



Public Preferences for a COVID-19 Vaccination Program in Quebec: A Discrete Choice Experiment

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Abstract

Objectives We aimed to elicit preferences of the French-speaking Quebec population regarding a COVID-19 vaccination program and to characterize individuals with respect to their vaccination behaviors.

Methods A discrete choice experiment was conducted in Autumn 2020 via a web-based survey. Its design included seven attributes: vaccine origin, vaccine effectiveness, side effects, protection duration, priority population, waiting time to get vaccinated, and recommender of the vaccine. Utilities were estimated using a mixed-logit model and a latent class logit model.

Results Our sample included 1599 individuals. From this total, 119 always chose the opt-out option (7.4%). According to the mixed-logit model, the relative weights of attributes were as follows: effectiveness (28.48%), side effects (23.68%), protection duration (17.41%), vaccine origin (12.75%), recommender (11.96%), waiting time to get vaccinated (3.62%), and priority population (2.11%). Five classes were derived from the latent class logit model. Class 1 (9.13%) wanted to get vaccinated as fast as possible and was composed of uncertain and more vulnerable individuals. Class 5 (25.14%) was similar to the full sample, mostly favoring vaccination. Classes 2 (7.69%) and 4 (15.82%) included “vaccine hesitant and demanding” individuals but were different in their sociodemographic profiles. Finally, “anti-vaccine” and other “vaccine hesitant” individuals were in class 3 (42.21%).

Conclusions This study showed the vaccine characteristics that are likely to improve vaccine uptake, which may more easily lead to herd immunity. Different profiles of respondents also showed various levels of acceptance toward a COVID-19 vaccination program, which may help to better understand vaccine hesitancy behaviors.

1 Introduction

As of 24 November, 2021, 5,166,192 deaths had been reported due to the novel coronavirus disease 2019 (COVID-19) [1]. Following the race to develop a vaccine, four vaccines are now available in Canada [2] (Pfizer-BioNTech, Moderna, Janssen, and AstraZeneca), 25 have been granted emergency use authorizations by national authorities, and seven have been approved by the World

Key Points for Decision Makers

This is the first study to conduct a discrete choice experiment to elicit preferences of the Quebec population toward a vaccination program.

Beyond effectiveness and side effects, the duration of the protective effect and the origin of the vaccine were found to be the most preferred attributes.

This study provided indications that vaccination hesitancy is likely not a dichotomic issue with “pro-vaccine” and “anti-vaccine”.

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Health Organization (WHO)-recognized stringent regulatory authority. Each of these vaccines has specific characteristics in terms of efficacy (from 62 to 95%), side effects (e.g., pain, redness, fever, swelling), number of doses (one or two shots), or technology used (viral vector or messenger RNA). Regarding the side effects, several safety concerns have appeared. Blood clots were observed following the vaccines from AstraZeneca, which was restricted to adults aged under 55 years in Canada in late March 2021 [3], and from Johnson & Johnson in the USA, which was not recommended for women aged under 50 years in April 2021 [4]. Additionally, vaccine hesitation and aversion in some groups can be explained by health controversies and scandals, such as Dengvaxia [5] or the Pandemrix [6–8], and by false information/misinformation, such as associations with autism [9, 10] or multiple sclerosis [11], the use of aluminum [12], or new technologies such as messenger RNA [13, 14].

The growing hesitation of populations about vaccination is a major issue in the COVID-19 crisis. As defined by MacDonald and the SAGE Working Group on Vaccine Hesitancy, “vaccine hesitancy refers to delay in acceptance or refusal of vaccination despite availability of vaccination services. Vaccine hesitancy is complex and context specific, varying across time, place and vaccines. It is influenced by factors such as complacency, convenience and confidence” [15]. To achieve herd immunity, it is necessary to understand which populations are hesitant to better meet their demands and thus increase the uptake of a vaccine.

Using a discrete choice experiment (DCE), we aimed to assess the vaccination preferences of the Quebec population and to establish sociodemographic profiles to highlight which characteristics of the vaccination program are of particular importance in the decision to receive the vaccine. Our DCE is the first conducted in Canada to achieve this aim. Although information on COVID-19 vaccine preferences remains fragmented and limited to a few countries, some vaccine attributes are recurrent in the recent literature (e.g., effectiveness, safety, protection duration).

For instance, in China, Leng et al. [16] estimated that a vaccine with 85% effectiveness and a low probability of side effects is strongly preferred, while other attributes were considered of lower importance. According to the best vaccine scenario, they estimated an 85% uptake. Dong et al. [17] found similar preferences in addition to a protection duration of 18 months or more. Among healthcare workers, Fu et al. [18] found that those attributes were not always as important as in studies that targeted a general representative population. Indeed, these authors underlined the importance of the perceived trend of the epidemic and the infection probability over effectiveness.

In Europe, McPhedran and Toombs [19] showed a high utility induced by a vaccine effectiveness of 90% compared with a level of 70% in the British population. In France, the study by Schwarzinger et al. [20] highlighted the importance of the origin of the vaccine. Indeed, the general French adult population preferred a vaccine manufactured in the European Union or in the USA and rejected a Chinese vaccine, showing a preference for Western countries. They also found a consistent decrement in preferences about the effectiveness and the risk of serious side effects.

In the USA, Kreps et al. [21] and Motta [22] found similar results with a preference for the USA as the manufacturer compared to the UK, China, or Russia, and a consistent decrement in preferences for the effectiveness and the probability of side effects of the vaccine. Kreps et al. also added the recommender of the vaccine as an important attribute in vaccine choice and found a preference for a vaccine recommended by the Centers for Disease Control and Prevention or by the WHO. Craig [23] estimated an 86% probability of uptake under the best vaccine scenario (i.e., effective and safe) with a choice of setting and vaccination card offered. He highlighted that anti-vaccine proponents tended to be less educated and less vulnerable to severe forms of COVID-19 illness (e.g., younger adults, without medical conditions).

In Australia, Borriello et al. [24] estimated the probability of uptake at 99% in the best-case scenario. However, in this study, effectiveness was not considered as important as safety, and individuals also gave importance to the date until when the vaccine was available.

Other DCEs related to the COVID-19 vaccination program have been conducted but aimed to assess the preference for deservingness and priority populations. Luyten et al. [25] defined two prioritization strategies for a vaccination program based on five attributes, including belonging to a medical risk group, being a virus spreader, and being an essential worker. They defined a “utilitarian” strategy consisting of prioritizing spreaders of the virus and a “prioritarian” strategy consisting of prioritizing the medical risk groups. Another study by Reeskens et al. [26] defined a profile of an individual who should get prioritized for vaccination: an individual aged between 40 and 60 years, in a healthy condition, who respects the COVID-19 measures and is a healthcare worker. In the Netherlands, priority preference was given to young and health-worker individuals with high risk-conscious behavior [27].

In this study, which was conducted prior to the start of the vaccine program, we focused mainly on the origin, effectiveness, and safety of the vaccine, as well as on who recommended the vaccine and which groups should be given priority. In the next sections, we describe the methodology used and then present and discuss the results.

2 Methodology

2.1 Survey Design

Our target population was the French-speaking Quebec population aged over 18 years. The online survey was conducted between 19 October and 17 November, 2020 by Dynata Inc. and was structured to achieve quota sampling by age, sex, and educational level with reference to the national statistics provided by the Institut de la Statistique du Québec. The sampling was done among the panel owned by Dynata Inc. To reach a statistical power of 95% with a first-species risk α of 3% (i.e., rejecting the null hypothesis when it is actually true) and a relevant population of 6.5 million, 1067 individuals were needed (<https://fr.surveymonkey.com/mp/sample-size-calculator/>). Consequently, this was the minimal sample size targeted to have a representative sample of the French-speaking general population in Quebec. In addition, some authors have suggested a minimum of 10–20 responses per choice task [28, 29]. Considering that we had 360 choice tasks (see below) and that each respondent answered 12 choice tasks, this suggestion was achieved with a minimum of 600 respondents (i.e., $360 \times 20 / 12$).

The survey included a sociodemographic section, questions related to health condition, COVID-19 experience, the Fear of COVID19 Scale (FCV-19S) [30], health-related quality-of-life questionnaires [31–33], the DCE with follow-up questions, personal vaccination perception questionnaire, and the 3-item Sense of Coherence questionnaire (SOC-3) [34]. The sociodemographic section included age, sex, marital status, household income, occupation, education, type of residence, and family information. The FCV-19S is a 7-item validated questionnaire with a 5-point Likert scale range from “strongly disagree” to “strongly agree”. The higher the score, the higher the fear of COVID-19. We measured vaccination trust via four questions whose sum scored between 0 and 5 (the higher the score, the higher the vaccination trust). We also measured vaccination hesitancy via an eight-item questionnaire with a five-point Likert scale inspired by Shapiro et al. [35] and calculated a score range from 0 to 32 (the higher the score, the higher the vaccination aversion). Both latter questionnaires are partially validated instruments as they were adapted from previous questionnaires for child immunization acceptance. In this study, they were mainly used to summarize the information about trust and hesitancy.

2.2 DCE Design, Attribute, and Levels

As recommended by various experts in the field [36–38], we performed a mixed-methods study to build our DCE questionnaire. First, we conducted a rapid review of the literature to find relevant information about the attributes and levels

of vaccination programs that are of importance for people in their decision to be vaccinated or not. This was done in PubMed and Scopus using the keywords “discrete choice experiment” and “vaccine”. This led to various studies [17, 39–45], including reviews of the literature and original studies dealing with focus groups and published surveys. A first list of attributes and levels that can be used to influence vaccine choice was set at this stage. Second, we consulted experts in public health ($n = 2$) and health economics ($n = 1$), as well as a few citizens ($n = 3$), to hear their opinion about what was found in the literature and to provide insight into other potential attributes. This was done face to face through a phone or web meeting. This information made it possible to determine the attributes and levels to be used to characterize the risks and benefits of the vaccine and thus to define choice tasks for the DCE. In particular, this led to a list of eight attributes that were considered important, and one was excluded because it would have generated incoherent choice tasks combined with the other attributes (i.e., number of injections). The levels for each attribute were then adjusted to the extant knowledge about future vaccines that will be available by the end of 2020 as well as political concerns in Quebec (e.g., which population to prioritize, acceptable delay). Some levels were also selected for their capacity to ensure a better discrimination (i.e., effectiveness, side effects, protective duration). The experts and citizens then considered through an iterative process by e-mails whether the attributes and levels used made sense and qualitatively validated the questionnaire. This was done with a specific focus on univocity (i.e., unambiguous) of the phrasing and relevance of the attributes and levels based on the judgment of the participants. Likewise, a pretest was carried out on individuals from the general population to validate the consistency and unambiguity of the content of the questionnaire.

Our DCE was composed of seven attributes with three to six levels each (Table 1). Using an orthogonal selection procedure, a set of 300 choice tasks was produced. Each choice task consisted of two scenarios, and an opt-out option (no vaccine) was allowed. These choice tasks were randomly divided into 30 blocks. In each block, a rationality test was added (i.e., one scenario completely dominated the other scenario), and one choice task was repeated (choice tasks 2 and 12) to test the temporal consistency of respondents. This yielded a total of 360 choice tasks. Each respondent was randomly attributed one block of choice tasks. An illustration of a choice task is presented in Fig. 1. The first column in the choice task corresponded to the generic names of the seven attributes, the second to the levels presented in vaccine program A, and the third to the levels presented in vaccine program B. In the database, each possible choice (i.e., A, B, or opt-out) for each choice task corresponded to an observation (i.e., yielding three observations [or a triad] per choice task responded). Dummies were created for each

level of the seven attributes, and each dummy was coded with a value of 1 when the level was described in the vaccination program offered and 0 otherwise [46]. In the estimates, levels were dummy coded relative to the best level of each attribute. For the alternative specific constant, which captures the experimentally designed profiles in the survey, if the respondent answered choice A or B, the first two observations in each triad were coded 1, and the third observation for the opt-out option was coded 0; if the respondent answered the opt-out choice, the first two observations in each triad were coded 0, and the third observation for the opt-out option was coded 1.

2.3 Models

Two models were tested: a mixed-logit (MXL) model [47, 48] and a latent class logit (LCL) model [49, 50]. The MXL model estimates the distribution of the mean and the standard deviation of each individual's preferences. The LCL model allows the generation of different groups of individuals presenting similar preference patterns (intra-class) that are heterogeneous from one group to another (inter-class). For the sake of clarity, the models are presented with the best vaccination program as a reference: a vaccine manufactured in Canada, 95% efficacy with the fewest side effects, 24 months of protection duration, elderly individuals as a priority population, a waiting time of 2 months, and both the WHO and the Quebec Public Health Department as recommenders. Models were assessed using Akaike Information Criteria and likelihood function. The LCL model was run with several classes, and we based our choice on the Akaike Information Criteria, the likelihood function, and the interpretation of the results.

2.4 Descriptive Analysis

Using the LCL model, descriptive analyses were performed with five classes as well as with the full sample. We presented each class and the full sample with its sociodemographic characteristics and all relevant information aforementioned. We also computed several scores: certainty of DCE choices, FCV-19S, vaccination trust, vaccine hesitancy, and SOC-3. We used means to describe continuous variables. Finally, depending on the nature of the variable, we tested independence between classes using the Chi-squared test, Fisher's exact test, or Kruskal–Wallis test and means' test equality with analysis of variance. A p value less than 0.1 was considered statistically significant. Because these results do not consider confounding effects, a multinomial logistic regression to measure the class membership probability function was also conducted and used respondent characteristics as arguments.

2.5 Ethics

This study was approved by the ethics committee of our institution. Subjects indicated their consent by clicking on the start button at the end of the explanatory letter. All questionnaires were completed anonymously.

3 Results

3.1 Sample

Of the 3615 individuals solicited to participate, 1980 accepted, and 1696 completed the DCE. Among these 1696, several were excluded because they responded to the 12 choice tasks in the DCE in less than 1 minute and chose the opt-out option 75% of the time or less ($n = 47$; 2.77%), they always responded choice A ($n = 15$; 0.88%) or choice B ($n = 2$; 0.12%), they responded that their answers were of "poor" or "very poor" quality ($n = 8$; 0.47%), or they indicated not having answered their best ($n = 42$; 2.48%). This led to 97 individuals dropping out (5.72%) and to a full sample of 1599 individuals for analysis.

The answers for analysis corresponded to 19,188 choices, including 14,072 (73.34%) vaccine choices and 5116 vaccine refusals (26.66%). Approximately 37.71% of the sample never chose the opt-out option, 7.44% always chose to not get vaccinated, 11.44% refused the vaccine in the first-choice task (i.e., rationality test), 3.50% chose the second scenario (i.e., choice B was dominated by choice A), and 74.23% made the same choice to both scenarios 2 and 12 (i.e., consistency test). The refusal rate was 28.05% over choice tasks 2–12.

3.2 Choice Models

The main results of the MXL model are presented in Table 2, and the coefficients were ordered as expected when relevant (a version without the alternative specific constant is presented in the Electronic Supplementary Material [ESM]). All parameters were significant at least at $p < 0.1$, except for the levels "mild fevers" and "4 months". On average, there was a preference for Western countries (Canada, European Union, and USA) as vaccine producers; Russia and China led to a strong disutility. A vaccine effectiveness of 85% showed a negative marginal utility compared to a 95% effectiveness, thus indicating that a vaccine may be unlikely to be accepted at 85% and below. A one-third chance of having side effects, such as redness, mild itching, or mild fever, did not appear to matter. However, a one-third chance of being

Table 1 Discrete choice experiment attributes and levels

Attributes	Levels
Vaccine origin	Canada USA European Union Russia China Japan
Vaccine effectiveness (%)	95 85 60 30
Side effects of the vaccine	1 in 3 chances of having redness and mild itching at the injection site for 1 or 2 days 1 in 3 chances of having mild fevers for 1 or 2 days 1 in 3 chances of being hospitalized in an intensive care unit for 10 days
Duration of vaccine protection (months)	3 9 24
Priority population to receive the vaccine	No priority population Healthcare workers will be prioritized as soon as the vaccine becomes available 65 years and over will be prioritized as soon as the vaccine becomes available
Waiting time to get vaccinated when a vaccine will be available (months)	2 4 8
Recommender of the vaccine	World Health Organization Quebec Public Health Department World Health Organization and Quebec Public Health Department

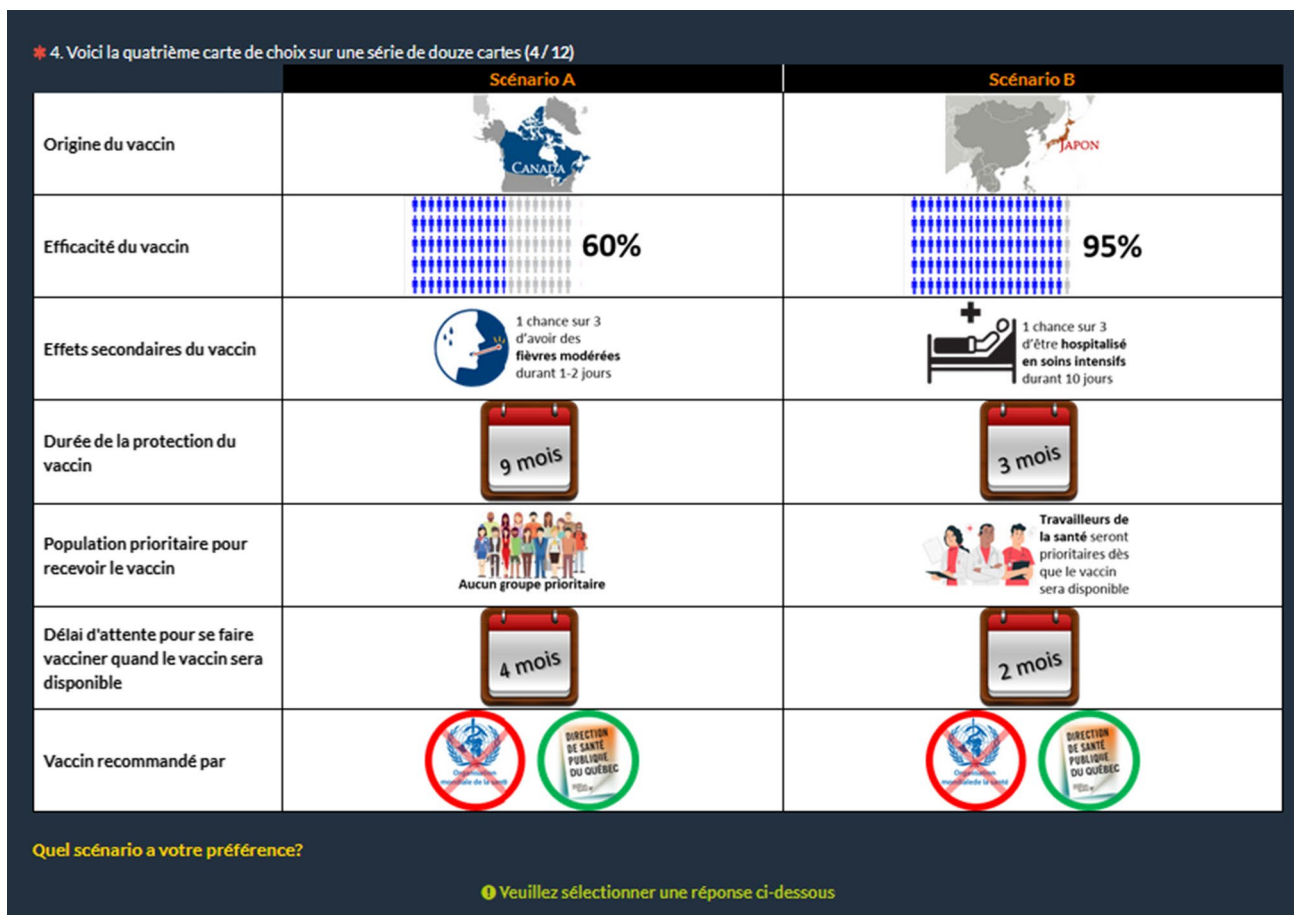
hospitalized following vaccination was very likely to lead to vaccine refusal. A duration of protection of at least 9 months was well accepted, while a period of 3 months resulted in greater disutility. Regarding the priority population, our sample was indifferent, with a very slight preference to prioritize the older population. Notably, this attribute had the lowest relative weight. Individuals were indifferent to a waiting time period to get vaccinated of 4 months compared to 2 months, whereas a waiting time of 8 months resulted in a significant but quite low disutility compared with the magnitudes of other coefficients. Finally, both the recommendations of the WHO and of the Quebec Public Health Department were necessary to best meet the expectations of our sample. If this was not the case, the recommendation of the Quebec Public Health Department was preferred to that of the WHO. The preference ranking between attributes is presented in Table 3 and was as follows: effectiveness, safety, duration, origin, recommendation, waiting time, and priority population.

Considering that preferences are generally heterogeneous, we ran a LCL model that resulted in five classes. We

predicted the posterior class membership probabilities [48] and considered the maximum probability to assign individuals to each class. We first present the vaccine preferences and then describe the five classes with all characteristics and scores presented above. Note that coefficient estimates are also presented graphically in the ESM for both models.

3.3 Preference Analysis by Classes

The results of the LCL are presented in Table 4, and the relative weights of the attributes are presented in Table 3. An analysis with four classes is also provided in the ESM. Class 1 (share of 0.117) had very few significant coefficients. Mainly, the delay to get vaccinated and the recommender of the vaccine had an impact on individuals' utilities. In class 2 (share of 0.097), almost all levels were associated with strong disutility compared with the reference. Individuals preferred a vaccine that can cause moderate fevers instead of redness/itching but especially not hospitalization, 95% efficacy, with as short a delay to get vaccinated as possible, and of Canadian origin. Individuals in class 3 (share of 0.308) granted a high disutility if the vaccine was not



- Scénario A
- Scénario B
- Aucun de ces scénarios (pas de vaccin)

Fig. 1 A vaccine choice card illustration (in French)

at least at 85% effective, with moderate side effects, and a minimal protective duration of 9 months. Class 4 preferences (share of 0.195) were identical to those of class 2 but very less pronounced. Finally, class 5 (share of 0.283) individuals wanted a vaccine with a Western country origin, at least 85% effective, with moderate fevers as side effects and a minimal protective duration of 9 months. Except for class 2, individuals did not take into account the priority population or the delay to get vaccinated in their choice tasks.

3.4 Descriptive Analysis by Classes

The following descriptive facts are given for informational purposes and to highlight the fact that there is no single behavior in vaccine choice, which reflects both the importance of the vaccination program characteristics and those of the respondents (Table 5 and ESM). Half of the

respondents were women (male/female ratio of 0.95) [$p = 0.018$] and the sample had a mean age of 50.23 years ($p < 0.001$) [ESM]. Classes 2 and 4 were mainly composed of men (male/female ratios equal to 1.16 and 1.26, respectively), and class 3 was mainly feminine (male/female ratio equal to 0.78). Class 1 was the youngest (45.62) and class 4 the oldest (53.64). Most participants were married/lived with a partner (59.10%) or single (28.77%) [$p = 0.001$] and were employed (51.09%) or retired (32.27%) [$p = 0.040$]. Individuals in class 1 were more employed (59.59%) and students (6.16%), and individuals in classes 2 and 4 were mainly retired (39.02% and 37.55%, respectively) and married or living with a partner (64.23% and 62.45%, respectively). One-third were poorly educated ($p = 0.064$), with classes 1 and 4 being the least educated (42.47% and 40.71%, respectively, had the lowest educational level) and class 2 being the most educated (41.46% had the highest

Table 2 Mixed-logit model

Attribute	Mean					Standard error				
	Coefficient	Standard error	P value	95% confidence interval		Coefficient	Standard error	P value	95% confidence interval	
ASC	31.646	17,542.260	0.999	-34,350.552	34,413.843	0.072	18,920.898	1.000	-37,084.207	37,084.352
Vaccine origin										
Canada	(Reference)									
European Union	-0.559***	0.062	0.000	-0.681	-0.438	-0.176	0.207	0.396	-0.580	0.229
USA	-0.636***	0.060	0.000	-0.754	-0.518	0.284*	0.156	0.068	-0.021	0.590
Japan	-0.774***	0.064	0.000	-0.900	-0.649	-0.471***	0.118	0.000	-0.702	-0.240
Russia	-1.149***	0.064	0.000	-1.275	-1.023	0.617***	0.110	0.000	0.402	0.832
China	-1.376***	0.070	0.000	-1.513	-1.239	1.004***	0.096	0.000	0.816	1.192
Vaccine effectiveness (%)										
95	(Reference)									
85	-0.380***	0.046	0.000	-0.469	-0.290	0.176	0.114	0.121	-0.047	0.399
60	-1.087***	0.052	0.000	-1.188	-0.985	-0.415***	0.094	0.000	-0.598	-0.231
30	-2.361***	0.070	0.000	-2.498	-2.223	1.096***	0.078	0.000	0.944	1.248
Side effects of the vaccine										
Redness and mild itching	(Reference)									
Mild fevers	-0.038	0.037	0.297	-0.110	0.034	-0.048	0.069	0.488	-0.184	0.088
Hospitalization	-1.770***	0.069	0.000	-1.906	-1.634	1.716***	0.079	0.000	1.561	1.870
Duration of vaccine protection (months)										
24	(Reference)									
9	-0.375***	0.040	0.000	-0.454	-0.296	-0.044	0.075	0.557	-0.190	0.103
3	-0.803***	0.044	0.000	-0.890	-0.717	-0.306***	0.092	0.001	-0.486	-0.127
Priority population to receive the vaccine										
65 years and over	(Reference)									
Healthcare workers	-0.068*	0.040	0.087	-0.145	0.010	-0.003	0.084	0.968	-0.168	0.162
No priority population	-0.082**	0.041	0.045	-0.162	-0.002	-0.154*	0.088	0.080	-0.326	0.018
Waiting time to get vaccinated (months)										
2	(Reference)									
4	-0.030	0.042	0.477	-0.112	0.052	0.001	0.092	0.993	-0.180	0.181
8	-0.219***	0.041	0.000	-0.299	-0.139	0.148**	0.074	0.044	0.004	0.292
Recommender of the vaccine										
World Health Organization and Quebec Public Health Department	(Reference)									
Quebec Public Health Department	-0.360***	0.042	0.000	-0.441	-0.278	0.031	0.082	0.703	-0.130	0.193
World Health Organization	-0.439***	0.042	0.000	-0.521	-0.358	0.001	0.087	0.989	-0.169	0.171

Table 2 (continued)

Attribute	Mean		Standard error					
	Coefficient	Standard error	P value	95% confidence interval	Coefficient	Standard error	P value	95% confidence interval
Observations	57,564							
Chi2	817							
Log likelihood	-6400.122							
Null Log likelihood	-6808.609							
AIC	12,876.240							

AIC Akaike Information Criterion, ASC alternative specific constant, * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

educational level). The average household annual income ranged from 63,356 CAD in class 1 to 77,134 CAD in class 2, with a mean of 66,857 CAD ($p < 0.001$). The sample was thus somewhat representative of the adult Quebec population (ESM). Other data showed that half of the sample did not experience financial losses due to COVID-19 ($p = 0.143$) and continued to work during the first lockdown ($p = 0.430$). Class 3 suffered the least from financial losses (52.15%), while class 1 suffered the most from financial losses (21.43% declared “fairly significant” or “very significant” financial losses) and continued to work (56.16%). Only 10.82% declared their health status as “fair” or “poor” ($p = 0.303$), with a maximum in class 2 (13.01%). The willingness to take risks was equal to 4.69 of 10 ($p < 0.001$). Individuals in classes 1 and 5 were the most risk lovers (5.47 and 5.00, respectively). Almost 30% declared suffering from a disease or a clinical or mental health problem ($p = 0.112$). The health-related quality-of-life scores were lower only in class 1 (ESM).

The average response time to the DCE was 5 minutes 8 seconds ($p = 0.045$), with class 4 being the fastest (4 minutes) and class 3 being the slowest (5 minutes 35 seconds) [ESM]. The choice certainty score was equal to 95.61 of 120 ($p < 0.001$), with a minimum in class 1 (84.32) and a maximum in class 3 (98.52). Class 2 was more likely to declare the exercise as “easy” or “very easy” (65.85%, $p = 0.011$), to consider at least three dimensions (71.54%, $p < 0.001$), and to declare a “good” or “very good” quality of answers (94.31%, $p < 0.001$). This was in contrast to classes 1 and 4. More than 40% of choices in class 3 were vaccine refusals ($p < 0.001$), while it was approximately 15% in classes 1, 2, and 5 compared with 26.66% in the total sample.

Vaccine trust and vaccine hesitancy scores were equal to 4.08 of 5 ($p < 0.001$) [i.e., high trust] and 11.61 of 32 ($p < 0.001$) [i.e., moderate hesitancy], respectively (Table 5). Classes 1 and 3 had the lowest vaccine trust score and the highest vaccine hesitancy score (3.83 and 14.03 in class 1 and 3.75 and 12.22 in class 3, respectively), while class 2 was the most confident (4.48) and the least hesitant (9.72). Regarding COVID-19, the FCV-19S was equal to 16.45 of 35 ($p < 0.001$), with a maximum in class 1 (18.45). About 1.81% of individuals caught the virus ($p = 0.010$), while this proportion was 4.01% for a family member ($p = 0.015$) and 10.76% for a relative ($p = 0.077$). Individuals in class 1 were the most likely to declare having suffered from the disease, while in class 4, they were the least likely. Last, the SOC-3 was approximately 3.94 of 6 ($p = 0.078$) with a minimum in class 1 (3.67) [ESM]. The results of the multinomial logistic regression confirmed that many of the variables presented above explained the probability of belonging to the 5 classes identified (ESM).

Table 3 Relative weights of attributes according to the different models

	Mixed-logit model	Latent class logit model				
		Class 1	Class 2	Class 3	Class 4	Class 5
Relative weights of attributes by model (%)						
Vaccine origin	12.75	5.06	11.57	5.78	35.93	9.84
Effectiveness of the vaccine	28.48	15.56	19.50	20.80	15.93	48.61
Side effects of the vaccine	23.68	12.98	33.99	35.74	8.64	9.09
Duration of vaccine protection	17.41	4.46	3.67	18.35	11.71	24.43
Priority population to receive the vaccine	2.11	9.80	7.99	1.72	1.18	0.73
Waiting time to get vaccinated	3.62	24.03	16.33	3.16	4.14	2.68
Recommender of the vaccine	11.96	28.12	6.95	14.45	22.48	4.62

4 Discussion

In this study, we assessed the vaccination preferences against COVID-19 in the Quebec population. Using a DCE, we showed the relevance of the effectiveness, safety, and protective duration of the vaccine in the choice of vaccination of individuals. As preferences may vary depending on groups’ characteristics [51], we also analyzed the heterogeneity of behaviors with an LCL model. Five profiles emerged from our analysis: an average group in favor of vaccines (class 5); two vaccine hesitant and very demanding groups (classes 2 and 4); a very hesitant group with many anti-vaccine individuals (class 3); and an uncertain, impatient, more vulnerable group or those who did not understand the DCE and may have provided inconsistent answers (class 1). Indeed, the latter is composed of individuals who wanted to be vaccinated as soon as possible and were more exposed to the disease. Classes 2 and 4 were very demanding regarding different attributes. However, class 2 granted a higher relative weight to vaccine effectiveness and side effects. Class 4 was mainly worried about the vaccine origin and who recommends it. Both attributes can be summarized as a form of trust in Western institutions. All respondents who always refused the vaccine (7.44%) were in class 3 (some descriptive facts are available in the ESM), and we can suppose that they were “anti-vaccine”. However, most respondents in class 3 were “vaccine hesitant” individuals (17.63% of the class always refused the vaccine program, 60.89% chose to accept the vaccine program at least once, and 21.48% always accepted the vaccine program) and granted the highest utility to vaccine safety. Class 5 can be considered a “pro-vaccine” group that gave a very high importance to effectiveness and protective duration. This class had few discriminant characteristics, and the majority of sociodemographic variables, DCE-related variables, and COVID-19 experience variables were equal to those of the full sample. In brief, if the available vaccines are efficient,

manufactured in Western countries and with low side effects; classes 2 and 4 should decide to get vaccinated.

As in other studies, we found that vaccine acceptance tends to increase with age, education, and income [52–58]. It has been shown that female individuals were more hesitant to get vaccinated against COVID-19 [17, 56, 59, 60] or were willing to wait longer [61], which is also in line with our findings: the largest proportion of women were in the group of hesitant and anti-vaccine individuals (class 3). Elderly patients seemed to be more concerned about side effects and were more demanding regarding vaccine characteristics (classes 2 and 4). A higher fear of COVID-19 and vaccine trust also increased the willingness to get vaccinated [60, 62], whereas individuals with current health problems and who had an experience with COVID-19 were less likely to accept the vaccine [51, 62].

Our results match different opinion polls conducted in Canada. According to an IPSOS survey for Radio Canada [63] conducted in December 2020, 63% of residents were willing to get vaccinated, and 72% were worried about vaccination side effects. In March 2021 [64], 66% were willing to get vaccinated, and 16% preferred to wait. Long-term side effects were the main reason to refuse the vaccine.

In Canada, COVID-19 vaccines are available for free. Thus, we did not consider the price as an attribute as it could have been misperceived. Some studies have included the vaccine price as an attribute, but it was associated with low coefficients or was not significant [16, 17, 24].

Our survey suffers from several limitations. The first is linked to the fact that an online survey may create a selection bias. Individuals who did not have access to the Internet or had poor literacy were thus excluded. However, 93% of adult residents have access to the Internet in Quebec [65], which may have limited this bias. In addition, an online survey also allowed us to better manage social desirability bias [66] and to treat the information faster, in addition to being less expensive. Another constraint of an online survey is related to the financial incentive offered by the platform to the respondents, which could have fostered them to adopt

Table 4 Latent class logit model with five classes

Attribute	Class 1	Class 2	Class 3	Class 4	Class 5
<i>Latent class logit model</i>					
ASC	81.735	124.144	48.588	48.221	46.778
Vaccine origin					
Canada	(Reference)				
European Union	-0.105	-10.233***	-0.434**	-1.007***	-0.660***
USA	-0.093	-6.369***	-0.738***	-0.995***	-0.678***
Japan	-0.053	-13.377***	-0.510***	-1.697***	-0.700***
Russia	-0.048	-16.034***	-0.731***	-2.697***	-0.883***
China	0.090	-18.225***	-1.017***	-3.478***	-0.810***
Vaccine effectiveness (%)					
95	(Reference)				
85	0.030	-7.679***	-0.370**	-0.109	-0.721***
60	-0.204	-9.292***	-1.143***	-0.455***	-1.996***
30	-0.214	-23.843***	-3.126***	-1.121***	-4.191***
Side effects of the vaccine					
Redness and mild itching	(Reference)				
Mild fevers	0.004	0.657**	-0.200*	-0.096	0.055
Hospitalization	-0.204*	-40.397***	-4.315***	-0.417***	-0.671***
Duration of vaccine protection (months)					
24	(Reference)				
9	0.047	-0.314**	-0.614***	-0.168	-0.546***
3	0.016	-3.558***	-1.454***	-0.456***	-1.211***
Priority population to receive the vaccine					
65 years and over	(Reference)				
Healthcare workers	-0.004	-5.035***	0.085	0.005	-0.008
No priority population	-0.133	-4.047***	-0.119*	0.057	-0.045
Waiting time to get vaccinated (months)					
2	(Reference)				
4	-0.095	-10.415***	0.274*	0.045	-0.069
8	-0.257**	-8.200***	-0.115*	-0.182	-0.132
Recommender of the vaccine					
World Health Organization and Quebec Public Health Department	(Reference)				
Quebec Public Health Department	-0.087	-4.785***	-0.709***	-0.599***	-0.160*
World Health Organization	-0.305***	-2.505***	-0.898***	-0.581***	-0.168*
Class share	0.117	0.097	0.308	0.195	0.283
Observations	1599				
LLF	-6020.47				
AIC	12,238.95				

AIC Akaike Information Criterion, ASC alternative specific constant, LLF likelihood function, * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

“satisficer” behavior and to answer with weak coherence in a relatively short time [67, 68]. This could explain the results of class 1 despite the use of exclusion criteria.

A second limitation is related to the design of the DCE. Indeed, we chose seven attributes, which may have led to a cognitive burden for respondents. There is still debate about the optimal number of attributes in the literature [69–71], but increasing the number of attributes increases the likelihood

of self-simplifying the exercise by heuristics [72]. Several preference-based surveys about COVID-19 vaccination included six [17, 22, 27] or seven [16, 18, 21, 24] attributes.

Third, the study was designed before the first COVID-19 vaccines were available. Although it was based on the best knowledge at that time, it could have led to a hypothetical bias by choosing attributes that were not of utmost importance in the actual (real) situation. In addition, by

Table 5 Coronavirus disease 2019 (COVID-19) experiences and vaccine hesitancy

COVID-19 and vaccine hesitancy	Class 1	Class 2	Class 3	Class 4	Class 5	Total	<i>P</i> value
Vaccine trust score (range from 0 to 5) ^a							
Mean	3.83	4.48	3.75	4.30	4.46	4.08	< 0.001
Standard deviation	1.42	0.88	1.66	1.08	0.95	1.39	
Vaccine hesitancy score (range from 0 to 32) ^b							
Mean	14.03	9.72	12.22	10.88	10.75	11.61	< 0.001
Standard deviation	5.99	5.75	7.09	6.12	6.08	6.59	
Fear of COVID-19 score (range from 7 to 35) ^c							
Mean	18.45	16.32	15.17	17.49	17.27	16.45	< 0.001
Standard deviation	6.84	5.58	5.67	6.62	6.34	6.22	
Have you or a relative been sick with COVID-19 in the past few months?							
Yourself							
Yes	6.16%	1.63%	1.48%	0.79%	1.49%	1.81%	0.010
No	93.84%	98.37%	98.52%	99.21%	98.51%	98.19%	
A family member							
Yes	8.90%	5.69%	3.11%	2.77%	4.23%	4.07%	0.015
No	91.10%	94.31%	96.89%	97.23%	95.77%	95.93%	
A relative							
Yes	17.12%	11.38%	10.52%	7.91%	10.45%	10.76%	0.077
No	82.88%	88.62%	89.48%	92.09%	89.55%	89.24%	

^aThe vaccine trust score is based on four questions (see ESM for details) and has a range from 0 to 5. The “Yes/No” questions are encoded 1 and 0 and the fourth question is encoded 0, 1, and 2. The score corresponds to the sum of each modality

^bThe vaccine hesitancy score is based on eight questions (see ESM for details) with a 5-point Likert scale from “Strongly disagree” (0 or 4) to “Strongly agree” (4 or 0). The modality “Do not know” is encoded 2 and questions 3, 4, 5, and 7 have been reversed. The score per individual corresponds to the sum of each modality

^cThe fear of COVID-19 score is based on the 7-item Fear of COVID-19 scale (see ESM for details) with a 5-point Likert scale from “Strongly disagree” (1) to “Strongly agree” (5). The score has a range from 7 to 35 and corresponds to the sum of each modality

considering the most appropriate and realistic levels for these attributes, it allowed us to limit the potential dependency between some attributes, such as the priority population and the waiting time to get vaccinated. However, scientific information about the disease and vaccines, their availability, and public trust are rapidly evolving, and this study needs to be considered within its context at the time it was conducted. Future studies should examine vaccine programs as the situation evolves (e.g., variants, long-term COVID-19) by considering other attributes. Moreover, we did not use a simple question to ask respondents if they were willing to get vaccinated against COVID-19 when the vaccine was available. Instead, we performed a DCE and assessed their general behavior when facing vaccination with additional questions.

One of the strengths of the study is that the sample size was quite large (1599 individuals) [73] compared to the average sample size of other DCEs about the COVID-19 vaccination program in the literature. It was also above the minimal requirement, thus ensuring higher efficiency in estimates. Finally, both the MXL and the LCL models were

consistent in their results and in the decrement in disutility according to effectiveness, probability of side effects, protection duration, and waiting time to get vaccinated.

In 2019, the WHO classified vaccine hesitancy as one of the top ten threats to global health [74]. Nevertheless, it does not rely on a dichotomic view with “anti-vaccine” on the one hand and “pro-vaccine” on the other hand but on a continuum between those two extremes. Hesitancy to vaccination is multifactorial. Determinants explaining vaccination hesitancy and refusal are contextual (influences and media), individual (sociodemographic, knowledge, and experiences), and organizational (availability, healthcare worker perception, and vaccine characteristics) [75]. We believe that this study reflects this situation well, although it was more about vaccine choice than hesitancy per se. Indeed, the LCL model clearly indicated five main groups with diverse behaviors regarding whether they chose to accept a vaccine, and this choice was potentially driven both by the characteristics of the vaccination program and their own sociodemographic and attitudinal characteristics.

5 Conclusions

Vaccination campaigns should consider various attributes of the program as well as individual profiles to improve trust in vaccination programs and expand herd immunity. However, this requires transparent and consistent information [76]. Different behaviors regarding vaccination restrict global immunization (i.e., vaccine hesitancy and vaccine refusal) and are worse during the COVID-19 crisis. The comprehension of such behaviors is crucial in determining the success of a vaccination campaign. In this study, we examined the preferences of the general population in Quebec and highlighted several characteristics of vaccine behavior patterns that should help decision makers establish a more effective vaccination campaign.

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Declarations

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Conflict of interest The authors have no conflicts of interest to declare.

Ethics Approval This study was approved by the Ethics Committee of the CIUSSS de l'Est de l'île de Montréal under the number 2021-2385.

Consent to participate Informed consent was obtained from participants before to start the survey.

Consent for publication All authors provide this consent.

Availability of Data and Material Because of restrictions from our ethics committee, data will be available upon reasonable request by contacting the corresponding author.

Code availability Please contact the corresponding author for any requests for any study materials including codes.

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