 infection.

Convenience was never associated with vaccine uptake or hypothetical vaccine intention, likely due to the high accessibility of COVID-19 vaccination for HCSWs during the pandemic.

Our study has several limitations. The generalizability of our results is limited because our samples are not representative of the HCSWs French population. Some professions such as nurse assistants were under represented across the survey periods and thus, we cannot conclude whether there were vaccine disparities between professions. Another main limitation is that we cannot assume that the same persons participated at each step. Also, our study uses a limited number of cross-sectional surveys, which affects the description of 7C-psychological antecedents over time, but has less impact on measuring their associations with vaccine behavior. Thus, it does not accurately capture the variability within the population. Our original plan was to obtain a longitudinal follow up of participants, but our ID creation system proved not adapted to real life, with many participants opting for simpler, instantaneous participations or losing their ID. Nevertheless, we have included the results of the small sample obtained in the [Supplementary File 1](#), as inspiration for future work.

Given the difficulty in obtaining longitudinal data, we have to rely on careful interpretation of 7C-attitude frequencies across the surveys. The characteristics of the participant groups remained relatively stable, based on which we attempt an interpretation of the 7Cs evolution over time. In particular, the interpretation of associations between 7C and

vaccine behaviour maintains reasonable validity, as selection bias impacts less these estimates [30]. Our study is, to the best of our knowledge, the first to assess the association of the 7C-model with vaccine acceptance throughout time and during a pandemic. It is also the first, to evidence that psychological antecedents of vaccination vary through time and context at an individual level. Despite the limitations mentioned above, given the absence of previous data, this study could serve as a starting point for future longitudinal research regarding vaccine acceptance and its promotion in epidemic contexts.

5. Conclusion

Our study provides some evidence that several 7C-psychological antecedent's attitudes of vaccination are context-specific and thus change over time, while others, in particular the perception of vaccination as a collective action and the capacity for reactance, remain relatively stable. Also, our finding provides some evidence on the importance of Confidence in the vaccine to improve vaccine intention at a population level. As important determinants on the long-term, including given coercive policies, the perception of the vaccine's BRB and of the collective dimension of a vaccine recommendation stand out. By contrast, during the initial stage of a novel vaccine campaign in an epidemic context, the influence from the social environment, reactance against a recommendation source (the employer) and fear of vaccine side effects also play an important role.

If 7C-attitudes evolve over time and are influenced by context, and are strongly associated to vaccine behavior, the question arises if they can be influenced. Our finding calls for longitudinal studies to track changes of 7C-psychological antecedents of vaccination and their association with vaccine decision. A better understanding of the dynamic nature of 7C-psychological antecedents would help tailoring vaccine promotion strategies to profiles of vaccine hesitancy and readiness.

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CRediT authorship contribution statement

Lucia Araujo-Chaveron: Writing – review & editing, Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Cyril Olivier:** Writing – review & editing, Validation, Data curation. **Gérard Pellissier:** Writing – review & editing, Validation. **Elisabeth Bouvet:** Writing – review & editing, Validation. **Judith E. Mueller:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.vaccine.2024.07.004>.

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