Preferences for COVID-19 epidemic control measures among French adults: a discrete choice experiment

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Abstract
In this stated preferences study, we describe for the first time French citizens’ preferences for various epidemic control measures, to inform longer-term strategies and future epidemics. We used a discrete choice experiment in a representative sample of 908 adults in November 2020 (before vaccination was available) to quantify the trade-off they were willing to make between restrictions on the social, cultural, and economic life, school closing, targeted lockdown of high-incidence areas, constraints to directly protect vulnerable persons (e.g., self-isolation), and measures to overcome the risk of hospital overload. The estimation of mixed logit models with correlated random effects shows that some trade-offs exist to avoid overload of hospitals and intensive care units, at the expense of stricter control measures with the potential to reduce individuals’ welfare. The willingness to accept restrictions was shared to a large extent across subgroups according to age, gender, education, vulnerability to the COVID-19 epidemic, and other socio-demographic or economic variables. However, individuals who felt at greater risk from COVID-19, and individuals expressing high confidence in the governmental management of the health and economic crisis, more easily accepted all these restrictions. Finally, we compared the welfare impact of alternative strategies combining different epidemic control measures. Our results suggest that policies close to a targeted lockdown or with medically prescribed self-isolation were those satisfying the largest share of the population and achieving high gain in average welfare, while average welfare was maximized by the combination of all highly restrictive measures. This illustrates the difficulty in making preference-based decisions on restrictions.

Keywords SARS-CoV-2 epidemic · COVID-19 · Epidemic control measures · Preferences · Discrete choice experiment · Correlated mixed logit model · Choice certainty

JEL Classification C91 · I12 · I18

Introduction
Epidemic control measures—or non-pharmaceutical interventions—have been widely used during the COVID-19 epidemic to curb increases in hospitalizations, admissions to intensive care units, and mortality. In the absence of highly effective treatments, these measures are required either on an on–off mode or throughout a period of several months until vaccination directly protects vulnerable populations, or until a sufficient level of immunity is achieved (through natural

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infection or vaccination) to eliminate the disease or at least transform its occurrence into endemically.

Strict lockdowns are extreme epidemic control measures that put a high burden on social and economic life. Other individual measures can represent more nuanced degrees of constraints and can be adapted to the required impact and societal needs. Governments need to arbitrate between the negative consequences of a complete lockdown and the consequences of hospital overload. Economic analysis can provide guidance regarding these trade-offs in two ways. First, cost–benefit analysis can inform about optimal allocation of resources by comparing each measure (or set of measures) cost to their benefits, converted from number of lives saved into monetary equivalent based on value of a statistical life (VSL) estimates [27]. Yet, VSL values calculated in one context may not be easily transposed in another, and this approach makes it difficult to account for non-monetary costs of Sars-Cov-2 infection (e.g., post-COVID-19 syndrome) or control measures’ side effects (e.g., mental health disorders).

A second approach is to directly account for individuals’ opinions and preferences, using preference elicitation tools such as stated preferences surveys [3, 9, 14]. The usefulness of this second approach relies on the assumption that the closer the measures are aligned with public preferences, the more sustainable and acceptable they will be for individuals and society. It can be argued that studies based on individual preferences are crucial to ensure population’s compliance with the set of epidemic control measures over several months. Therefore, we propose to follow this stream of research to identify the most acceptable measures as well as their combinations (strategies) in France. We designed an original discrete choice experiment (DCE) [15, 28] administered to a representative sample of the French 18+ years old population, to quantify the trade-offs French adults were willing to make between epidemic control measures and their public health consequences. DCE is a type of stated preferences survey, where each respondent is asked to repeatedly choose among a set of several (hypothetical) alternatives, the one they would prefer [2, 16]. Discrete choice models are grounded in standard economic theory, thus aiming for making predictions about the demand for alternative goods or programmes [18, 19].

In this study, we estimate for the first time the welfare losses or gains that is induced by each constraint composing a strategy, relative to a benchmark welfare characterized by a baseline strategy. At this time (end of November 2020), the baseline strategy was a low-level lockdown following the second wave of COVID-19. The French population could move freely to go to work, but there were some restriction: the so-called “non-essential shops and businesses” (including cultural sites and restaurants) were closed, high school teaching was on-site but higher-degree education was fully online. Intensive care admissions and deaths had just peaked in mid-November, but uncertainties for the future were high. Besides, the perspective of the Christmas holiday seasons worried politicians and the population. The potential success of a strategy can be measured by the magnitude of its theoretical acceptance/adhesion rate in the population, this latter being deduced from the number of individuals experimenting a welfare increase after a strategy change. The welfare impacts of these strategies are specific to the individual and societal needs, as well as to the values of the country. Therefore, the results of our study cannot a priori be easily transposed to another country.

We compared six ad hoc alternative policy scenarios—i.e., combinations of attributes and levels defined in our experiment (also referred as “strategies”)—each of one being more restrictive than the baseline strategy already implemented in France in November 2020. These alternative strategies, which were publicly discussed, were imagined to respond to an increase of the pandemic with the main objective to lower the peak of occupation of hospital intensive care beds. Four main tools were considered: “restrictions measures on economic, cultural and social life”, “targeted lockdown”, “homeschooling at high school”, “constraints to directly protect vulnerable persons”. With a specific degree of strictness, these four measures were combined to define each strategy under the constraint that the combination allowed reducing intensive care unit (ICU) overload.

Our first results suggests that all six analyzed strategies generate positive welfare gains (increased mean utility) by avoiding the need to postpone surgery, at the expense of stricter control measures than those prevailing at the end of November 2020 (the baseline scenario). Our more detailed results show that two scenarios increase welfare for more than 85% of the population while achieving high gain in mean utility: a scenario close to a targeted lockdown and a scenario with medically prescribed self-isolation and with restrictions in nursing homes. On the opposite, the scenario with the highest restrictions on public spaces and the scenario favoring the highest restrictions on schooling both generate a lower mean utility and a smaller fraction of the population experimenting a welfare increase (lower than 75%). Therefore, it seems that scenarios that directly protect (and restrict) vulnerable persons improve welfare for the largest proportion of the population even if they do not allow to reach the highest increase in average welfare. We expect that the results of our study can provide relevant information that helps to define a sustainable mid-term (1 year) and long-term strategies of epidemic control in France. While high vaccination coverage will have reduced the need for extensive restrictions, similar situations may occur in the future in case of seasonal epidemic resurgence, vaccine-escape variants or other emerging diseases.
Our study complements previous research that evaluated the epidemic control for influenza pandemic threats [31], as well as studies about the perceptions and practices of the French population concerning the 8-weeks lockdown that occurred in France in between March and May 2020 [22]. In May 2020, one DCE study has investigated the trade-offs French people were willing to make to avoid a lockdown extension by 8 weeks: wearing masks and limiting inter-regional travel [3]. Another DCE study in Germany investigated the trade-offs Germans citizens were willing to make between various exit strategies from lockdown and showed that two attributes dominated the trade-offs: avoiding a mandatory tracing application, and providing sufficient intensive care capacities [14].

The remainder of the paper is structured as follows. We detail the DCE design, participant selection, and recruitment in “The discrete choice experiment (DCE)”. “Econometric modeling” presents the econometric models and “Sensitivity analyses” details the sensitivity analyses. “Results” presents our results, which are discussed in “Discussion. “Conclusion” concludes.

The discrete choice experiment (DCE)

Selection of attributes and levels

Our selection of attributes and levels describing the hypothetical epidemic management strategies was based on a three-step procedure. First, analysis of existing literature and theoretical relevance allowed pre-selection of attributes and levels. Second, the list was refined based on qualitative work including consultation of experts involved in the Sars-CoV-2 epidemic management (epidemiology, clinical medicine, modeling, social psychology, economics, and public policy). Third, we conducted think-aloud interviews by self-administering the questionnaire to a sample of nine participants and recording their thoughts and information processing behavior [30]. All participants provided feedback that helped us refine the formulation of some attributes’ levels, and simplify the introduction text of scenarios.

The final list of attributes and levels is displayed in Table 1. Four attributes concern economic and social life, including school closure and targeted lockdown. The last attribute describes the measures took to overcome the risk of ICU overload and its consequences. The occupation of ICU beds appeared to be the most appropriate health care outcome to consider in trade-offs around the Sars-CoV-2 epidemic. Consequences of variable degree of negative impact are, for example, reprogramming of non-urgent surgery, transfer of COVID-19 patients to other hospitals in distant geographic areas, and ultimately, triage of patients for admission in ICU based on prognostic factors (a level that was not considered in our DCE for ethical reasons). The choice and definition of our “risk of ICU overload” attribute was based on several rationales. First, we wanted to translate the health impact of the epidemic situation into something qualitative, tangible, that could

Table 1 Definition of attributes and levels

| Attributes                                      | Level | Level description                                      |
|------------------------------------------------|-------|--------------------------------------------------------|
| Restriction measures on economic and social life | 1     | No generalized closure measure                         |
|                                                | 2     | Closure of public spaces                               |
|                                                | 3     | Closure of public spaces + transport and office        |
| Targeted lockdown                              | 1     | No targeted lockdown                                    |
|                                                | 3     | Targeted lockdown for sectors with high COVID-19 incidence |
| Homeschooling at high school                   | 1     | All teaching in-site                                   |
|                                                | 2     | Homeschooling at high school for 2 weeks               |
|                                                | 3     | Homeschooling at high school for 2 months              |
| Medically prescribed self-isolation            | 1     | Information campaign on COVID-19 risk factors          |
|                                                | 2     | Medically prescribed self-isolation (SI)               |
|                                                | 3     | Medically prescribed SI + restrictions for visits in nursing homes |
| Measures to overcome the risk of ICU overload  | 1     | Measures to increase the number of health care workers available |
|                                                | 2     | Need to postpone elective surgery                      |
|                                                | 3     | Need to postpone surgery + patient evacuation          |

Legend

| Level 1 of restriction (low) – Reference level in choice models |
| Level 2 of restriction (moderate)                              |
| Level 3 of restriction (high)                                  |
Reminder: We ask you to imagine a post-lockdown situation in which a clear increase in the number of people treated in intensive care or who died as a result of COVID-19 is observed in your area [NUTS level 3, departement in French]. A competent decision-maker will announce additional measures for your area, which will enter into force from the following week.

Between the two scenarios presented, choose the scenario that would be the most acceptable overall. There are no right or wrong answers, only your opinion matters.

| Restriction measures on economic and social life | Scenario 1 | Scenario 2 |
|-----------------------------------------------|------------|------------|
| Targeted lockdown | No targeted lockdown | Targeted lockdown for sectors with high incidence * |
| Homeschooling at high school | Homeschooling for 2 weeks | Homeschooling for 2 months |
| Protection of vulnerable people | - Medically prescribed self-isolation - Restrictions for visits in nursing homes | Information campaign on COVID-19 risk factors |
| Measures to overcome the risk of ICU overload | Measures to increase the number of health care workers available | Need to postpone elective surgery |

Q1. Which scenario would be most acceptable to you? (tick one box)

Q2. On a scale from 0 à 10, how certain are you of the choice you just made? (0: absolutely uncertain; 10: perfectly certain)

Note: figure adapted from the original survey (in French), and translated by the authors.

Fig. 1 Example choice task

be understood by a large share of the population. Second, at the time of the survey, the political justification of the restriction measures was focused on avoiding hospital overload. This attribute thus synthesized the main “health damages” to expect in case of increased virus propagation. For each attribute—except targeted lockdown (two levels)—we defined three levels with increasing severity, from low severity/strictness (level 1) to high severity/strictness (level 3).

**Experimental design**

We used a pairwise DCE design, a format that asked respondents to repeatedly choose which scenario would be most acceptable between two hypothetical scenarios (see Fig. 1 for an example choice task). The content of scenarios (optimal combinations of attributes’ level) was selected using an efficient fractional design using NGENE software (Choice metrics). We defined non-informative prior values for the preferences parameters corresponding to the four non-ICU related attributes (i.e., negative values close to zero: $\beta = -0.1$), and negative prior values for the levels “need to postpone elective surgery” ($\beta = -0.5$) and “need to postpone elective surgery + patient evacuation” ($\beta = -0.8$) of the ICU overload attribute. We specified a non-linear utility function allowing independent estimation of all attributes’ levels (using level 1—the less restrictive measures—of each attribute as reference) as well as some...
preferences. We hypothesized that respondents could be reluctant to choose scenarios presenting a restriction measure that appeared particularly ‘soft/lenient’ given the measures taken to avoid the risk of ICU overload. We thus posited a negative interaction between the level 3 (need to postpone elective surgery + patient evacuation) of the ICU overload attribute, and the level 1 (lowest restriction) of the economics and social life (i.e., “no generalized closure measure”), homeschooling (i.e., “all teaching in site”), and medically prescribed self-isolation (i.e., “information campaign on COVID-19 risks factors”) attribute. A total of 18 pairwise tasks were necessary to estimate all main effects and the above-mentioned interactions (no more interactions could be tested with this design). We randomly assigned six tasks to the respondents, and the order of choice task varied for each respondent (Online resource Appendix A shows the content of all 18 choice tasks). After each choice task, respondents were asked to indicate the degree of their decision certainty on a scale from 0 to 10 [7, 17, 24]. Based on the framework of Regier et al. [24], this scale was used to identify less throughout individuals (see “Sensitivity analyses”).

Participant selection and recruitment

We used Johnson and Orme’s rule of thumb formulae (see [6] for a comparison of formulas for sample size calculation) to determine the minimum acceptable sample size requirement per strata analysis. Considering six choice tasks, two alternatives per choice task, and a maximum of three levels per attribute, the minimum required sample size was 167. We arbitrarily multiplied this minimum sample size by a factor of 5—thus aiming for > 850 respondents—to investigate preference heterogeneity by modeling variation in preferences according to different individual characteristics. Based on model parameter estimates, we calculated the minimum sample size required to estimate a statistically significant effect for each attribute levels at the 5% level using Rose and Bliemer [26] formulae (see Online resource Appendix B).

Any French resident aged between 18 and 80 years was eligible for participation. Participants were recruited through a survey institute using a representative internet panel, using the quotas method, and the usual procedures of confidentiality and incentives (i.e., a 3€ voucher per completed questionnaire). The selection procedure defined quotas according to age, gender, geographical location, and socio-economic groups (study invitations were sent until the completion of the expected sample size was reached). Invited respondents completed the anonymous online questionnaire between November 26th and December 1st, at the end of the second lockdown, during which the French population could move freely to go to work, high school teaching was on-site, and before first efficacy data from COVID-19 vaccine trials were published. French citizens had strong views on this crisis, which had been undergone for nearly 9 months. Intensive care admissions and deaths had just passed their peak in mid-November (Fig. 2), but uncertainties for the future were high. The closure of so-called non-essential retailers raised questions, as did the non-re-opening of cultural venues. French people were moving from lockdown to an equally tight curfew.

Design of the final questionnaire

The final questionnaire consisted of two parts. In part 1, basic socio-economic information was collected. Socio-economic status was approximated through the level of the highest diploma obtained (below, at or above French baccalaureate), subjective deprivation (positive answer to the question: “did your household have financial problems during the last 12 months that hindered paying in time the rent, mortgage, consumer credits or every-day bills such as water, gas or electricity?”), having a dependent child (elementary or high school), and having a close relative in a nursing home. We also evaluated whether respondents were affected (or knew someone who was affected) by the COVID-19, whether they thought having a risk factor for severe COVID-19, and their degree of confidence towards the national authorities (“on a 0–10 scale, how much confidence do you place in the authorities to manage the health and economic crisis due to COVID-19?”). Part 2 was the DCE, which contained an introduction describing the context of choices (namely, a post-lockdown situation, and non-availability of an effective treatment or vaccine), followed by the six random choice tasks.

The study protocol received internal clearance and the database was registered by Institut Pasteur according to the GRDP regulation. Participants saw a complete study information and had to agree to participate before starting the questionnaire. Study participation was entirely anonymous.

Econometric modeling

Analysis of individual preferences

The choice data were analyzed within a random utility maximization framework, i.e., assuming a random utility function

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1 We did not plan to estimate an interaction effect between levels of the ICU overload attribute and the level 1 of the targeted lockdown attribute (“no targeted lockdown”), because at the time of the survey, the absence of targeted lockdown was not considered as a particularly lenient measure, but rather the default.
for each hypothetical scenario (including a systematic and unobserved portion of utility) and assuming utility maximization decision rule [19]. We used a mixed multinomial logit (MIXL) model specification, allowing the preference parameters to be randomly distributed across the sample and thus accounting for (i) unobserved preference heterogeneity and (ii) correlation of choices between participants [20]. The main utility function was specified as follows:

\[
U_{njt} = \alpha_n + \beta_{1,n} \text{Closure}_{2,j} + \beta_{2,n} \text{Closure}_{3,j} + \beta_{3,n} \text{Lockdown}_{j} + \beta_{4,n} \text{School}_{2,j} + \beta_{5,n} \text{School}_{3,j} + \beta_{6,n} \text{SelfIsolation}_{2,j} + \beta_{7,n} \text{SelfIsolation}_{3,j} + \beta_{8,n} \text{ICUoverload}_{2,j} + \beta_{9,n} \text{ICUoverload}_{3,j} + \varepsilon_{njt}
\]

where \(U_{njt}\) is the utility individual \(n\) derives from choosing alternative (scenario) \(j\) in choice situation \(t\). \(\text{Closure}_{2,j}, \ldots, \text{ICUoverload}_{3,j}\) represent dummy coded attributes’ levels displayed in scenario \(j\) (level 1 of all attributes was used as reference), \(\beta_{1,n}, \ldots, \beta_{9,n}\) are the respective random effects (part-worth utilities) associated with each attribute level (compared with the reference), the subscript \(n\) denoting respondent-specific parameters. We also added an alternative specific constant (ASC) for option A (ASC\(_{\text{optionA}}\)) with \(\alpha_n\), the associated random coefficient representing the propensity to select option A vs. option B, irrespectively of attributes’ levels values. Finally, \(\varepsilon_{njt}\) is the error term assumed extreme value type 1 distributed, thus leading to the multinomial logit choice specification [19].

We estimated a MIXL (using 500 Halton draws) with correlated random coefficients between all nine attributes’ levels (and the ASC), assuming normal distribution for each parameter \(\alpha_n\) and \(\beta_{k,n}\). Though particularly computationally intensive, this model is known to be most flexible [12]. In particular, it allows accounting for scale heterogeneity, i.e., various degrees of consistency of decisions across respondents [11].

### Analysis of preference heterogeneity

To model observed preference heterogeneity, we predicted individual-level coefficients from the MIXL model (i.e., \(\hat{\beta}_{k,n}, k = 1, \ldots, 9\)) using the methodology detailed in [25]. Second, we analyzed the determinants of each \(\hat{\beta}_{k,n}\) by estimating multivariate seemingly unrelated regressions (SURE) allowing for the unobserved determinants of each part-worth utility coefficient to be correlated. We estimated two SURE models: one model including the four ‘moderately’ severe restriction measures (i.e., level 2 of all attributes, see Table 1), the second model including the five ‘highly’ severe restriction measures (i.e., level 3 of all attributes). In each model, we included individual socio-demographic characteristics (e.g., age, gender, region of residence, education level, having a dependent child, subjective deprivation) as well as perception variables (feeling at risk for severe COVID-19, confidence level in disease management) to explain preferences.
Simulation of welfare impacts of alternative epidemic management strategies

Based on the resulting individual coefficients \( \hat{\beta}_{k,n} \) estimated from Eq. (1), we simulated the overall effect of alternative epidemic management strategies in terms of welfare gains (utility increases) or losses (utility decrease).

We defined a baseline scenario, similar to the situation in France at the time of the survey in November 2020 (after the “second wave” occurred and during the second lockdown), combining the following attributes’ levels: (i) closure of public spaces but not transport or offices, (ii) no targeted lockdown, (iii) all high school teaching on-site, (iv) information campaign on COVID-19 risk factors, (v) need to postpone elective surgery (baseline scenario). Then, we defined six alternative scenarios that varied in the levels of restriction for the four non-ICU-related attributes, with the less restrictive measures to overcome ICU overload (increase health care workforce). We aimed to simulate the welfare gains or losses of various strategies aiming at reducing hospital overload to a lower level.

- Maximal homogeneous scenario 1: highest levels of restrictions for all non-ICU-related attributes. This scenario must be expected to have higher effectiveness than scenarios 2–6 and does not put more constraint on one target group.
- Alternative focused scenario 2,3,4,5: highest levels of restriction for one attribute, and moderate level for the others, thus putting more constraint on one target group.
- Minimal homogeneous scenario 6: moderate levels of restrictions for all non-ICU-related attributes. This scenario must be expected to have lower effectiveness than scenarios 2–5 and 1, and does not put more constraint on one target group.

It is difficult to evaluate health outcomes of different epidemic control measures. However, based on the recent experiences in countries around the world, modeling studies have estimated the effectiveness of several measures (including school closure or public spaces closure) based on their capacity to reduce the frequency of contacts or risk of transmission given a contact [21]. If Sars-CoV-2 elimination is not feasible due to intensive transmission from asymptomatic persons, it appears that stricter control measures lead to lower transmission rates, with the gain of lower peak occupation of ICU beds, thus providing a rationale for the six proposed alternative strategies.

The welfare gains and losses of these alternative management strategies were first evaluated by computing the average utility variation between each fictive scenario and the baseline scenario. Second, by predicting the proportion of respondents with positive utility variation.

Sensitivity analyses

Use of decision heuristics

In stated preferences surveys, it is often the case that respondents may use decision heuristics or mental shortcuts to facilitate the decision process [4, 8]. Even flexible models (e.g., correlated MIXL models) may not be able to capture such behaviors. To analyse the robustness of our results, we re-estimated Eq. (1) by excluding respondents employing simplified (deterministic) lexicographic decision rules, i.e., when their choices could be explained only by the variation of one dominant attribute [5]. Such individuals were defined as those always choosing the scenario presenting the most favorable level of one attribute. We hypothesized that two attributes could dominate the decision-making and lead to lexicographic preferences: (i) the restriction measures on economic and social life, and (ii) the measures to overcome ICU overload. Indeed, these two attributes represent the trade-off that has been constantly put in front of the public debate after the first wave of COVID-19 epidemic. Besides, the two attributes were always, respectively, in first and last position of the choice tasks. Previous work suggested that attributes either ranked first [1] or last [13] could be more considered [29].

Low engagement in choice tasks

Choice certainty scales have been used in previous DCE applications with the aim to improve the precision and accuracy of DCE-based welfare estimates [17, 23]. Researchers have assumed that higher level of certainty indicated higher reliability, and more consistent choices. The most widely used technique to incorporate this information into choice models has been the scaling approach (see [24] for a literature review on the subject). The scaling approach consists in including choice certainty as a parameter of the scale function of an heteroskedastic multinomial logit model to down-weight uncertain responses. But this approach has two limitations. First, it has been shown that variability in choice certainty is also very important to identify thoughtful and deliberate respondents [24]. Second, the scaling approach assume homogenous preferences, whereas certainty variability and preference heterogeneity can be confounded. Following the framework defined by Regier et al. [24], we used information about mean choice certainty and certainty variability to identify more thoughtful respondents. We identified thoughtful respondents as those (1) being sufficiently certain of their choices (i.e., having a mean choice certainty > 5), and (2) having sufficient certainty variability. Indeed, Regier et al. [24] have shown that respondents with either low mean certainty or low certainty variability (or
both) exhibit lower response ‘quality’ as defined by the more frequent use of decision heuristics (such as serial non-trading or non-demanding behavior), more frequent deviations from monotonic preferences, lower interval validity and/or choice consistency. Estimation of heteroskedastic multinomial logit models on our data confirmed that respondents with either low certainty (<5) or no certainty variability had lower choice consistency (results not shown but available upon request). We thus re-estimated Eq. (1) by first excluding individuals with an average certainty <5, and second excluding individuals with no certainty variability. Though excluding these individuals may lead to a selection bias, it is qualitatively similar as down-weighting less thoughtful respondents in scaled multinomial logit models, but with the advantage of incorporating heterogeneity in preferences. Indeed, it is not possible to allow for both variability in scale and variability in preferences, because scale and preference heterogeneity cannot be distinguished in discrete choice models [11].

Non-linear utility function

As explained in “Experimental design” (Design), we suspected negative interaction effects suggesting disutility for laxist or ‘too lenient’ policies. We thus estimated a second model including pre-specified interactions between attributes, using the following specification:

\[
U_{njt} = \sum_{l=1}^{13} \beta_{kn} \text{Level}_{lj} + \beta_{10} \text{Closure}_{ij} \ast \text{ICUoverload}_{2j} + \beta_{11} \text{Closure}_{ij} \ast \text{ICUoverload}_{3j} + \beta_{12} \text{School}_{ij} \ast \text{ICUoverload}_{3j} + \beta_{13} \text{SelfIsolation}_{ij} \ast \text{ICUoverload}_{3j} + \epsilon_{njt}
\]

where Level\_l denotes a generic dummy indicator for each main attributes’ levels (nine parameters, see Eq. (1)), Closure\_{ij} \ast ICUoverload\_{2j}, …, SelfIsolation\_{ij} \ast ICUoverload\_{3j} denote the interaction effects between, e.g., “no generalized closure measure” (Closure\_{ij}) and “need to postpone elective surgery” (ICUoverload_{2j}), with \( \beta_{10}, …, \beta_{13} \) the associated (fixed) coefficients, and \( j \) indicates the choice task. We expected negative values for \( \beta_{10}, …, \beta_{13} \).

Results

Sample description

Our sample consists of 908 French citizens, aged 18 years old and over. To assess whether our sample was representative of the French population in terms of standard sociodemographic variables (i.e., age, gender, geographical location, education), we performed two-sided equality of proportion tests (assuming exact Bernoulli distribution for all binary variables) comparing our sample estimates from those of the Institut National de la Statistique et des Etudes Economiques (INSEE)—the French public statistics institute—when available (see Table 2). We confirm that our sample was representative in terms of age structure: for instance, 19.8% were aged between 18 and 29 years (vs. 20% in France) and 25.7% were >60 years old (vs. 26% in France). Our sample is also representative in terms of gender (48.8% were males, vs. 49% in France) and geographical location (e.g., 19.1 vs. 19.0% lived in Ile-de-France, 22.4 vs. 23.0% lived in North–West). However, our sample was more educated than the French 18–75 years population: 24.2% had an educational level below French baccalauréate (high school diploma, vs. 43.8% in French, \( p = 0.0065 \)), and 30.9% had second stage of tertiary education or higher (i.e., >2 years after high school, vs. 23.6% in France, \( p = 0.0391 \)). Besides, 11% felt subjectively deprived, 9% declared having a close relative in a nursing home, 14% declared having had the COVID-19 disease themselves (or knew a close relative who got it), 30% stating having a risk factor for severe COVID-19. The proportion of respondents reporting a confidence level of 0–3 (low), 4–6 (medium), or 7–10 (high) in the authorities to manage the health and economic crisis due to COVID-19 were, respectively, 32%, 33% and 36% (Table 2). Note that despite no national representative figures exist for these questions, our sample esti-

2 See, for instance, https://www.statista.com/statistics/1107643/covid-19-trust-government-france/ (last accessed, January 26, 2022).
measures being equal, respondents’ likelihood to choose one scenario over the other increased with these measures (relatively to the reference). Two epidemic control measures generated significant disutility: need to postpone elective surgery to overcome the risk of ICU overload (average $\beta = -0.477$) and need to postpone elective surgery and evacuate patients to other countries or regions (average $\beta = -0.553$). Finally, there was no systematic propensity to choose option A vs. option B ($\beta_{\text{optionA}} = 0.053$), but significant heterogeneity in this propensity (standard deviation = 0.89, $p < 0.001$).

Significant preference heterogeneity for all attributes’ levels was observed, with statistically significant standard deviations of the underlying normal random effects (Table 3).
The three measures that generated highest preference heterogeneity were the closure of public spaces (+ transport and office; standard deviation = 4.42), home schooling at school for 2 months (SD = 2.59) and the closure of public spaces (standard deviation = 1.56).

Analysis of preference heterogeneity and their determinants

Graphical distribution of the predicted individual-level coefficients ($\beta_{kn}$) (Fig. 3, panel A and panel B) confirm significant variability in preferences for the various control measures. For all measures, a fraction of estimated individual part-worth utilities had opposite sign from the average values presented in Table 3. In detail, the proportions of respondents with predicted negative utility for the more restrictive measures was as follows: closure of public spaces (38%), closure of public spaces + transport and office (47%), targeted lockdown for sectors with high incidence levels (32%), homeschooling for 2 weeks (23%), homeschooling for 2 months (39%), and medically prescribed self-isolation with limited visits in nursing homes (29%). The majority of respondents (90%) had negative predicted utility for the two measures to overcome the risk of ICU overload (Fig. 3).

Only three individual characteristics were significantly associated with lower (or higher) utility for the ‘moderately’ severe restriction measures (Table 4) or ‘highly’ severe restriction measures (Table 5). Respondents declaring having a close relative in a nursing home experienced relatively lower utility for the “need to postpone elective surgery” measure and “need to postpone elective surgery & patient evacuation”. Respondents stating they have a risk factor for severe COVID-19 risk had relatively higher utility for all measures, except the “need to postpone elective surgery”. Finally, individuals stating high confidence level (7+) in disease management by the authorities also had higher utility for “closure of public spaces” (including transport and office), and “need to postpone elective surgery” (including patient evacuation). Note that the conclusions did not change when (i) using univariate SURE models, (ii) including additional information of working situation for individuals in the labor market such as the type of work (salaried or self-employed) or the sector of activity (e.g., industry, tourism, food, healthcare, sport, culture).

Results of policy simulations

Compared to the baseline scenario that was expected to prevail in November 2020, the six alternative strategies generated positive welfare gains (increased mean utility) by avoiding the need to postpone surgery, at the expense of stricter control measures (Table 6). The distribution of the individual welfare gains or losses for each alternative policy scenario is displayed in Fig. 4. Scenario 1 generated most heterogeneous welfare variations, and scenario 6, most homogenous welfare variations (Fig. 4).

The most restrictive, but homogeneous scenario 1 generated the highest average welfare gains (+ 1.12 mean utility), but only 70% [95% CI (67–73%)] of the sample experienced a welfare increase compared to the baseline situation (Table 6). The minimal homogeneous scenario 6 generated a relatively low welfare gain (+0.76 mean utility) but increased welfare for 87% [95% CI [85–90%]] of the sample.

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**Table 3** Results of the mixed logit (MIXL) model with correlated random coefficients ($N$ = 908)

| Attributes levels | Mean | SD |
|-------------------|------|----|
| ASC: option 1     | 0.053 (0.063) | 0.896*** (0.175) |
| Closure of public spaces | 0.208** (0.091) | 1.555*** (0.396) |
| Closure of public spaces (+ transport and office) | 0.106 (0.139) | 4.4259*** (0.885) |
| Targeted lockdown for sectors with high incidence | 0.378*** (0.082) | 1.019*** (0.229) |
| Home schooling at high school for 2 weeks | 0.439*** (0.092) | 0.639*** (0.226) |
| Home schooling at high school for 2 months | 0.314*** (0.111) | 2.588*** (0.570) |
| Medically prescribed self-isolation (SI) | 0.032 (0.074) | 0.531** (0.237) |
| Medically prescribed SI+ restrictions for visits in nursing homes | 0.377*** (0.096) | 0.965*** (0.269) |
| Need to postpone elective surgery | -0.477*** (0.112) | 0.823** (0.336) |
| Need to postpone surgery + patient evacuation | -0.553*** (0.155) | 1.009*** (0.523) |

N (individuals) 908
Choice observations 5448
Log-likelihood −3520.3575

Statistical significance: ***: 1%; **: 5%; *: 10%
Among the alternative focused scenarios (scenarios 2 to 5), scenarios 3 and 5 increased welfare for more than 80% of the sample while achieving high gain in mean utility: 85% [95% CI (82–87%)] and +1.03 mean utility for scenario 3 (targeted lockdown), 86% [95% CI (84–88%)] and +1.00 for scenario 5 (medically prescribed self-isolation plus restrictions in nursing homes). In the scenario 2 and 4, increase in mean utility and the sample fraction with welfare increase were low: 74% [71–77%], +0.65 mean utility for scenario 2 (highest restrictions on public spaces) and 74% [(95% CI (71–77%)), +0.68 mean utility for scenario 4 (highest restrictions on schooling). Complementary analyses showed that welfare variations were not explained by individual

Fig. 3 Distribution of individual-level coefficients derived from the correlated mixed logit model (MIXL)

Panel A – Moderately severe restriction measures

Panel B – Highly severe restriction measures
characteristics (e.g., gender, age, education, working-related variables) at the 5% level.  

### Results of sensitivity analyses

#### Decision heuristics or choice certainty

Only 11 individuals (1.21%) always chose the scenario with the less restrictive measures to overcome the risk of ICU overload (decision heuristic ‘ICU overload’) and only 1 individual always chose the scenario with the lowest restrictions on economic and social life. In terms of decision certainty, 12.65% of individuals were classified as insufficiently certain (mean certainty < 5), and 22.25% did not vary in their certainty. We replicated the main analyses by excluding individuals who exhibited either issue of decision heuristic, low certainty, or no certainty variability (Online resource Appendix C, Table C.1). Results of policy simulations were unaffected by these subgroups analyses. For instance, the share of respondents having positive utility variation for scenario 1 varied from 69% (no decision heuristics)
Table 5  Seemingly unrelated regression of the determinants of individual part-worth utilities for ‘highly’ severe restriction measures

| Attribute level | Closure of public spaces, transport and office | Targeted lockdown | Homeschooling at high school for 2 months | Self-Isolation, restriction for visits in nursing homes | Need to postpone elective surgery and patient evacuation |
|-----------------|-----------------------------------------------|------------------|------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| Age             |                                               |                  |                                          |                                                     |                                                     |
| 18–29 years     | −0.007 (0.118)                                | −0.037 (0.061)   | 0.074 (0.076)                            | −0.036 (0.047)                                      | −0.031 (0.036)                                      |
| 30–49 years     | Ref                                           | Ref              | Ref                                      | Ref                                                 | Ref                                                 |
| 50–64 years     | 0.015 (0.106)                                 | −0.012 (0.055)   | 0.031 (0.069)                            | 0                                                   | 0.025 (0.033)                                      |
| 65 years+       | −0.058 (0.142)                                | −0.054 (0.074)   | −0.004 (0.092)                           | −0.071 (0.056)                                      | −0.025 (0.044)                                      |
| Sex: Male       | 0.038 (0.08)                                  | 0.013 (0.041)    | 0.053 (0.051)                            | 0.004 (0.032)                                       | −0.028 (0.024)                                      |
| Size of municipality of residence | Ref                                           | Ref              |                                           |                                                     |                                                     |
| Rural area (ref: < 2000 inhabitants) | Ref                                           | Ref              |                                           |                                                     |                                                     |
| 2000–20,000 inhab | −0.021 (0.111)                                | 0.013 (0.058)    | −0.025 (0.072)                           | −0.029 (0.044)                                      | −0.032 (0.034)                                      |
| 20,000–100,000 inhab | −0.029 (0.116)                               | −0.044 (0.061)  | −0.097 (0.075)                           | −0.064 (0.046)                                      | −0.011 (0.036)                                      |
| > 100,000 inhab  | −0.105 (0.126)                                | −0.026 (0.066)   | −0.034 (0.082)                           | −0.018 (0.05)                                       | 0.013 (0.039)                                       |
| Region          |                                               |                  |                                          |                                                     |                                                     |
| Ile-de-France   |                                               |                  |                                          |                                                     |                                                     |
| North–East      | −0.03 (0.13)                                  | 0.053 (0.067)    | 0.109 (0.084)                            | 0.074 (0.051)                                       | −0.013 (0.04)                                       |
| North–West      | −0.225* (0.131)                               | −0.072 (0.068)   | 0.024 (0.084)                            | 0.015 (0.052)                                       | −0.058 (0.04)                                       |
| South–East      | −0.045 (0.124)                                | 0.044 (0.065)    | 0.111 (0.08)                             | 0.053 (0.049)                                       | −0.080** (0.038)                                     |
| South–West      | 0.05 (0.156)                                  | 0.093 (0.081)    | 0.167* (0.1)                             | 0.085 (0.062)                                       | −0.072 (0.048)                                      |
| Education (ref: lower than French baccalaureate) |                                               |                  |                                          |                                                     |                                                     |
| Baccalaureate level | −0.061 (0.117)                                | −0.037 (0.061)   | 0.032 (0.075)                            | −0.001 (0.046)                                      | 0.015 (0.036)                                       |
| 2 years after baccalaureate | −0.066 (0.12)                                | −0.034 (0.062)   | −0.02 (0.077)                            | −0.037 (0.047)                                      | 0.011 (0.037)                                       |
| ≥ 3 years after baccalaureate | −0.159 (0.113)                               | −0.057 (0.059)   | 0.033 (0.073)                            | −0.015 (0.045)                                      | −0.015 (0.035)                                      |
| Subjective deprivation | −0.052 (0.127)                               | −0.007 (0.066)   | −0.012 (0.082)                           | 0.000 (0.051)                                       | −0.012 (0.039)                                      |
| Having a dependent child | 0.132 (0.093)                                | 0.007 (0.048)    | −0.008 (0.06)                            | −0.018 (0.037)                                      | 0.019 (0.028)                                       |
| Having a close relative in nursing home | −0.095 (0.142)                               | 0.001 (0.074)    | 0.064 (0.091)                            | 0.018 (0.056)                                       | −0.094** (0.043)                                     |
| Experience of Covid-19 (personal or among relatives) | 0.196* (0.117)                               | 0.068 (0.061)    | 0.099 (0.075)                            | 0.025 (0.046)                                       | 0.015 (0.036)                                       |
| Believing having a risk factor for severe Covid-19 | 0.270*** (0.092)                             | 0.154*** (0.048) | 0.131** (0.039)                          | 0.105*** (0.036)                                     | −0.015 (0.028)                                      |
| Confidence level in crisis management |                                               |                  |                                          |                                                     |                                                     |
| Low (0–3)       |                                               |                  |                                          |                                                     |                                                     |
| Moderate (4–6)  | 0.153 (0.099)                                 | 0.053 (0.052)    | −0.045 (0.064)                           | 0.038 (0.039)                                       | 0.081*** (0.03)                                     |
| High (7+)       | 0.264*** (0.097)                              | 0.097* (0.051)   | −0.024 (0.063)                           | 0.055 (0.039)                                       | 0.105*** (0.03)                                     |
| Constant        | −0.555 (0.341)                                | 0.009 (0.177)    | −0.218 (0.22)                            | 0.1 (0.135)                                         | −0.326*** (0.104)                                     |

Regression results on individual-level parameters predicted from MIXL model with correlated random parameters

Statistical significance: ***: 1%; **: 5%; *: 10%
to 71% (varying certainty). No statistically significant differences were found when comparing 95% confidence intervals in these subgroups compared to the total sample.

**Estimation of non-linear utility function (interactions)** Results of the interaction models (Online resource Appendix C.2) do not confirm our assumption that respondents may experience disutility from too “lenient” policies. First, none of the interaction coefficients were significant at the 5% level. Note that only the interaction between ‘all teaching in site’ and ‘need to postpone surgery + patient evacuation’ was close to be significant at the 10% level. The log-likelihood only increased by 3 points (compared to the non-interaction model), thus confirming the absence of model fit improvement, and appropriateness of the main effects model.

**Discussion**

In this stated preferences study, we contribute to the debate about the “social acceptability” of COVID-19 control measures, by describing French citizens’ preferences...
for various epidemic control measures, to inform longer-term strategies and future epidemics. We used a DCE in a large representative sample of French adults to quantify the trade-offs adults were willing to make between restrictions on the social, cultural, and economic life, school closing, targeted lockdown of high-incidence areas, constraints to directly protect vulnerable persons, and reduction in the risk of hospital overload. Our results show that some trade-offs exist to avoid overload of hospitals and intensive care units: (i) closure of public spaces if this did not imply restrictions on public transport and access to offices, (ii) targeted local lockdown even if it creates unequal treatments, (iii) school closure for short to medium term period, even if they can break the learning process of adolescents, (iv) self-isolation of high-risk groups if combined with restrictions in access to nursing homes. The willingness to accept restrictions was shared to a large extent across subgroups according to age, gender, vulnerability to the COVID-19 epidemic, and other socio-demographic or socio-economic variables. However, it appears that individuals who feel at greater risk from COVID-19, and individuals with high confidence in the governmental management of the health and economic crisis, more easily accept all these restrictions. The impact of these variables can be explained in two ways. First, individuals with higher COVID-19 risk perception would be more worse off if they get infected while ICU are overload. Second, most respondents (at least those experiencing positive utilities for stricter control measures) may have been rationalizing that more severe restrictions would result in lower infection rates (thus lower probability to get infected) independently of the effects on ICU overload. Similarly, the fact that respondents may have inferred how well the approaches could control the COVID-19 epidemic may explain the positive influence of confidence in disease management on utilities derived from restrictive measures.

One important question was whether preferences would be highly specific to subgroups (e.g., parents refusing homeschooling, high-risk groups refusing self-isolation) or shared. Our results suggest highly shared preferences beyond individual interests. Significant heterogeneity was found in preferences in mixed logit models, and most of this heterogeneity remained unobserved. We further tried to investigate the drivers of preference heterogeneity using latent class analyses (results not reported but available upon request). Latent class models allowed to confirm high heterogeneity in preferences, with a share of respondents (about 45%) experiencing disutilities for nearly all measures, and others.
experiencing positive utility for control measures, except for the ICU overload attribute. The individual determinants of variations in sensitivities (i.e., of class membership probability) were not different from those reported in the paper based on a continuous representation of preference heterogeneity.

Little evidence is available on preferences around epidemic control measures [3, 14], and this paper contributes to this emerging literature. The closest element in the literature is a DCE conducted in France at the end of the first lockdown, which focused on generally applicable measures such as wearing masks, travel limitation, and digital tracking [3]. Substantial differences were observed only for young adults with particular disutility from the extension of lockdown, digital tracking, and highest preference for financial compensation. Disutility from mandatory tracing and quarantine from the elderly was observed among German citizens, with almost equal weight given to these attributes’ levels compared to utility from sufficient available ICU capacities [14]. Note that the context under which the choice were elicited in Blayac et al. [3] was different compared to our study. The second lockdown in France was less restrictive than the first, and in November 2020, some preliminary work suggested the effectiveness on non-pharmaceutical interventions in containing the epidemic, while at the same time the incidence of new infections was still high. This could have improved the acceptability of these interventions.

Our study faces three main limitations. First, preference estimates and simulations of alternative epidemic management strategies are based on the assumption of stable intrinsic preferences for all control measures. It is, however, likely that these preferences may have varied in time along with the epidemic evolution, and lassitude generated by repeated lockdown and the absence of clear strategy (as well as organizational difficulties). Second, we cannot exclude a framing or contextual effect. Our study took place during the second lockdown in France, including restriction measures taken to avoid hospital overload. The trade-offs elicited in our DCE may thus suffer from this framing, with more weight given to sanitary outcomes. Besides, our DCE survey was developed to study preferences in the perspective of avoiding a general lockdown, and in a context where vaccination was not available. The trade-offs could be different when effective vaccination against severe disease is available. However, similar situations may occur in the future in case of seasonal epidemic resurgence, vaccine-escape variants or other emerging diseases. Future studies should thus consider these aspects to produce estimates that more closely match the current situation. In particular, the prevalence of vaccinated subjects and/or the effectiveness of vaccination (in the presence of SARS-CoV-2 mutations) should be included as additional attributes or contextual factors. Note also that the simulation of welfare gains or losses was based on the estimation of a linear in attributes utility function.

More complex utility functions could have been used, e.g., including two ways interactions between attributes. However, we did not find any significant interactions between attributes, so we can conclude that linear utility function was appropriate for this study.

Third, our experiment faces two methodological issues. In the design construction, we assumed negative preferences parameters for the non-ICU attributes, whereas positive part-worth utilities were estimated. This could have resulted in a lack of efficiency of our design. Second, our recruitment method (online survey based on an internet panel) may suffer from selection bias, as we found that respondents tended to be more educated than the general French population. Thus caution is needed before generalizing our results to the entire 18 years and over French population. Besides, the choice experiment was likely difficult for some individuals because of the complexity of trade-offs involving uncertain outcomes. Yet we showed that our results remained robust in the presence of individuals with either lexicographic preferences, low certainty [7], or no certainty variability, potentially less engaged in the choice exercise [24]. However, we used a rather simple “deterministic” conception of lexicographic preferences, based on the analysis of a single attribute deemed dominant, instead of using a more comprehensive modeling of possible decision heuristics [10].

Conclusion

Public policies around complex problems can be tailored and thus optimized based on evidence of the preferences of the population and their trade-offs. In this respect, we simulated the acceptance of various management strategies for control of the epidemic in France from autumn 2020 to summer 2021. In particular, our results suggest we showed that among the alternative scenarios decreasing the risk of ICU overload, the one close to a targeted lockdown as well as the one with medically prescribed self-isolation and with restrictions in nursing homes increased welfare for more than 85% of the sample (compared with a situation with potential ICU overload issue) while achieving high gain in average utility. In other words, in a situation without available pharmaceutical treatment or prevention, and pressure on hospitals due to increased number of ICU admission, French citizens would be likely to accept the above-mentioned epidemic control measures. The scenarios with the strongest restrictions on public spaces or highest restrictions on schooling generated the lowest increase in the average utility. Beyond the current Sars-CoV-2 epidemic, this information will be important to optimize control measure protocols for epidemic and pandemic preparedness.
Supplementary Information The online content contains supplemental material available at https://doi.org/10.1007/s10198-022-01454-w.

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