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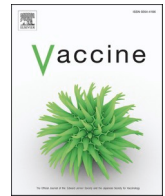
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Are the 7C psychological antecedents associated with COVID-19 vaccine behaviours beyond intentions? A cross-sectional study on at-least-one-dose and up-to-date vaccination status, and uptake speed among adults in France

Gaëlle Lièvre^{a,b}, Jonathan Sicsic^c, Simon Galmiche^{a,b}, Tiffany Charmet^a, Arnaud Fontanet^a, Judith E. Mueller^{a,d,*}

^a Emerging Diseases Epidemiology Unit, Institut Pasteur, Université Paris Cité, Paris, France

^b Sorbonne Université, Ecole Doctorale Pierre Louis de Santé Publique, Paris, France

^c Université Paris Cité, LIRAES F-75006, 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: Widely documented psychological antecedents of vaccination are confidence in vaccines, complacency, convenience, calculation, collective responsibility (5C model) with the recent addition of confidence in the wider system and social conformism. While the capacity of these seven antecedents (7C) to explain variance in COVID-19 vaccine *intentions* has been previously documented, we study whether these factors also are associated with vaccine *behaviours*, beyond intentions.

Methods: From February to June 2022, we recruited a sample of adults in France, including persons with notified recent SARS-CoV-2 infection, along with relatives and randomly selected non-infected persons. Participants completed self-administered questionnaires assessing COVID-19 vaccination history and the 7C antecedents. We defined vaccination behaviours as three outcomes: at-least-one-dose vaccine status by 2022 (N = 49,019), up-to-date vaccination status (N = 46,566), and uptake speed of first dose (N = 25,998). We conducted multivariable logistic regressions and Cox models.

Results: Among the 49,019 participants, 95.0% reported receipt of at least one dose and 89.8% were up to date with recommendations. All 7C antecedents were significantly associated with the outcomes, although effects were weaker for up-to-date vaccination status and uptake speed. The strongest effects (most vs. least vaccine-favourable attitude level, at-least-one-dose vaccination status) were observed for collective responsibility (OR: 14.44; 95%CI: 10.72–19.45), calculation (OR: 10.29; 95%CI: 7.53–14.05), and confidence in the wider system (OR: 8.94; 95%CI: 6.51–12.27).

Conclusion: This study demonstrates that the 7C not only explain vaccine intention, but also vaccine behaviours, and underpins the importance of developing vaccine promotion strategies considering the 7C antecedents.

1. Introduction

COVID-19 vaccination is estimated to have prevented over 1.5 million deaths in the WHO European region in the first year of COVID-19 vaccinations [1]. Despite high vaccine accessibility, evidence of high effectiveness, and demonstration of good safety profile in population-based studies [2,3], global vaccine coverage among adults remained below 85 % in the 27 countries of the European Union. In the context of strong vaccine-incentive policies (i.e., obligation to hold a valid COVID-19 certificate, then transformed into a COVID-19 vaccination pass

required to access leisure and cultural venues), vaccine coverage among French adults reached 92.4 % [4].

The majority of unvaccinated persons *chose* to remain unvaccinated, despite an appropriate vaccine offer [5]. In most populations, vaccine acceptance and refusal varied by vaccine type [6] (mRNA vs. viral-vector vaccines) and were related to sociodemographic determinants, such as age, gender, and educational attainment [7,8].

Over the last decade, several concepts have emerged to identify factors that help understanding vaccine acceptance beyond socio-demographic factors. Early models described vaccine uptake similar to

* Corresponding author at: Emerging Diseases Epidemiology Unit, Institut Pasteur, Paris, France.

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

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other health behaviours as a function of health literacy, social norms, and self-efficacy [9,10] Vaccine hesitancy was defined as a “delay in acceptance or refusal of vaccination despite availability of vaccination services” [11]. Vaccination readiness – a positive formulation – has more recently been coined to describe a constellation of psychological factors that increase or decrease an individual’s intention of getting vaccinated [12].

Widely documented psychological antecedents of vaccination are confidence in vaccine, complacency, and convenience (3C model [11]) as well as calculation and collective responsibility (5C model [13]). As part of extended 7C models, additional factors have been proposed by Geiger and colleagues (2022) [12] and Moirangthem and colleagues (2022) [14], and include confidence in the wider system (beyond vaccination), reactance or specific adherence to conspiracy theories, and social conformism or adherence to social norms. The capacity of the 5C- and 7C-model’s antecedents to explain the variance in vaccine intention has been documented in various populations and for several vaccines, including influenza, pneumococcal disease, shingles, HPV, and COVID-19 [14–17]. For example, in a study conducted among French health-care workers at the beginning of the COVID-19 vaccine roll-out, the 7C antecedents explained 65 % of the variance in COVID-19 vaccine intention [14]. Less is known in how far these antecedents are associated with actual vaccine behaviour, and whether speed of vaccine uptake shows the same associations – an aspect which is of relevance for the management of epidemic response vaccine campaigns.

In this article, we therefore evaluate the socio-demographic determinants and 7C psychological antecedents of COVID-19 vaccination with regard to three outcomes: receipt of at least one dose by 2022, speed of first-dose uptake, and level of adherence to booster recommendations by 2022.

2. Results

A total of 49,200 (30.4 %) eligible “ComCor” participants completed the “Cognitiv” questionnaire, including 44,881 recently infected, 3,099 non-infected persons, and 1,220 relatives. COVID-19 vaccine coverage was 95.0 % for at-least-one-dose and 87.8 % for up-to-date vaccination status (Table 1). Overall, 12,223 participants were vaccinated prior to eligibility and 392 on the day of eligibility. These early vaccinators were younger, higher educated, and had a lower tendency to have comorbidities (data not shown). The median delay from eligibility to first dose was 38 days, excluding individuals who were vaccinated prior to or on the day of eligibility.

In bivariable analysis, the prevalence of vaccination increased with age, education level, professional qualification level, and the presence of at least one comorbidity (Table 1). Similarly, these factors were associated with complete vaccination, while only education and professional qualification levels were associated with delays between eligibility and 1-dose vaccine uptake (Table 1).

In models including all socio-demographic variables and comorbidities (Table 2), higher age was significantly and strongly associated with at-least-one-dose and up-to-date vaccination status, but only weakly with uptake speed. Female sex was weakly associated with faster uptake speed, but not with at-least-one-dose nor up-to-date vaccination status. Higher diploma categories were significantly associated with the three outcomes. Compared to employees, several professional categories were significantly more likely to be (quickly) vaccinated (e.g., senior executive and intermediate professions), and labourers less likely. The presence of at least one comorbidity was associated with vaccination status and speed.

In analyses adjusting for socio-economic characteristics and comorbidities, all 7C antecedents were significantly associated with vaccination status and uptake speed (Table 3). For at-least-one-dose vaccination status, the strongest effect sizes (most vaccine-favourable vs. least vaccine-favourable attitude level) were observed for collective responsibility (the perception of vaccination as a collective action, OR:

14.44; 95 %CI: 10.72–19.45), calculation (positive perception of vaccination’s benefits-risks balance, OR: 10.29; 95 %CI: 7.53–14.05), and confidence in system (feeling encouraged by government’s incitation to get vaccinated, OR: 8.94; 95 %CI: 6.51–12.27; Table 3). Weaker effect sizes were observed for confidence in vaccine (the absence of fear of vaccination side effects, OR: 3.70; 95 %CI: 2.95–4.64) and low complacency (the fear of severe forms of COVID-19, OR: 1.87; 95 %CI: 1.49–2.34). Two antecedents showed particular associations with at-least-one-dose vaccination status: first, indecision regarding access convenience (perception of no practical difficulties to get an appointment) was associated with lower vaccine uptake (OR: 0.06; 95 %CI: 0.04–0.10). Secondly, describing a favourable majority opinion towards COVID-19 vaccination in one’s close social environment (antecedent item referring to social conformism) was negatively associated with ≥ 1 -dose vaccination status (OR: 0.69; 95 %CI: 0.52–0.93).

Most 7C antecedents showed similar associations with up-to-date vaccination status and uptake speed, however with substantially lower magnitude (Table 3). Notably, describing a favourable majority opinion in one’s close environment was positively associated with up-to-date vaccination status (OR: 1.34; 95 %CI: 1.07–1.68) and uptake speed (OR: 1.24; 95 %CI: 1.14–1.34).

For at-least-one-dose vaccination status, the combination of the most and second-to-most favourable attitude levels resulted in a higher odds ratio for calculation (OR: 11.27; 95 %CI: 9.06–14.01; Supplementary Table 2) than for collective responsibility (OR: 6.32; 95 %CI: 5.34–7.47; Supplementary Table 2), while collective responsibility had the highest OR when considering separately the one most favourable level (Table 3). Delays from eligibility date to vaccination varied substantially across levels of 7C antecedents. For example, median delays ranged from 30 to 68 days from most to least favourable level of calculation, from 31 to 76 days for collective responsibility, and from 32 to 78 days for confidence in system (Fig. 1).

Overall, models with the 7C antecedents and sociodemographic variables explained 58.9 % and 23.4 %, respectively, of variance in at-least-one-dose and up-to-date vaccination status.

Models including only the 7C psychological antecedents and not socio-demographic factors showed similar results (Supplementary Table 3).

3. Discussion

In this study, conducted in a large sample of adults in France in early 2022, we found that beyond sociodemographic factors and the presence of comorbidities, several of the 7C psychological antecedents, in particular calculation, collective responsibility, and confidence in the wider system (evaluated as reactance against the government), were strongly associated with COVID-19 vaccination behaviours, and that these antecedents applied to uptake speed of first the dose following eligibility as well.

3.1. Predicting vaccination behaviours beyond intentions

Intentions do not always translate into behaviours [18–20], a phenomenon called the “intention-behaviour gap” [21,22]. The COVID-19 vaccination campaign in early 2022 in France provided a particular situation in which vaccination was widely accessible, and intentions could be translated into actions with little to no extrinsic barriers. However, COVID-19 vaccine uptake in France did not necessarily imply genuine intention, due to the introduction of vaccination requirements to access public spaces. Refusal of any COVID-19 vaccination, assessed in our study through at-least-one-dose vaccination status, relates to strong opposition against COVID-19 vaccination, encountered in only 5.0 % of participants. A more nuanced behaviour is the adherence to booster dose recommendations, represented by up-to-date vaccination status, which lacked in 10.2 % of participants. Both behaviours occurred under a strong incentive for booster vaccination imposed by the vaccine

Table 1

Description of participant characteristics (sociodemographic, comorbidities, and the 7C psychological antecedents), by outcome status. *Cognitiv study. France, 24 February 2022 – 19 June 2022 (N = 49,019 adults).*

	Unvaccinated (no dose)	Vaccinated but not up to date (1 dose or 2 doses without infection)	Vaccinated and up to date (2 doses with infection, 3 doses or 4 doses)	All participants	Median time from eligibility to first-dose vaccination (days)
Total	2,453 (5.0 %)	2,564 (5.2 %)	44,002 (89.8 %)	49,019 (100.0 %)	25,998
Recently Infected	2,101 (4.7 %)	2,351 (5.3 %)	40,261 (90.0 %)	44,713 (100.0 %)	37
Relatives	23 (1.9 %)	28 (2.3 %)	1,168 (95.8 %)	1,219 (100.0 %)	29
Non-Infected	329 (10.7 %)	185 (6.0 %)	2,573 (83.4 %)	3,087 (100.0 %)	49.5
Age category (years)				p < 0.001	
18–28	235 (7.6 %)	249 (8.0 %)	2,624 (84.4 %)	3,108 (100.0 %)	40
29–38	684 (8.3 %)	663 (8.0 %)	6,932 (83.7 %)	8,279 (100.0 %)	41
39–48	617 (5.2 %)	670 (5.7 %)	10,571 (89.2 %)	11,858 (100.0 %)	33
49–58	533 (4.5 %)	549 (4.6 %)	10,826 (90.9 %)	11,908 (100.0 %)	39
59–68	281 (3.2 %)	339 (3.8 %)	8,224 (93.0 %)	8,844 (100.0 %)	37
69+	103 (2.1 %)	94 (1.9 %)	4,825 (96.1 %)	5,022 (100.0 %)	39
Sex				p < 0.001	
Male	573 (4.0 %)	621 (4.4 %)	13,040 (91.6 %)	14,234 (100.0 %)	35
Female	1 880 (5.4 %)	1 943 (5.6 %)	30,962 (89.0 %)	34,785 (100.0 %)	39
Diploma category				p < 0.001	
Inf. Baccalaureate	529 (8.2 %)	449 (7.0 %)	5,441 (84.8 %)	6,419 (100.0 %)	50
Bac. [1] or equivalent	615 (7.3 %)	541 (6.4 %)	7,274 (86.3 %)	8,430 (100.0 %)	45
Bac + 2 to Bac + 4	907 (4.6 %)	1,005 (5.1 %)	17,751 (90.3 %)	19,663 (100.0 %)	37
Bac + 5 to Bac + 8	402 (2.8 %)	569 (3.9 %)	13,536 (93.3 %)	14,507 (100.0 %)	30
Professional category				p < 0.001	
Employee	654 (8.6 %)	605 (7.9 %)	6,371 (83.5 %)	7,630 (100.0 %)	45
Independent profession	105 (9.8 %)	80 (7.5 %)	888 (82.7 %)	1,068 (100.0 %)	40
Senior executive	490 (3.2 %)	666 (4.3 %)	14,258 (92.5 %)	15,414 (100.0 %)	30
Intermediate profession	439 (4.3 %)	542 (5.3 %)	9,189 (90.4 %)	10,170 (100.0 %)	45
Farmer	4 (16.0 %)	4 (16.0 %)	17 (68.0 %)	25 (100.0 %)	61
Blue-collar worker	184 (13.8 %)	148 (11.1 %)	1,000 (75.1 %)	1,332 (100.0 %)	53
Pensioner	263 (2.6 %)	272 (2.7 %)	9,727 (94.8 %)	10,262 (100.0 %)	37
Student	54 (5.2 %)	65 (6.3 %)	912 (88.5 %)	1,031 (100.0 %)	37
Inactive	260 (12.5 %)	182 (8.7 %)	1,645 (78.8 %)	2,087 (100.0 %)	45
Country of birth				p < 0.001	
France	2,285 (5.0 %)	2,342 (5.1 %)	40,990 (89.9 %)	45,617 (100.0 %)	38
Abroad	154 (4.7 %)	210 (6.4 %)	2,930 (89.0 %)	3,294 (100.0 %)	35
Not answered	14 (13.0 %)	12 (11.1 %)	82 (75.9 %)	108 (100.0 %)	43.5
Comorbidity[2]				p < 0.001	

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Table 1 (continued)

	Unvaccinated (no dose)	Vaccinated but not up to date (1 dose or 2 doses without infection)	Vaccinated and up to date (2 doses with infection, 3 doses or 4 doses)	All participants	Median time from eligibility to first-dose vaccination (days)
No comorbidity	1,896 (5.4 %)	1,959 (5.6 %)	31,316 (89.0 %)	35,172 (100.0 %)	31
1 + comorbidity	514 (3.9 %)	562 (4.2 %)	12,265 (91.9 %)	13,341 (100.0 %)	50
Not answered	43 (8.2 %)	43 (8.2 %)	421 (79.9 %)	506 (100.0 %)	44
Calculation (perception of more benefits than risks with COVID-19 vaccination)				p < 0.001	
Completely disagree	1,381 (45.0 %)	424 (13.8 %)	1,265 (41.2 %)	3,070 (100.0 %)	68
Rather disagree	444 (17.7 %)	373 (14.9 %)	1,692 (67.4 %)	2,509 (100.0 %)	62
Does not know	422 (6.7 %)	852 (13.4 %)	5,054 (80.0 %)	6,328 (100.0 %)	58
Rather agree	63 (0.6 %)	494 (4.7 %)	10,042 (94.7 %)	10,599 (100.0 %)	40
Completely agree	70 (0.3 %)	380 (1.5 %)	25,261 (98.3 %)	25,711 (100.0 %)	30
Not answered	73 (9.1 %)	41 (5.1 %)	688 (85.8 %)	802 (100.0 %)	41
Collective responsibility (perception of COVID-19 vaccination as a collective action)				p < 0.001	
Completely disagree	1,253 (45.1 %)	448 (16.1 %)	1,077 (38.8 %)	2,778 (100.0 %)	76
Rather disagree	488 (22.7 %)	366 (17.0 %)	1,299 (60.3 %)	2,153 (100.0 %)	67
Does not know	359 (12.6 %)	457 (16.0 %)	2,042 (71.5 %)	2,858 (100.0 %)	65
Rather agree	200 (2.3 %)	630 (7.1 %)	8,046 (90.7 %)	8,876 (100.0 %)	45
Completely agree	73 (0.2 %)	616 (2.0 %)	30,737 (97.8 %)	31,426 (100.0 %)	31
Not answered	80 (8.6 %)	47 (5.1 %)	801 (86.3 %)	928 (100.0 %)	42
Confidence in system (positive perception of the government's incitation to get vaccinated against COVID-19)				p < 0.001	
Deters from vaccination	1,024 (33.8 %)	574 (19.0 %)	1,428 (47.2 %)	3,026 (100.0 %)	78
No effect	1,376 (6.5 %)	1,461 (7.0 %)	18,193 (86.5 %)	21,030 (100.0 %)	43
Encourages vaccination	53 (0.2 %)	529 (2.1 %)	24,381 (97.7 %)	24,963 (100.0 %)	32
Confidence in vaccine (absence of fear of COVID-19 vaccination side effects)				p < 0.001	
Completely disagree	1,276 (26.1 %)	724 (14.8 %)	2,895 (59.1 %)	4,895 (100.0 %)	63
Rather disagree	563 (7.6 %)	744 (10.1 %)	6,083 (82.3 %)	7,390 (100.0 %)	50
Does not know	244 (3.1 %)	450 (5.7 %)	7,266 (91.3 %)	7,960 (100.0 %)	43
Rather agree	119 (0.9 %)	367 (2.9 %)	12,172 (96.2 %)	12,658 (100.0 %)	33
Completely agree	166 (1.1 %)	249 (1.6 %)	15,387 (97.4 %)	15,802 (100.0 %)	30
Not answered	85 (27.1 %)	30 (9.6 %)	199 (63.4 %)	314 (100.0 %)	65
Social conformism (majority opinion towards COVID-19 vaccination in one's close social environment)				p < 0.001	
Very sceptical	526 (29.0 %)	276 (15.2 %)	1,013 (55.8 %)	1,815 (100.0 %)	72
Rather sceptical	468 (13.9 %)	462 (13.7 %)	2,449 (72.5 %)	3,379 (100.0 %)	59
Equal share of sceptical and favourable	900 (9.7 %)	872 (9.4 %)	7,559 (81.0 %)	9,331 (100.0 %)	50
Rather favourable	446 (2.2 %)	720 (3.6 %)	18,907 (94.2 %)	20,073 (100.0 %)	35
Very favourable	113 (0.8 %)	234 (1.6 %)	14,074 (97.6 %)	14,421 (100.0 %)	28
Convenience (perception of no practical difficulties to get an appointment for COVID-19 vaccination)				p < 0.001	

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Table 1 (continued)

	Unvaccinated (no dose)	Vaccinated but not up to date (1 dose or 2 doses without infection)	Vaccinated and up to date (2 doses with infection, 3 doses or 4 doses)	All participants	Median time from eligibility to first-dose vaccination (days)
Completely disagree	24 (2.2 %)	82 (7.5 %)	992 (90.4 %)	1,098 (100.0 %)	45
Rather disagree	27 (0.8 %)	195 (5.6 %)	3,284 (93.7 %)	3,506 (100.0 %)	39
Does not know	739 (31.0 %)	185 (7.8 %)	1,459 (61.2 %)	2,383 (100.0 %)	43
Rather agree	204 (1.9 %)	538 (4.9 %)	10,308 (93.3 %)	11,050 (100.0 %)	37
Completely agree	1,110 (3.7 %)	1,512 (5.0 %)	27,695 (91.4 %)	30,317 (100.0 %)	37
Not answered	349 (52.5 %)	52 (7.8 %)	264 (39.7 %)	665 (100.0 %)	64
Low complacency (fear of severe forms of COVID-19 disease)				p < 0.001	
Completely disagree	986 (10.9 %)	622 (6.9 %)	7,442 (82.2 %)	9,050 (100.0 %)	40
Rather disagree	540 (4.5 %)	611 (5.1 %)	10,816 (90.4 %)	11,967 (100.0 %)	35
Does not know	374 (5.0 %)	417 (5.6 %)	6,720 (89.5 %)	7,511 (100.0 %)	40
Rather agree	295 (2.5 %)	519 (4.5 %)	10,806 (93.0 %)	11,620 (100.0 %)	37
Completely agree	185 (2.2 %)	362 (4.3 %)	7,923 (93.5 %)	8,470 (100.0 %)	37
Not answered	73 (18.2 %)	33 (8.2 %)	295 (73.6 %)	401 (100.0 %)	51

Reading grid: Results are presented as n (%). Percentages refer to the total in each row, for instance among individuals aged 18–28, 235 (7.6 %) did not receive any dose of COVID-19 vaccine, 249 (8.0 %) received an incomplete vaccination, and 44,002 (87.8 %) were fully vaccinated. The median delay for this subgroup to receive their first dose of COVID-19 vaccine was 40 days.

¹ “Bac.” refers to Baccalaureate, that is, the academic degree granting completion of secondary education in France.

² Data on comorbidities was available for immunodepression, diabetes, high blood pressure, history of myocardial infarction/angina pectoris, and chronic respiratory disease.

pass: a COVID-19 sanitary pass, then turned COVID-19 vaccination certificate, was required to access national and international transportations as well as leisure and cultural venues. By contrast, uptake speed of first dose covers mainly a period during which no strong incentive (health pass) to vaccination existed in France and occurred on average 44 and 40 days after eligibility among adults aged 18–29 and above 69, respectively. This outcome represents a finer nuance of vaccination eagerness during the acute epidemic phase.

Higher effects sizes for at-least-one-dose compared to up-to-date vaccination status may be explained by the greater contrast of persons refusing any dose of COVID-19 vaccine despite steady incentives and high accessibility. Although the hazard ratios of uptake speed were closer to the null than the odds ratios of at-least-one-dose and up-to-date vaccination status, the according effects should not be interpreted as smaller, as these effect measures cannot be directly compared.

Median delays from eligibility to uptake were longer by 38, 45, and 46 days for least vs. most favourable levels of calculation, collective responsibility, and confidence in system, respectively. This suggests that not only the 7C psychological antecedents influence vaccination status, but that they also consistently impact the speed at which individuals engage in vaccination during epidemics. These differences in vaccine uptake speed are of practical importance for the implementation of future vaccine campaigns, especially in epidemic contexts when the response speed is crucial to contain the spread of viruses.

From a scientific and public health perspective, intentions, up-to-date vaccination status and uptake speed are distinct relevant outcomes, and their exploration allows for a more precise understanding of barriers to successful vaccine programmes. Surprisingly, the antecedents of calculation, collective responsibility, and confidence in system showed similar strong associations with the three outcomes, which tends to underscore their general importance in vaccine decisions during COVID-19 epidemic response.

Taken together, our results on these three distinct outcomes

improves the understanding of vaccine acceptance and refusal: individual attitudes around vaccination explained not only COVID-19 vaccine intentions, but also actual decisions to receive vaccination and even the delay between eligibility and vaccination.

3.2. Confidence in system, collective responsibility, and calculation

The outstanding role of confidence in system, collective responsibility, and calculation in vaccine decisions is consistent with previous research that found these antecedents to be strong determinants of intentions to vaccinate against COVID-19 [14,17].

The importance of confidence in system corroborates previous research by Moirangthem and colleagues [14] which showed that the expansion of the 5C model with confidence in system and social conformism significantly improved the model's quality. In this study, the effect sizes of corresponding items were among the strongest in multivariable analysis. Confidence in national authorities has become a foremost characteristic polarising the population during the COVID-19 epidemic [23] that impacts individuals' adherence to prevention, control measures, and vaccination. Consistently, research found that low vaccination intentions predicted psychological reactance to vaccination policies, eliciting behaviours that opposed these regulations [24,25]. Vaccine recommendation and incentive may, in some individuals, encounter reactance, which refers to negative emotion that elicits the motivation to reassert otherwise restricted freedom [26]. Such perceived restrictions of freedom may arise from hierarchal relations, or from mandates or related policies. It should be noted, however, that although the effects of confidence in system have been described for other vaccinations, such as influenza [15], they have likely been enhanced by the COVID-19 epidemic situation and might be lower in other vaccination contexts.

The importance of collective responsibility is also consistent with previous research, as it was associated with stronger intention to be

Table 2

Associations between sociodemographic factors and comorbidities and the three vaccination outcomes (at-least-one-dose vaccination status, up-to-date vaccination status, and uptake speed) among adults. Multivariable logistic and Cox proportional hazard models including socio-demographic characteristics and comorbidity. *Cognitiv study. France, 24 February 2022 - 19 June 2022 (N = 49,019 adults).*

	At-least-one-dose vaccination status (N = 49,019)			Up-to-date vaccination status (N = 46,566)			Uptake speed (N = 25,998)		
	OR	95 % Confidence Interval	p-value	OR	95 % Confidence Interval	p-value	HR	95 % Confidence Interval	p-value
Age category (years)									
18–28	1.00	–	–	1.00	–	–	1.00	–	–
29–38	0.95	0.80–1.12	0.523	1.04	0.88–1.22	0.675	0.97	0.91–1.03	0.338
39–48	1.55	1.31–1.84	<0.001	1.58	1.34–1.87	<0.001	1.18	1.11–1.25	<0.001
49–58	1.96	1.65–2.34	<0.001	2.09	1.76–2.49	<0.001	1.07	1.01–1.14	0.031
59–68	2.60	2.06–3.29	<0.001	2.18	1.76–2.71	<0.001	1.18	1.01–1.16	0.029
69+	3.68	2.63–5.15	<0.001	3.97	2.86–5.86	<0.001	1.04	0.96–1.13	0.341
Sex									
Male	1.00	–	–	1.00	–	–	1.00	–	–
Female	0.97	0.88–1.08	0.619	0.97	0.88–1.07	0.519	0.93	0.90–0.96	<0.001
Diploma category									
Inf. Baccalaureate	1.00	–	–	1.00	–	–	1.00	–	–
Bac. [1] or equivalent	1.18	1.04–1.33	0.012	1.20	1.05–1.37	0.008	1.09	1.04–1.14	<0.001
Bac + 2 to Bac + 4	1.63	1.44–1.84	<0.001	1.44	1.27–1.63	<0.001	1.25	1.20–1.30	<0.001
Bac + 5 to Bac + 8	2.66	2.27–3.11	<0.001	1.97	1.69–2.29	<0.001	1.39	1.33–1.46	<0.001
Professional category									
Employee	1.00	–	–	1.00	–	–	1.00	–	–
Independent profession	0.72	0.58–0.90	0.003	0.91	0.71–1.16	0.450	1.02	0.93–1.12	0.688
Senior executive	1.76	1.53–2.02	<0.001	1.48	1.29–1.69	<0.001	1.18	1.13–1.23	<0.001
Intermediate profession	1.72	1.51–1.96	<0.001	1.41	1.25–1.60	<0.001	0.89	0.85–0.93	<0.001
Farmer	0.49	0.16–1.44	0.194	0.41	0.14–1.24	0.115	0.76	0.46–1.26	0.283
Labourer	0.67	0.56–0.80	<0.001	0.70	0.57–0.85	<0.001	0.90	0.83–0.98	0.014
Pensioner	1.43	1.12–1.82	0.004	1.70	1.31–2.06	<0.001	1.30	1.22–1.38	<0.001
Student	2.13	1.57–2.91	<0.001	1.79	1.34–2.39	<0.001	1.13	1.03–1.25	0.014
Inactive	0.57	0.48–0.66	<0.001	0.76	0.63–0.90	0.002	0.98	0.92–1.05	0.616
Country of birth									
France	1.00	–	–	1.00	–	–	1.00	–	–
Abroad	0.89	0.75–1.06	0.191	0.68	0.59–0.79	<0.001	1.00	0.96–1.06	0.854
Not answered	0.40	0.22–0.72	0.002	0.44	0.24–0.82	0.010	0.83	0.62–1.10	0.192
Comorbidity[2]									
No comorbidity	1.00	–	–	1.00	–	–	1.00	–	–
1 + comorbidity	1.33	1.20–1.48	<0.001	1.19	1.08–1.32	<0.001	0.72	0.70–0.74	<0.001
Not answered	0.80	0.57–1.11	0.175	0.69	0.50–0.96	0.028	0.82	0.72–0.93	0.002

Reading grid: The OR of the association between age and at-least-one-dose vaccination status was 0.95 (n.s.) for individuals between 29–38 with respect to individuals between 18 and 28. OR, odds ratio; HR, hazard ratio.

¹ “Bac.” refers to Baccalaureate, that is, the academic degree granting completion of secondary education in France.

² Data on comorbidities was available for immunodepression, diabetes, high blood pressure, history of myocardial infarction/angina pectoris, and chronic respiratory disease.

vaccinated against COVID-19 in Hong Kong [27] and France [14,28]. Vaccination is both an individual preventative behaviour and a prosocial act [29], as it not only provides direct personal benefits to vaccinated individuals, but also indirect social benefits to unvaccinated others. In this sense, collective responsibility captures the willingness to protect others by one’s own vaccination by means of herd immunity [30]. The importance of collective responsibility is not specific to COVID-19 vaccination, as a systematic review found that 29 out of 470 studies identified social benefit (e.g., collective responsibility) as a significant influence on influenza vaccine uptake [31]. Several empirical studies additionally found that people with higher levels of collective responsibility showed increased vaccination intentions and reported more vaccine uptake [12,14,32].

Consistently with our results, previous models already proposed that non-vaccination could result from utility calculation and the degree of rational calculation that individuals engage in before deciding [33]. In our study, we focussed on the favourable perception of vaccine’s benefit-risk balance, which was the strongest antecedent of COVID-19 vaccine

intention among French healthcare sector professionals [14]. Other research has suggested that strategic behaviour plays a role in vaccination decision making [30,34–39]. Such calculation may induce non-vaccination.

The strong association of calculation with at-least-one-dose vaccination status for both the most favourable and second-to-most favourable attitude levels may be explained by the gradual nature of the perceived benefits-risks balance. Conversely, collective responsibility may be regarded as a more polarised dimension, especially given the emphasis of the French vaccination promotion campaign on presenting COVID-19 vaccination as a collective action. The surprising negative association between at-least-one-dose vaccination status and a favourable environment (inverse social conformism) may be explained by the fact that our survey was conducted during a late phase of the vaccination campaign, after when strong incentives and a change in social norms had operated: non-vaccinated individuals may have felt highly isolated and consistently reported others as favourable. As such, asking about the influence of one’s close environment in 2022 may not be relevant for

Table 3
Associations between the seven antecedents of vaccination (7C) and the three vaccination outcomes (at-least-one-dose vaccination status, up-to-date vaccination status, and uptake speed) among adults. Multivariable logistic and Cox proportional hazard models including socio-demographic characteristics, comorbidity, and the 7C antecedents. *Cognitiv study. France, 24 February 2022 - 19 June 2022 (N = 49,019 adults).*

	At-least-one-dose vaccination status (N = 49,019)			Up-to-date vaccination status (N = 46,566)			Uptake speed (N = 25,986)		
	OR	95 % Confidence Interval	p-value	OR	95 % Confidence Interval	p-value	HR	95 % Confidence Interval	p-value
Calculation (perception of more benefits than risks with COVID-19 vaccination)									
Completely disagree	1.00	–	–	1.00	–	–	1.00	–	–
Rather disagree	2.14	1.81–2.53	<0.001	1.22	1.02–1.46	0.033	1.04	0.95–1.13	0.421
Does not know	4.53	3.81–5.38	<0.001	1.24	1.05–1.46	0.013	1.05	0.97–1.13	0.255
Rather agree	14.88	11.06–20.01	<0.001	2.04	1.70–2.45	<0.001	1.18	1.09–1.28	<0.001
Completely agree	10.29	7.53–14.05	<0.001	3.14	2.56–3.86	<0.001	1.31	1.21–1.42	<0.001
Not answered	3.37	2.25–5.05	<0.001	1.83	1.20–2.78	0.005	1.16	1.01–1.34	0.033
Collective responsibility (perception of COVID-19 vaccination as a collective action)									
Completely disagree	1.00	–	–	1.00	–	–	1.00	–	–
Rather disagree	1.27	1.07–1.50	0.006	1.18	0.98–1.41	0.078	1.05	0.96–1.15	0.298
Does not know	2.08	1.74–2.49	<0.001	1.40	1.18–1.68	<0.001	1.10	1.01–1.20	0.033
Rather agree	4.25	3.47–5.21	<0.001	2.22	1.87–2.63	<0.001	1.27	1.18–1.38	<0.001
Completely agree	14.44	10.72–19.45	<0.001	3.63	3.03–4.36	<0.001	1.44	1.33–1.56	<0.001
Not answered	2.66	1.82–3.87	<0.001	2.26	1.53–3.34	<0.001	1.32	1.16–1.51	<0.001
Confidence in system (positive perception of the government's incitation to get vaccinated against COVID-19)									
Deters from vaccination	1.00	–	–	1.00	–	–	1.00	–	–
No effect	1.35	0.19–1.54	<0.001	1.58	1.39–1.80	<0.001	1.22	1.15–1.30	<0.001
Encourages vaccination	8.94	6.51–12.27	<0.001	2.55	2.18–2.99	<0.001	1.39	1.30–1.48	<0.001
Confidence in vaccine (absence of fear of COVID-19 vaccination side effects)									
Completely disagree	1.00	–	–	1.00	–	–	1.00	–	–
Rather disagree	1.72	1.48–2.00	<0.001	1.34	1.18–1.52	<0.001	1.12	1.06–1.19	<0.001
Does not know	2.65	2.18–3.21	<0.001	1.94	1.68–2.24	<0.001	1.19	1.13–1.26	<0.001
Rather agree	3.77	2.96–4.80	<0.001	2.42	2.07–2.83	<0.001	1.33	1.26–1.40	<0.001
Completely agree	3.70	2.95–4.64	<0.001	3.93	3.28–4.70	<0.001	1.40	1.33–1.48	<0.001
Not answered	1.49	1.01–2.21	0.046	1.62	1.03–2.55	0.035	1.07	0.89–1.29	0.468
Social conformism (majority opinion towards COVID-19 vaccination in one's close social environment)									
Very sceptical	1.00	–	–	1.00	–	–	1.00	–	–
Rather sceptical	0.84	0.69–1.02	0.075	0.75	0.62–0.91	0.003	0.96	0.88–1.05	0.363
Equal share of sceptical and favourable	0.69	0.57–0.82	<0.001	0.82	0.68–0.97	0.023	1.02	0.94–1.10	0.618
Rather favourable	0.72	0.59–0.88	0.001	1.11	0.92–1.34	0.264	1.17	1.08–1.26	<0.001
Very favourable	0.69	0.52–0.93	0.013	1.34	1.07–1.68	0.011	1.24	1.14–1.34	<0.001
Convenience (perception of no practical difficulties to get an appointment for COVID-19 vaccination)									
Completely disagree	1.00	–	–	1.00	–	–	1.00	–	–
Rather disagree	1.90	1.03–3.50	0.041	1.28	0.95–1.72	0.100	1.16	1.06–1.27	0.001
Does not know	0.06	0.04–0.10	<0.001	0.89	0.65–1.20	0.432	1.13	1.01–1.25	0.028
Rather agree	0.60	0.37–0.98	0.040	1.29	0.99–1.69	0.062	1.15	1.06–1.25	0.001
Completely agree	0.40	0.25–0.64	<0.001	1.11	0.86–1.44	0.417	1.11	1.02–1.21	0.012
Not answered	0.05	0.03–0.08	<0.001	0.74	0.48–1.14	0.174	1.00	0.85–1.19	0.958
Low complacency (fear of severe forms of COVID-19 disease)									
Completely disagree	1.00	–	–	1.00	–	–	1.00	–	–
Rather disagree	0.98	0.83–1.16	0.836	1.12	0.98–1.28	0.097	1.11	1.07–1.16	<0.001
Does not know	1.30	1.08–1.56	0.005	1.36	1.17–1.58	<0.001	1.14	1.09–1.19	<0.001

(continued on next page)

Table 3 (continued)

	At-least-one-dose vaccination status (N = 49,019)			Up-to-date vaccination status (N = 46,566)			Uptake speed (N = 25,998)		
	OR	95 % Confidence Interval	p-value	OR	95 % Confidence Interval	p-value	HR	95 % Confidence Interval	p-value
Rather agree	1.60	1.32–1.94	<0.001	1.44	1.25–1.65	<0.001	1.18	1.14–1.23	<0.001
Completely agree	1.87	1.49–2.34	<0.001	1.47	1.26–1.73	<0.001	1.18	1.13–1.24	<0.001
Not answered	1.17	0.75–1.82	0.501	1.17	0.75–1.81	0.489	1.03	0.89–1.19	0.697
Age category (years)									
18–28	1.00	–	–	1.00	–	–	1.00	–	–
29–38	0.80	0.63–1.01	0.060	1.02	0.85–1.22	0.812	0.97	0.92–1.04	0.423
39–48	0.88	0.69–1.11	0.270	1.28	1.07–1.53	0.008	1.14	1.07–1.21	<0.001
49–58	0.76	0.60–0.97	0.027	1.27	1.05–1.53	0.012	0.91	0.86–0.97	0.003
59–68	0.81	0.59–1.12	0.206	1.15	0.91–1.45	0.251	0.89	0.83–0.96	0.002
69+	1.11	0.70–1.75	0.657	1.86	1.32–2.64	<0.001	0.80	0.73–0.87	<0.001
Sex									
Male	1.00	–	–	1.00	–	–	1.00	–	–
Female	1.35	1.17–1.56	<0.001	1.30	1.17–1.45	<0.001	0.99	0.97–1.02	0.699
Diploma category									
Inf. Baccalaureate	1.00	–	–	1.00	–	–	1.00	–	–
Bac. [1] or equivalent	0.96	0.81–1.15	0.672	1.01	0.87–1.17	0.879	1.06	1.01–1.11	0.007
Bac + 2 to Bac + 4	1.01	0.85–1.19	0.949	0.94	0.82–1.08	0.417	1.17	1.12–1.22	<0.001
Bac + 5 to Bac + 8	0.97	0.78–1.20	0.773	0.89	0.76–1.05	0.179	1.21	1.16–1.27	<0.001
Professional category									
Employee	1.00	–	–	1.00	–	–	1.00	–	–
Independent profession	0.61	0.44–0.84	0.003	0.78	0.60–1.02	0.070	0.99	0.91–1.09	0.902
Senior executive	1.13	0.93–1.37	0.232	1.09	0.94–1.26	0.248	1.07	1.03–1.12	0.002
Intermediate profession	1.56	1.31–1.86	<0.001	1.37	1.20–1.56	<0.001	0.84	0.81–0.88	<0.001
Farmer	0.54	0.11–2.64	0.444	0.37	0.09–1.06	0.063	0.78	0.47–1.29	0.342
Labourer	0.67	0.52–0.87	0.003	0.71	0.57–0.88	0.002	0.91	0.84–0.99	0.056
Pensioner	0.84	0.60–1.17	0.301	1.20	0.94–1.53	0.134	1.21	1.14–1.28	<0.001
Student	1.19	0.79–1.79	0.402	1.29	0.94–1.76	0.116	1.00	0.91–1.11	0.944
Inactive	0.60	0.48–0.76	<0.001	0.68	0.56–0.83	<0.001	0.97	0.91–1.04	0.393
Country of birth									
France	1.00	–	–	1.00	–	–	1.00	–	–
Abroad	0.77	0.61–0.97	0.029	0.62	0.52–0.73	<0.001	0.99	0.94–1.04	0.600
Not answered	0.87	0.40–1.91	0.730	0.74	0.38–1.46	0.390	0.90	0.68–1.19	0.463
Comorbidity[2]									
No comorbidity	1.00	–	–	1.00	–	–	1.00	–	–
1 + comorbidity	1.19	1.03–1.37	0.019	1.18	1.06–1.32	0.003	0.67	0.65–0.69	<0.001
Not answered	0.82	0.53–1.28	0.387	0.91	0.64–1.29	0.593	0.93	0.81–1.05	0.245

Reading grid: Individuals who rather disagreed with to the statement “COVID-19 vaccination has more benefits than risks for me” were 2.14 times more likely to have received at least one dose of COVID-19 vaccine by 2022. OR, odds ratio; HR, hazard ratio.

¹ “Bac.” refers to Baccalaureate, that is, the academic degree granting completion of secondary education in France.

² Data on comorbidities was available for immunodepression, diabetes, high blood pressure, history of myocardial infarction/angina pectoris, and chronic respiratory disease.

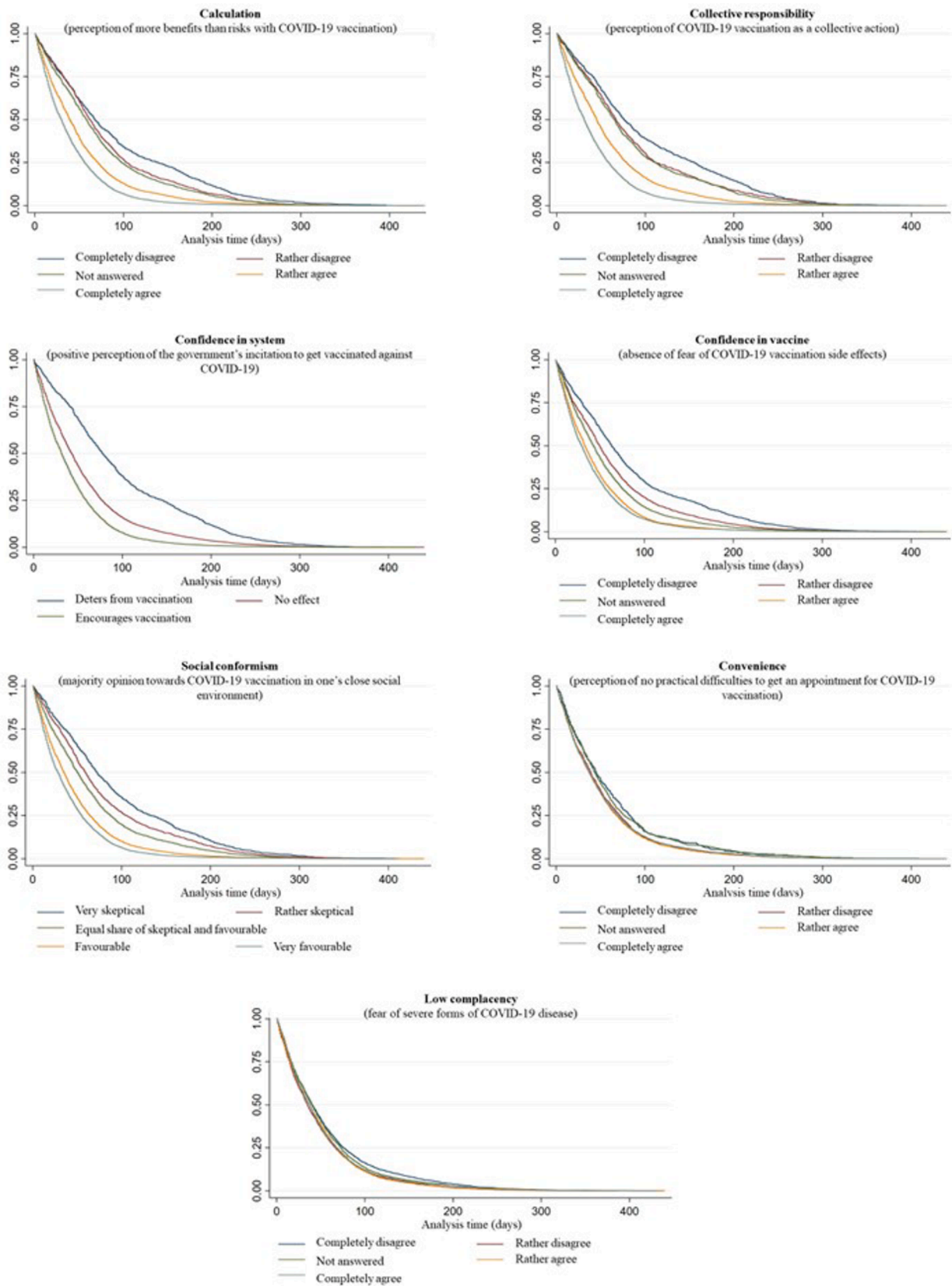


Fig. 1. Kaplan-Meier survival estimate (vaccination delay) stratified by the 7C psychological antecedents. *Cognitiv study, France, 24 February 2022 – 19 June 2022 (N = 49,019 adults).* Reading grid: The median delay to first dose of COVID-19 vaccination was 68 days for individuals who completely disagreed with the proposal “I think COVID-19 vaccination has more benefits than risks for me” and 30 days for those who completely agreed. The delay to vaccination for 75 % of the subgroup who completely disagreed to have their first dose of COVID-19 vaccine was 139 days and 56 days for those who completely agreed.

2021 vaccination. The finding of the expected positive association between description of opinions in the social environment and up-to-date vaccination status and uptake speed supports this interpretation.

For the convenience antecedent, indecision regarding practical barriers to get an appointment was associated with lower vaccine uptake. This may be explained by a lack of interest in vaccination, as these persons may not even have searched for an appointment.

3.3. The role of socio-demographic characteristics and comorbidities

A large body of evidence has described the socio-demographic determinants of COVID-19 vaccine acceptance: sociodemographic factors that have most commonly been associated with a higher intention to receive COVID-19 vaccination – across countries and context – are age (especially individuals older than 65 years of age), education (higher education), and employment (being gainfully employed) or income (higher income or higher socioeconomic position group) [39–44]. Consistently with previous research, age category, diploma category, and professional category were the main socio-demographic predictors of COVID-19 vaccination in our study. A similar but less pronounced pattern has been documented for receiving two vaccine doses [45], consistently with the effects for up-to-date vaccination status in comparison to those of at-least-one dose vaccination status in our study.

In some studies [42], sex was associated with higher intention to receive a COVID-19 vaccine, with men showing more intention to vaccinate than women. However, other research showed lower uptake of at least one dose of a COVID-19 vaccine in men [45]. This apparent paradox may be resolved to some extent, as it appears in our study that men showed quicker vaccine uptake than women, but differences in vaccination coverage waned over time.

Consistently with our results, previous research found that COVID-19 vaccination intention and booster vaccination was significantly higher among persons with comorbidity [45,46].

3.4. Public health implications

Our results suggest that the 7C antecedents are powerful tools to explain and possibly even predict COVID-19 vaccination behaviours, including uptake speed during an epidemic-response vaccination campaign. This is particularly relevant for epidemic preparedness strategies, when the speed of vaccine uptake is critical. Vaccine promotion strategies should consider the 7C antecedents. Specifically, public health efforts directed at enhancing understanding and attitudes regarding collective responsibility, calculation, and confidence in system could produce valuable results. However, it is unclear whether these psychological antecedents are the expression of stable personality traits, in which case they may not easily be modified. If modifiable, interventional research should test optimised information and communication tools to increase vaccine uptake and uptake speed during epidemics. Calculation regarding the risks and benefits of vaccination might be improved by effective education [47,48]. Individual or relatives' experience may also change the perceived benefits-risks balance for persons who chose to vaccinate after a previous infection or whose relative(s) have suffered from COVID-19 infection(s). Collective responsibility relates to broader altruism, prosocial behaviours, and ethics [29]. Vaccination promotion campaigns may be aimed at improving attitudes on both the calculation and collective responsibility dimensions. Confidence in system, which likely varies by country and over time within countries, could be enhanced by clear and transparent communication [49,50]. Research investigating the independence of the 7C antecedents from personality traits could provide further insights regarding the public health implications of the role of the 7C antecedents.

3.5. Limitations

This study has several limitations. Firstly, the sample is not

representative of the adult population in France in 2022, despite the large sample size of the study. Infected participants were recruited nationwide, and non-infected participants were selected from a panel from a market and public opinion research company, matched to infected participants on age, sex, region, population size of area of residence, and calendar week. The source population for the study was therefore the adult population infected by SARS-CoV-2, and not the French population. Moreover, factors such as willingness to participate in a study, computer literacy, and access to a computer were additional characteristics that made our study population differ from the source population. Previous analyses of the study population have revealed that respondents, both infected and non-infected, tended to be younger, and include more women and wealthier persons, compared to the source population [51]. As such, prevalence estimates (e.g., vaccine coverage) should not be generalised to the French population, while the observed associations are likely less prone to selection bias. Secondly, data collection was cross-sectional, with risk of reverse causality (e.g., vaccine uptake could have impacted attitudes) and residual bias by unobserved variables. This limitation may be particularly relevant for the uptake speed outcome, for which the outcome events occurred several months before exposure assessment. Lastly, the large sample size of this study may yield statistically significant results, even when effects are potentially not of practical relevance.

4. Conclusion

The present research demonstrates that beyond sociodemographic factors and comorbidities, the 7C psychological antecedents are associated with three different measures of vaccination behaviour evaluating distinct levels of adherence to vaccination. Consistent effects were observed for receipt of at least one dose by 2022, level of adherence to booster recommendations by 2022, and speed of first-dose uptake. This complements previous studies that showed associations between intentions to vaccinate and the 7C antecedents. Future research should explore to which extent the 7C are the expression of stable personality traits, which needs to be taken into account for the development of vaccine promotion through appropriate information and public health campaigns.

5. Methods (short version)

5.1. Participant enrolment and data collection

We analysed data collected for the previously described “ComCor” case-control study [52]. Briefly, between October 2020 and October 2022, adults with recent SARS-CoV-2 infection were recruited as “cases” by the French national health insurance agency. A sample of “non-infected controls” were recruited from a national representative panel as non-infected adults matched to cases by age, sex, region, population size of area of residence, and calendar week. Additional participants were recruited from cases' relatives. For all participants, the “ComCor” questionnaire comprised information on sociodemographic factors, SARS-CoV-2 infection history, and detailed self-reported COVID-19 vaccination history, including vaccination dates and dose number. From 24 February 2022 to 19 June 2022, participants were in addition invited to complete a self-administered questionnaire on cognitive factors and attitudes towards vaccination (the “Cognitiv” study). This questionnaire collected, among other, information on 7C attitudes regarding COVID-19 vaccination (Appendix 1), which were assessed using a short form of the 7C questionnaire previously described [14]. The questionnaire was adapted to the general adult population and to the 2022 vaccination context and limited to one item per antecedent domain. Answer modalities were mostly coded on 5-point Likert scales, with indecision as central modality. In addition, participants could refuse to answer items. The invitation to complete the “Cognitiv” questionnaire was accepted predominantly by recently infected participants, who received the

questionnaire along with instructions to limit onward transmission.

The “ComCor” study received ethical approval by the Comité de Protection des Personnes Sud Ouest et Outre Mer 1 on 21 September 2020. The addition of the “Cognitiv” questionnaire received ethical approval by the Comité de Protection des Personnes Sud Ouest et Outre Mer 1 on 1 February 2022. The data protection authority Commission Nationale de l’Informatique et des Libertés (CNIL) authorised the processing of data on 21 October 2020. The study is registered with ClinicalTrials.gov under the identifier NCT04607941.

5.2. Data management: the three vaccination outcomes

We defined three outcomes based on COVID-19 vaccination history. A first binary outcome, called “at-least-one-dose vaccination status”, was defined as uptake of at least one dose of COVID-19 vaccine. At-least-one-dose vaccination status was coded as a binary variable with No dose (0) and One dose or more (1). Due to high accessibility and strong incentivisation towards COVID-19 vaccination (a vaccine pass was required in France in early 2022 to access public spaces), the absence of uptake can be interpreted as vaccine refusal. A second binary outcome, termed “up-to-date vaccination status” distinguished between individuals who adhered to the recommended vaccine schedule by early 2022 and those who did not. This schedule included primary vaccination with at least one booster dose, where documented infections could replace vaccine doses. Up-to-date vaccination status was coded as a binary variable with Zero, one or two doses without infection (0) and Two doses with infection / three doses or more (1). Having (0) for this outcome can be interpreted as strong reluctance against vaccination, as in early 2022 a booster dose was required to access specific public spaces.

The third outcome was uptake speed and referred to time to vaccination, that is, the delay between the date of age- and comorbidity-specific vaccine eligibility and the date of first vaccine injection. Individuals with a previous episode of SARS-CoV-2 infection were not included in the uptake speed outcome, due to early questioning of the need for COVID-19 vaccination for those with a previous infection. At the beginning of the COVID-19 vaccination campaign, individuals with a previous infection may have perceived themselves as less concerned about receiving an initial vaccine dose, which could have impacted the delay to first dose. Eligibility dates varied for different ages and comorbidities (see **Detailed Methods**). Unvaccinated individuals were censored at the end of the observation period. While there were tensions to obtain vaccination slots until summer 2021, vaccination then became widely available in vaccination centres and mobile campaigns. We therefore suggest interpreting later dates of vaccination as lower vaccine eagerness.

5.3. Statistical analyses

We first described participants’ characteristics (N, %) overall and by vaccination status. We assessed the determinants of at-least-one-dose and up-to-date vaccination status using multivariable logistic regression models, and the determinants of uptake speed using Cox proportional hazard models. After exploring bivariable models, we evaluated the association between the three outcomes and individual characteristics in two blocs: sociodemographic factors and comorbidities, and 7C psychological antecedents. Given the large sample size, we show full models containing all available variables.

Participants recruited as cases, controls, and relatives were initially analysed separately. Because the associations of the determinants of vaccine uptake were similar for cases, controls, and relatives, results that combine the three groups are presented.

We estimated the variance of at-least-one-dose and up-to-date vaccination status that was explained by items blocks as pseudo-R-square from regression models. Statistical significance was defined as P-value < 0.05, and exact P-values are shown for full interpretation. All

statistical analyses were performed using Stata 17.0 (StataCorp, College Station, TX, USA).

Author contributions

GL, JEM, AF, SG, TC, and JS designed the study.
SG, TC, and AF developed the “ComCor” questionnaire on vaccination history and sociodemographic factors.
GL, JEM, and JS developed the “Cognitiv” questionnaire including psychological antecedents of vaccination.
GL performed the statistical analyses.
GL and JEM drafted the first versions of the manuscript.

Materials & Correspondence

Correspondence and material requests should be addressed to GL and JEM.

Data sharing

The participant data (with identifiers) of this study are available from the French National Health Insurance Fund and from Ipsos. Restrictions apply to the availability of these data, which were used under authorised agreement for this study by the French data protection authority Commission Nationale de l’Informatique et des Libertés (CNIL; the French National Commission on Informatics and Liberty). Access to these data would therefore require previous authorisation by the CNIL.

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CRedit authorship contribution statement

Gaëlle Lièvre: Conceptualization, Investigation, Methodology, Data curation, Project administration, Software, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jonathan Sicsic:** Conceptualization, Supervision. **Simon Galmiche:** Data curation, Project administration. **Tiffany Charmet:** Data curation, Project administration. **Arnaud Fontanet:** Conceptualization, Methodology, Funding acquisition, Supervision. **Judith Mueller:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

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

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.vaccine.2024.04.024>.

References

- [1] Watson OJ, Barnsley G, Toor J, Hogan AB, Winskill P, Ghani AC. Global impact of the first year of COVID-19 vaccination: a mathematical modelling study. *Lancet Infect Dis* 2022;22:1293–302.
- [2] Polack FP, Thomas SJ, Kitchin N, et al. Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. *N Engl J Med* 2020;383:2603–15.
- [3] Baden LR, El Sahly HM, Essink B, et al. Efficacy and safety of the mRNA-1273 SARS-CoV-2 vaccine. *N Engl J Med* 2021;384:403–16.
- [4] Our world in data Coronavirus Explorer. <https://ourworldindata.org/coronavirus-data-explorer>. Accessed 24 April 2023.
- [5] Limbu YB, Gautam RK, Pham L. The health belief model applied to COVID-19 vaccine hesitancy: a systematic review. *Vaccines* 2022;10:973.
- [6] Salerno L, Craxì L, Amodio E, Lo CG. Factors affecting hesitancy to mRNA and viral vector COVID-19 vaccines among college students in Italy. *Vaccines* 2021;9:927.
- [7] Ru-Chien CHI, Neuzil KM. The association of sociodemographic factors and patient attitudes on influenza vaccination rates in older persons. *Am J Med Sci* 2004;327:113–7.
- [8] McElfish PA, Willis DE, Shah SK, Bryant-Moore K, Rojo MO, Selig JP. Sociodemographic determinants of COVID-19 vaccine hesitancy, fear of infection, and protection self-efficacy. *J Prim Care Community Health* 2021;12:21501327211040746.
- [9] Gerend MA, Shepherd JE. Predicting human papillomavirus vaccine uptake in young adult women: comparing the health belief model and theory of planned behavior. *Ann Behav Med* 2012;44:171–80.
- [10] Williams MS. A mixed methods study of health literacy and its role in HPV vaccine uptake among college students. The University of Alabama at Birmingham; 2014.
- [11] MacDonald NE. Vaccine hesitancy: definition, scope and determinants. *Vaccine* 2015;33:4161–4.
- [12] Geiger M, Rees F, Lilleholt L, et al. Measuring the 7Cs of vaccination readiness. *Eur J Psychol Assess* 2022;38:261.
- [13] Betsch C, Schmid P, Heinemeier D, Korn L, Holtmann C, Böhm R. Beyond confidence: development of a measure assessing the 5C psychological antecedents of vaccination. *PLoS One* 2018;13:e0208601.
- [14] Moirangthem S, Olivier C, Gagneux-Brunon A, et al. Social conformism and confidence in systems as additional psychological antecedents of vaccination: a survey to explain intention for COVID-19 vaccination among healthcare and welfare sector workers, France, December 2020 to February 2021. *Euro Surveill* 2022;27:2100617.
- [15] Nicholls LAB, Gallant AJ, Cogan N, Rasmussen S, Young D, Williams L. Older adults' vaccine hesitancy: psychosocial factors associated with influenza, pneumococcal, and shingles vaccine uptake. *Vaccine* 2021;39:3520–7.
- [16] Tokiya M, Hara M, Matsumoto A, et al. Acceptance of booster COVID-19 vaccine and its association with components of vaccination readiness in the general population: a cross-sectional survey for starting booster dose in Japan. *Vaccines* 2022;10:1102.
- [17] Oudin Doglioni D, Amandine G-B, Aurélie G, et al. Psychometric validation of a 7C-model of antecedents of vaccine acceptance among healthcare workers, parents and adolescents in France. *Sci Rep* 2023;13:19895.
- [18] Fife-Schaw C, Sheeran P, Norman P. Simulating behaviour change interventions based on the theory of planned behaviour: impacts on intention and action. *Br J Soc Psychol* 2007;46:43–68.
- [19] Sheeran P. Intention—behavior relations: a conceptual and empirical review. *Eur Rev Soc Psychol* 2002;12:1–36.
- [20] Faries MD. Why we don't "just do it" understanding the intention-behavior gap in lifestyle medicine. *Am J Lifestyle Med* 2016;10:322–9.
- [21] Rhodes RE, de Bruijn GJ. How big is the physical activity intention-behaviour gap? A meta-analysis using the action control framework. *Br J Health Psychol* 2013;18:296–309.
- [22] Mullan B, Allom V, Brogan A, Kothe E, Todd J. Self-regulation and the intention behaviour gap. Exploring dietary behaviours in university students. *Appetite* 2014;73:7–14.
- [23] Peretti-Watel P, Seror V, Cortaredona S, Launay O, Raude J, Verger P, et al. A future vaccination campaign against COVID-19 at risk of vaccine hesitancy and politicisation. *Lancet Infect Dis* 2020;20:769–70.
- [24] Sprengholz P, Betsch C, Böhm R. Reactance revisited: consequences of mandatory and scarce vaccination in the case of COVID-19. *Appl Psychol Heal Well-Being* 2021;13:986–95.
- [25] Schmelz K, Bowles S. Opposition to voluntary and mandated COVID-19 vaccination as a dynamic process: evidence and policy implications of changing beliefs. *Proc Natl Acad Sci* 2022;119:e2118721119.
- [26] Brehm JW. A theory of psychological reactance. Oxford: Academic Press; 1966.
- [27] Kwok KO, Li KK, Wei WI, Tang A, Wong SYS, Lee SS. Influenza vaccine uptake, COVID-19 vaccination intention and vaccine hesitancy among nurses: a survey. *Int J Nurs Stud* 2021;114:103854.
- [28] Luévano CD, Sicsic J, Pellissier G, et al. Quantifying healthcare and welfare sector workers' preferences around COVID-19 vaccination: a cross-sectional, single-profile discrete-choice experiment in France. *BMJ Open* 2021;11:e055148.
- [29] Böhm R, Betsch C. Prosocial vaccination. *Curr Opin Psychol* 2022;43:307–11.
- [30] Betsch C, Böhm R, Korn L. Inviting free-riders or appealing to prosocial behavior? Game-theoretical reflections on communicating herd immunity in vaccine advocacy. *Health Psychol* 2013;32:978–85.
- [31] Schmid P, Rauber D, Betsch C, Lidolt G, Denker ML. Barriers of influenza vaccination intention and behavior – a systematic review of influenza vaccine hesitancy, 2005–2016. *PLoS One* 2017;12:e0170550.
- [32] Liu PL, Ao SH, Zhao X, Zhang L. Associations between COVID-19 information acquisition and vaccination intention: the roles of anticipated regret and collective responsibility. *Health Commun* 2022.
- [33] Betsch C, Böhm R, Chapman GB. Using behavioral insights to increase vaccination policy effectiveness. *Policy Insights Behav Brain Sci* 2015;2:61–73.
- [34] Bauch CT, Bhattacharyya S. Evolutionary game theory and social learning can determine how vaccine scares unfold. *PLoS Comput Biol* 2012;8:e1002452.
- [35] Bauch CT, Earn DJ. Vaccination and the theory of games. *Proc Natl Acad Sci* 2004;101:13391–4.
- [36] Chapman GB, Li M, Vietri J, et al. Using game theory to examine incentives in influenza vaccination behavior. *Psychol Sci* 2012;23:1008–15.
- [37] Cohen MJ, Brezis M, Block C, Diederich A, Chinitz D. Vaccination, herd behavior, and herd immunity. *Med Decis Making* 2013;33:1026–38.
- [38] Galvani AP, Reluga TC, Chapman GB. Long-standing influenza vaccination policy is in accord with individual self-interest but not with the utilitarian optimum. *Proc Natl Acad Sci* 2007;104:5692–7.
- [39] Ibuka Y, Li M, Vietri J, Chapman GB, Galvani AP. Free-riding behavior in vaccination decisions: an experimental study. *PLoS One* 2014;9:e87164.
- [40] Meier BP, Dillard AJ, Lappas CM. Predictors of the intention to receive a SARS-CoV-2 vaccine. *J Public Health* 2021;44:713–5.
- [41] Caycho-Rodríguez T, Tomás JM, Carbajal-León C, et al. Sociodemographic and psychological predictors of intention to receive a COVID-19 vaccine in elderly Peruvians. *Trends Psychol* 2022;30:206–23.
- [42] Mondal P, Sinharoy A, Su L. Sociodemographic predictors of COVID-19 vaccine acceptance: a nationwide US-based survey study. *Public Health* 2021;198:252–9.
- [43] Spetz M, Lundberg L, Nwaru C, et al. An intersectional analysis of sociodemographic disparities in Covid-19 vaccination: a nationwide register-based study in Sweden. *Vaccine* 2022;40:6640–8.
- [44] Dolby T, Finning K, Baker A, et al. Monitoring sociodemographic inequality in COVID-19 vaccination uptake in England: a national linked data study. *J Epidemiol Commun Health* 2022;76:646–52.
- [45] Abedin M, Islam MA, Rahman FN, et al. Willingness to vaccinate against COVID-19 among Bangladeshi adults: understanding the strategies to optimize vaccination coverage. *PLoS One* 2021;16:e0250495.
- [46] Bendezu-Quispe G, Caira-Chuquineyra B, Fernandez-Guzman D, Urrunaga-Pastor D, Herrera-Anazco P, Benites-Zapata VA. Factors associated with not receiving a booster dose of COVID-19 vaccine in Peru. *Vaccines* 2022;10:1183.
- [47] Davis TC, Fredrickson DD, Bocchini C, et al. Improving vaccine risk/benefit communication with an immunization education package: a pilot study. *Ambul Pediatr* 2002;2:193–200.
- [48] Navin MC, Wasserman JA, Ahmad M, et al. Vaccine education, reasons for refusal, and vaccination behavior. *Am J Prev Med* 2019;56:359–67.
- [49] Quinn SC, Parmer J, Freimuth VS, et al. Exploring communication, trust in government, and vaccination intention later in the 2009 H1N1 pandemic: results of a national survey. *Biosecur Bioterror* 2013;11:96–106.
- [50] Vaughan E, Tinker T. Effective health risk communication about pandemic influenza for vulnerable populations. *Am J Public Health* 2009;99:324–32.
- [51] Galmiche S, Charmet T, Schaeffer L, et al. Exposures associated with SARS-CoV-2 infection in France: a nationwide online case-control study. *Lancet Reg Health Eur* 2021;7:7100148.
- [52] Charmet T, Schaeffer L, Grant R, et al. Impact of original, B. 1.1. 7, and B. 1.351/P. 1 SARS-CoV-2 lineages on vaccine effectiveness of two doses of COVID-19 mRNA vaccines: Results from a nationwide case-control study in France. *Lancet Reg Health Eur* 2021; 8: 100171.