COVID-19 Vaccine Hesitancy in Eight European Countries: Prevalence, Determinants and Heterogeneity

Janina Steinert (janina.steinert@tum.de)
Technical University of Munich https://orcid.org/0000-0001-7120-0075

Henrike Sternberg
Technical University of Munich

Hannah Prince
Technical University of Munich

Barbara Fasolo
London School of Economics and Political Science

Matteo Galizzi
London School of Economics and Political Science

Tim Büthe
Technical University of Munich

Giuseppe Veltri
University of Trento https://orcid.org/0000-0002-9472-2236

Article

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Abstract

Vaccine hesitancy poses a major obstacle to containing COVID-19. Previous experimental studies of communication strategies for promoting COVID-19 vaccine uptake have been conducted in a single country each, often testing strategies that have differed from those studied in other countries. On the few occasions when two or more single-country studies have tested similar treatments, they have yielded inconsistent findings. For example, highlighting pro-social benefits increased participants' willingness to get vaccinated in the UK and the US, but had no effect in France and the UK, thus calling into question the often implied generalisability of previous findings. We experimentally assess the effectiveness of different information treatments across eight European countries and examine heterogeneity in the willingness to get vaccinated against COVID-19, as well as in the perceptions of the different vaccines available, within and across countries. We reveal striking differences in COVID-19 vaccine hesitancy across countries, ranging from 5.5% of the adult population in Spain to 50.94% in Bulgaria. The main barriers to vaccine acceptance were fears regarding the quality and safety of the vaccines, as well as mistrust in government. Receiving information emphasising (i) COVID-19 risk reduction through vaccination, (ii) non-medical benefits of a vaccination certificate, and (iii) hedonistic benefits significantly increases vaccination willingness in Germany, but only the vaccination certificate message significantly increases willingness in the UK. No information treatment has significant effects in any other country. A machine-learning technique, model-based recursive partitioning, reveals that the effectiveness of some information treatments is highly heterogeneous among subsets of the population, with adverse effects for Spanish, German and Italian participants without active employment. The heterogeneity of vaccine hesitancy and responses to different messages suggests that health authorities should avoid one-size-fits-all messages and instead tailor vaccination campaigns to their specific target populations, with special care to more disadvantaged populations.

Introduction

Vaccination is a highly effective public health tool that has substantially reduced the global burden of infectious diseases.[9–11] Estimates suggest that mass immunisation has contributed to a 55% decline in the mortality of children under five years of age since 1990.[12] Between 2010 and 2015 alone, vaccination campaigns helped prevent ten million deaths globally.[13] Similarly, vaccines against COVID-19 provide a vital instrument to help fight the pandemic – with both economic and health system advantages over non-pharmaceutical interventions.

However, vaccine hesitancy – the choice of delaying or refusing available vaccines – poses a major obstacle to the effectiveness of ongoing COVID-19 immunisation programmes.[1,10,14] Already prior to the pandemic, the World Health Organisation has declared vaccine hesitancy as "top 10 health threat",[15] evidenced by a resurgence in measles outbreaks as well as an increase in the prevalence of other vaccine-preventable diseases.[9,10,13,16] Controlling the spread of COVID-19 will require achieving herd immunity through vaccination. The required threshold for herd immunity depends on multiple disease-

and vaccine-specific parameters, but recent modelling studies suggest that – in light of more contagious variants – public vaccination rates may need to be as high as 90%.[11,17] Two systematic reviews of opinion poll data revealed that COVID-19 vaccine acceptance rates currently do not exceed 70% in most countries[18,19] – well below the required threshold.

A better understanding of vaccine hesitancy and its determinants is therefore paramount, not only for combating the current pandemic, but also for ensuring sufficient uptake of COVID-19 booster vaccination in the coming year(s) and for promoting pandemic preparedness in the future. In addition, effective public health campaigns to promote vaccine acceptance across hesitant population segments are urgently needed. Recent experimental studies in several European countries and the US have tested the effectiveness of different communication strategies for addressing vaccine hesitancy. While evidence on the general effectiveness of such strategies is mixed, several messages have significantly increased the reported vaccine uptake, at least in some countries, including those that emphasised (1) altruistic motives,[1] (2) the efficacy and safety of COVID-19 vaccines,[3,4,6] or (3) the collective medical and non-medical benefits of mass vaccination.[2] However, evidence regarding the effectiveness of different information treatments *across* countries remains scarce. In addition, we lack an understanding of what explains the variability in the results of previous studies.

To address these gaps in the existing knowledge, we aim, first, to identify the level of COVID-19 vaccine hesitancy across eight European countries, including public perceptions of the four COVID-19 vaccines currently available in the European Union and the UK. Second, we seek to uncover determinants of vaccine hesitancy through a mix of quantitative and qualitative analyses to understand the fears and concerns driving vaccine hesitancy. Third, using randomised controlled survey experiments, we test the effectiveness of different information treatments in increasing the willingness to receive COVID-19 vaccines. Fourth, we aim to gain a more nuanced understanding of different reactions to such messages through machine learning analysis of heterogeneity. Taken together, our findings provide crucial insights for the design and targeting of COVID-19 vaccination campaigns in Europe – and possibly beyond.

Results

Prevalence and Determinants of Hesitancy

A total of 11,860 vaccinated and 10,122 unvaccinated participants across eight countries were recruited between 8 April and 2 July 2021. The prevalence of COVID-19 vaccine hesitancy disaggregated by participants' gender is presented in *Figure 1* (for further detail, see *Figures S5-S7 & S11-S14*). These estimates are based on the full sample of 21,982 respondents, i.e. including those who had already received one or two vaccine shots and who were coded as not hesitant, and were screened out of the survey after collecting their key sociodemographic characteristics.

[Please show Figure 1 about here]

The estimates point to considerable heterogeneity across countries. COVID-19 vaccine hesitancy was lowest in Spain, with 5·86% (95% CI 0·05-0·07) of women and 5·19% (95% CI 0·04-0·06) of men hesitant to receive the COVID-19 vaccine, compared to Bulgaria, showing the highest rates with 55·16% (95% CI 0·52-0·59) of women and 46·87% (95% CI 0·43-0·50) of men hesitant. Across countries, men were less skeptical of the COVID-19 vaccine compared to women.

Unvaccinated participants who indicated that they would only intend to get vaccinated with vaccines of a certain type were asked to specify which vaccines they would accept (see *Figure 2 and Figures S8-S10*). Across countries, vaccine-specific willingness to get vaccinated was highest for the BioNTech/Pfizer vaccine, ranging from 57·09% (95% CI 0·51-0·63) of respondents in Poland, to 93·17% (95% CI 0·92-0·95) in Germany. While overall acceptance of the viral vector vaccines was consistently lower than it was for the mRNA vaccines, we did observe substantial differences in the perceptions surrounding the AstraZeneca vaccine. Notably, 31·92% (95% CI 0·26-0·38) of the conditionally willing respondents in the UK indicated that they would accept this vaccine, compared to only 2·6% (95% CI 0·02-0·04) in Germany.

[Please show Figure 2 about here]

A summary of the sociodemographic characteristics of the unvaccinated participants who completed the full survey and participated in the survey experiment is provided in *Table S1*, including a breakdown by target country. To understand the sample composition further, we provide additional information about the COVID-19 vaccination rate in each target country by age group at the time of data collection (see supplementary *Table S2*) as well as census information on gender, age, and education (see *Table S3*).

Findings from multivariate logistic regression analyses assessing demographic factors associated with vaccine hesitancy are summarised in *Table S4.* With the exception of Spain, Sweden, and Poland, women were significantly more hesitant towards COVID-19 vaccines than men. In most countries, vaccine hesitancy was significantly higher in older age groups (ranging from OR=1·12, 59% CI 1·02- 1·24, p<0·01 in Poland to OR=1·67, 95% CI 1·48 - 1·89, p<0·001 in Sweden and the UK). The trend was reversed in Germany, with a significant decrease in vaccine hesitancy among older age groups (OR=0·80, 95% CI 0·75 - 0·85, p<0·001). These differences are most likely a result of age-based priority access to vaccinations as well as variation in the timing of our surveys. Specifically, while the German survey was launched earlier and the sample of unvaccinated participants is thus less biased (given that only around 25% of the population had received a COVID-19 vaccine by then, see *Table S2*), the samples of unvaccinated participants in other countries may over-represent vaccine-hesitant individuals in the older age groups as those willing had likely already received their vaccination at that point in time. This explanation is further supported by the differential representation of older participants in Germany compared to the other countries (above-65-year-old participants account for around 16% of the German sample, but for less than 2% in all other countries' samples).

In some countries, vaccine hesitancy was significantly associated with lower education. In Germany, for instance, the predicted probability of refusing the COVID-19 vaccine was 45·07% (95% CI 39·95-50·20 %,

p<0·001) for participants who had not completed secondary education, compared to 15·89% (95% CI 12·98-18·79 %, p<0·001) for participants who held a university degree, all else equal. Participants who were employed reported significantly lower levels of COVID-19 vaccine hesitancy in Spain and in Sweden (OR= 0·56, 95% CI 0·39 – 0·80, p<0·001, OR= 0·62, 95% CI 0·45-0·86, p<0·001, respectively), whereas respondents' employment status did not significantly affect vaccine hesitancy in any other country.

Participants' motives and reasons for their vaccine hesitancy, elicited from their free-text statements, can be grouped into five themes (see *Table S5*). Fear of side effects constituted the most common theme, mentioned by 22% of vaccine-hesitant participants in Spain and up to 41% of vaccine-hesitant participants in Italy. While many participants listed side effects as a general concern, some responses offered stronger sentiments, referring to COVID-19 vaccines as "poison" and revealing a fear of experiencing lethal side effects. Some respondents were concerned about side effects linked to (1) pre-existing medical conditions such as chronic diseases or allergies, (2) potential infertility or harm to an (unborn) child, and (3) certain characteristics of specific vaccines, including concerns about "genetic modification" introduced by mRNA vaccines or blood clot incidents associated with the AstraZeneca vaccine.

The lack of evidence regarding the long-term effects of the COVID-19 vaccines was listed as another major concern spurring vaccine hesitancy, cited by 17% of participants in Bulgaria and up to 44% of participants in France. Several respondents portrayed the current vaccination campaign as a large-scale human experiment ("*we are all just guinea pigs* ", see *Table S5*) and expressed concerns about the speed with which the vaccines were developed. Relatedly, many respondents pointed to fears about detrimental middle- to long-term health impacts of the COVID-19 vaccines and the lack of scientific evidence on such long-term effects.

In addition, some participants cited low levels of trust in the quality and efficacy of COVID-19 vaccines as a key barrier to getting vaccinated (ranging from 6% of participants in the UK to 11% of participants in France), which was often linked to concerns about the vaccines' potency against more recent variants of the coronavirus and uncertainty or concerns about whether and to what extent vaccinated individuals might still transmit the virus.

Another theme that emerged, listed by 7% of participants in Poland and by up to 14% of Swedish respondents, was related to the perception that COVID-19 does not represent a substantial health threat, thus rendering vaccination unnecessary. Here, many participants emphasised their own good health and argued they were confident that their own immune system would be sufficiently capable of fending off the virus. Others reported a low perceived risk of contracting the virus due to limited social interactions or little mobility, and referred to COVID-19 as simply "a flu" or even denied its existence altogether.

A final commonly cited barrier to vaccination was distrust towards the government, pharmaceutical companies or "elites" in general, listed by 3% of participants in Poland and up to 12% of participants in Spain. More specifically, participants repeatedly suggested that profits for pharmaceutical companies

were the primary purpose of the vaccination campaign, viewed the vaccination as a means of state control, and voiced concerns or fears about being experimented on, while some participants sympathised with conspiracy theories surrounding the vaccines or COVID-19.

Causal Effects of Information Treatments

The outcomes of the survey experiment are presented separately for each country in *Table 1* (and additionally in supplementary *Figures S15-S22*). In Germany, three out of four treatments significantly increased participants' willingness to vaccinate. Specifically, the odds of accepting the COVID-19 vaccine were 1·5 times higher for participants who were presented with the COVID-19 risk reduction message, relative to participants in the control group (OR=1·46, 95% CI 1·09 –1·97, p<0·05). Starting from a baseline acceptance level of 27% in the control group, the treatment effect thus corresponds to a six-percentage-point increase in respondents' intention to vaccinate. Messages highlighting hedonistic benefits and the benefits of owning a vaccination passport were also significantly associated with significantly higher odds of COVID-19 vaccination willingness: 1·43 (95% CI 1·06 – 1·93, p<0·05) and 1·45 (95% CI 1·09 – 1·95, p<0·05), respectively. Respondents exposed to the altruistic message were also somewhat more likely to indicate that they would accept a vaccination offer, but the difference to the control group was not statistically significant (OR=1·32, 95% CI 0·99 – 1·77, p=0·06). Due to budget restrictions, we excluded the altruistic message as the least effective treatment from the survey experiment in the seven remaining countries.

There was vast heterogeneity across countries with regard to the impact of the three experimental information treatments on respondents' willingness to get vaccinated. In the UK, the vaccination certificate message significantly increased the odds of intending to get vaccinated by 1·51 (95% CI 1·02 – 2·24, p<0·05) compared to the control group, corresponding to an increase from 22% to 28% of participants being willing to get vaccinated. In Bulgaria, Poland, France, Italy, and Sweden, none of the information treatments significantly improved participants' reported vaccination intentions. In fact, treatment effects even pointed in the opposite direction in some countries, thus revealing potential harmful effects of public messaging, though these effects were significant only in Spain. While informing participants about the risk reduction effects associated with COVID-19 vaccines was found to have positive effects in Germany, the same information treatment caused an adverse effect on vaccination intentions in Spain, leading to an eight-percentage-point drop in vaccination willingness relative to the control group (OR=0·66, 95% CI 0·46 – 0·96, p<0·05), albeit from the higher baseline rate of 67% in Spain.

[Please show Table 1 about here]

Heterogeneity in Treatment Effects

Heterogeneity in treatment effects both across and within countries was further assessed in a model-based recursive partitioning approach, including age, gender, education, employment and country of residence as explanatory variables (see *Table 1*). For the *hedonistic benefits treatment*, none of the subgroups identified by the algorithm based on a combination of these variables exhibited significant treatment effects. The corresponding regression tree shown in *Figure S23* displayed only seven nodes, thus suggesting that there was, overall, relatively little heterogeneity with regards to the impact of the hedonism treatment. In contrast, there was evidence for substantial heterogeneity in the impact of the *COVID-19 risk reduction* and *vaccination certificate* treatments, as illustrated by a total number of 29 and 27 nodes in the regression trees, respectively (see *Figures S24-S25*). More specifically, two subgroups who received the risk reduction message revealed a significantly lower likelihood to get vaccinated against COVID-19, relative to the control group: Spanish participants who were not employed were less likely to accept the COVID-19 vaccine, relative to the control group (OR=0·49, 95% CI 0·25-0·93, p=0·030) (see *Table 2*). Participants who were Italian or German, female and not employed also had lower odds of accepting the vaccine (OR=0·38, 95% CI 0·17-0·83, p=0·015). Conversely, the risk reduction message had positive effects for the subgroup of Italian and German women who were employed and had a lower level of education (OR=2·23, 95% CI 1·02-4·90, p=0·045). With regard to the vaccine certificate message, there were two subgroups with positive effects: Italian, Swedish and German participants, aged 18-24 or 65+ years, with primary, secondary, or further education showed a substantial increase in the likelihood of vaccinating (OR=3·15, 95% CI 1·56-6·36, p=0·001); similarly, those with higher education and in the middle and higher age groups (OR=2·76, 95% CI 1·53-4·98 p=0·001).

[Please show Table 2 about here]

Discussion

Vaccines offer the most cost-effective instrument in combating the COVID-19 pandemic. This study set out to determine the prevalence and determinants of COVID-19 vaccine hesitancy in Bulgaria, France, Germany, Italy, Poland, Spain, Sweden, and the UK. Even across countries, which are geographically close and culturally similar, we documented substantial heterogeneity in the prevalence of stated COVID-19 vaccine hesitancy, ranging from every other person being unwilling to get vaccinated in Bulgaria, to one in every twenty persons in Spain.

We also found profound differences in participants' perceptions of different COVID-19 vaccines. While acceptance was generally higher for the mRNA vaccines BioNTech/Pfizer and Moderna, the AstraZeneca vaccine was marked by strikingly divergent levels of acceptance, with a third of British participants reporting high levels of trust in this UK-produced vaccine, compared to less than 5% of German and Italian participants. In light of this vaccine-specific variation in acceptance, letting citizens choose which vaccine to receive may help boost current vaccination rates.[20]

Despite considerable cross-country variation in the level of vaccine hesitancy, some key determinants were consistent across countries. Generally, women appeared to be more hesitant towards the COVID-19

vaccine than men, which corroborates the findings of previous studies.[2,10,11,21–25] Explanations for this pattern remain speculative, but the gender gap may be linked to a lower mortality risk for female COVID-19 patients[26], to broader gender differences in risk-taking,[27] or to more general gender disparities in health care access and patient-provider relationships.[28] In addition, similar to previous studies, we found that in some countries vaccine hesitancy declined with higher education and employment.[2,10,21,23] An important policy implication that emerges from these findings is the need of a more intensified outreach to groups with a higher probability of refusing the COVID-19 vaccine, including women and socially disadvantaged population segments.

Innovatively, our study sheds light on the underlying motives behind participants' COVID-19 vaccine hesitancy. In line with previous research, fear of side effects, fast development and approval, and distrust in the effectiveness and quality of the COVID-19 vaccines were cited as major driving factors of vaccine hesitancy.[6,11,22,25,29] In light of these obstacles to vaccine acceptance, public health messages that focus on the rigorous and extensive testing of the vaccines currently available as well as on the prevalence, prevention, and treatment of possible side effects could prove most effective in addressing public concerns and fears directed at the COVID-19 vaccines. In support of this, a previous survey experiment in the United States found that participants' vaccine acceptance could be increased significantly by providing information on the safety of COVID-19 vaccines.[6] Building on this finding, future studies should explore the effectiveness of similar messages in other countries.

Furthermore, our study found that some participants considered COVID-19 vaccination to be unnecessary. This result might be related to a substantial decline in infection cases in most European countries at the time participants were surveyed, resulting in a lower perceived threat posed by the pandemic. To address this aspect of vaccine hesitancy, public health messaging that emphasises the salience of the disease threat – including the risk and prevalence of "long-COVID" symptoms – may help increase vaccination acceptance.[13,30]

Crucially, our randomised controlled survey experiments revealed that none of the tested information treatments consistently increased COVID-19 vaccine acceptance across all European countries. The information treatment that significantly improved vaccination acceptance in Germany and UK, highlighting the individual benefits and leisure privileges of having a vaccination certificate, did not work elsewhere. Even more alarmingly, the information treatment highlighting the COVID-19 risk reduction associated with vaccination, which improved vaccination willingness in Germany, not only did not work in most other countries, but even backfired in Spain. Health authorities and governments are urged to learn from other countries' interventions that have been found to work but pre-test them in their own country, before adopting them on a large scale.

Our study is also the first to apply a machine learning approach to gain a more nuanced understanding of the sociodemographic characteristics behind the heterogeneity in the effectiveness of different messaging strategies to boost COVID-19 vaccine uptake. Notably, we identified certain subgroups for whom some information treatments worked particularly well or, in contrast, had an adverse effect on

vaccine willingness. First, the COVID-19 risk reduction treatment had a negative effect on the willingness to get vaccinated among individuals who were not employed in Italy, Spain, and Germany. While the reasons behind this observation remain unknown, one tentative interpretation could relate to lower mobility and less frequent social interactions among individuals who are not employed. This may affect their actual COVID-19 risk status as well as their risk perceptions, and could thus also shape the way in which the risk reduction information is processed. Second, the vaccination certification message had a positive effect among respondents (in Italy, Sweden, and Germany) that may be particularly reliant on travelling, either for work-related purposes (the higher educated, medium age groups) or for leisure (the lowest and highest age groups). It is therefore critical that messages are targeted and tested with the appropriate socio-economic groups, especially women and those more disadvantaged (low education, not employed) to avoid an inadvertent increase in inequity in reach, and ultimately vaccination rate and health outcomes.

A limitation of our study is the reliance on participants' self-reports with regard to their vaccination intentions, which may deviate, in some cases, from their actual vaccination behaviour.[8] In addition, we cannot claim full representativeness of the sample in view of the quota-based sampling and selecting participants contingent on their vaccination status. More importantly, differences in the progress of nation-wide vaccination campaigns in our target countries affected each country's sample composition and representativeness differently, particularly among older age groups. Lastly, we prioritised broad geographical coverage across countries over statistical power within a single country. We were therefore unable to detect potential small differences in vaccination willingness between participants in the treatment and control groups.

Despite these shortcomings, this study offers novel insights into our understanding of COVID-19 vaccine hesitancy, and public health communication strategies to overcome it in an equitable manner across Europe and the UK. In light of the substantial differences in the prevalence and nature of vaccine hesitancy across European countries, as well as in the response to different messaging strategies, we encourage governments and health officials, both at the European and country level, to steer away from a "one-size-fits-all" approach, which is unlikely to effectively combat vaccine mistrust in Europe. Instead, vaccination campaigns and communication strategies should be carefully tailored around each country's target population and consider its specific concerns and psychological barriers, as well as education and employment status. In view of COVID-19's global death toll of more than four million at the time of writing, and its devastating economic and social repercussions, boosting population-wide confidence in COVID-19 vaccines has become more important than ever. Carefully designed and target-group-specific public health communication strategies are urgently needed, to promote equitable access to vaccines, to prevent future infection waves fuelled by new coronavirus variants as well as to build resilience for future pandemics.

Declarations

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Author Contributions

GAV, TB, MMG, BF, and JIS acquired funding for this research study. JIS, GAV, TB, MMG, and HS conceptualised and led the study and developed the pre-analysis plan. JIS, GAV, MMG, and HS oversaw and managed the data collection. JIS merged and cleaned the data, and JIS, GAV, and HP conducted the quantitative data analyses and data visualisations. JIS, TB, GV, MG, BF, and HS contributed to the interpretation of the quantitative findings. HP, JIS, and HS conducted and discussed the qualitative analyses. JIS drafted the first version of the manuscript and all authors provided substantial revisions and feedback. We confirm that all authors have read and approved the final version of the manuscript.

Competing Interest Declaration

The funding organisation had no role in the study design, data collection, data analysis, data interpretation, or writing of the manuscript.

Supplementary Information

Supplementary Information (including tables, figures, and data) is available for this paper.

Corresponding Author

Janina I Steinert, Richard Wagner Str. 1, 80333 München, Germany, Phone: +4915784562543, janina.steinert@tum.de

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Methods

Study Sample

We conducted an online survey experiment in eight European countries: Bulgaria, France, Germany, Italy, Poland, Spain, Sweden, and the UK. The German survey was fielded in April 2021; the remaining surveys were carried out in June 2021. In each country, we recruited respondents aged 18 years and older from panels maintained by the survey company *Respondi.* We sampled participants based on quotas that were matched to the official census of each country with regards to (1) gender, (2) age, (3) education, and (4) geographic or political-administrative subdivision. After gathering demographic information and establishing whether respondents had already gotten vaccinated, we screened out respondents who had already received one or two COVID-19 vaccine shots, because for our purposes it was most important to collect information on the intentions and perspectives of individuals who had not yet been vaccinated. On the first page of the online survey, we informed participants of the study's purpose as well as data protection regulations, and reminded them of their right to decline or withdraw from participation at any time. Those who selected to proceed received a voucher worth three to five Euros, distributed through the survey company, for participating in the survey.

Survey Experiment

We conducted a randomised controlled survey experiment in each target country by randomly assigning participants to a control group or one of three information treatments, which according to prior studies should increase their willingness to get vaccinated against COVID-19.[1,2,4] The messages in the experimental conditions were: (1) *COVID-19 Risk Reduction:* information about the efficacy of different COVID-19 vaccines, specifically highlighting the effectiveness of vaccines to prevent COVID-19 related deaths and severe disease progressions among vaccinated individuals, relative to unvaccinated individuals; (2) *Vaccination Certificate:* information about exclusive benefits for the vaccinated, including access to travel and leisure activities contingent on providing proof of vaccination in the form of a COVID-19 vaccination certificate*; (3) Hedonistic Benefits:* information about the prospects of a full restoration of public life and a return to normality, including a wide range of leisure activities (restaurants, theatres, bars, sports, etc.), after population-wide vaccination; (4; in Germany only) *Altruistic Benefits:* information portraying vaccination as a prosocial, altruistic act, which could help protect groups for whom COVID-19 vaccines had not yet been approved, such as pregnant women and children. All information treatments were translated from English into each country's national language and piloted prior to launching the survey. Moving beyond previous studies of COVID-19 information treatments,[2] and building on previous research suggesting greater effectiveness of visual information treatments,[31] the text-based messages were combined with images *(see supplementary material, Figures S1-S4*). We first carried out the survey experiment with a larger sample size in Germany, which allowed us to test the effectiveness of the four different information treatments. Based on these findings, the three most effective information treatments were selected for testing in the remaining seven countries.

All participants (including those assigned to the control group) were first provided with general information about the COVID-19 vaccines available in their respective countries at the time of the survey. Subsequently, participants were randomised into one of four (in the case of Germany: five) groups, using stratification to ensure equal distribution across the treatments by participants' gender, age, and education level: respondents either received no message (control group) or one of the three (in the case of Germany: four) different information treatments. To nudge participants toward taking sufficient time to read through and process the presented information, the survey design forced respondents in all treatment groups to spend twenty seconds on the page with the information treatment before they could progress to the next page of the survey.

Outcomes

The study's primary outcome was participants' intention to get vaccinated against COVID-19, elicited by means of a question asking participants whether they would get vaccinated if they were given the opportunity in the following week. Participants were able to select one of four response options to indicate whether they (1) would definitely get vaccinated, (2) would only get vaccinated if offered certain vaccine types, (3) were still undecided, or (4) would definitely not get vaccinated. Participants who selected the second response option were prompted to indicate the vaccine type(s) with which they were willing to get vaccinated, based on a list of vaccines that were approved and available in their respective

country at the time of the survey. These included the mRNA vaccines BioNTech-Pfizer and Moderna and the non-replicative viral vector vaccines AstraZeneca and Johnson & Johnson/Janssen (the latter was excluded in the UK, where it was not yet available at the time the survey was launched). Participants who indicated that they were unsure or unwilling to get vaccinated were required to specify reasons in their own words, in an open text field.

To estimate the prevalence of vaccine hesitancy, we created an indicator variable of COVID-19 *vaccine hesitancy*, which was coded 1 for respondents who were unsure or unwilling to take the COVID-19 vaccine; 0 otherwise. To evaluate the effectiveness of the experimental treatments, we focused on unconditional *vaccine willingness*, measured by an indicator variable coded 1 if the respondents reported that they would definitely get vaccinated; 0 otherwise.

Sociodemographic Determinants of COVID-19 Vaccine Hesitancy

We focus on sociodemographic determinants of vaccine hesitancy: gender (male, female, non-binary), age (grouped into: 18-24, 25-34, 35-44, 45-54, 55-64, and 65+ years of age), education (i.e., primary education, secondary education, higher education including A-levels, and university degrees), and employment status.

Statistical and Qualitative Analyses

The association between sociodemographic factors and COVID-19 vaccine hesitancy was analysed separately for each country using a logistic regression model. For ease of interpretation, we also calculated predicted probabilities of vaccine hesitancy for different sociodemographic profiles. Participants' free-text statements explaining their reluctance or refusal to accept the COVID-19 vaccine were translated into English (except for the survey data collected in the UK) and arranged into overarching themes based on qualitative content analysis. The themes were coded independently by three authors (JIS, HP, HS) and then discussed and finalised jointly.

The power calculations for the randomised controlled experiment assumed a minimum detectable effect size of Cohen's $\delta=0{\cdot}25$, based on a recent comparable survey experiment implemented in the UK.[1] With an alpha level of 0·05, a sample size of approximately 260 participants for each study arm would ensure statistical power of 80 percent. We therefore followed a target sample size of 1,040 participants per country (for three treatment arms and one control arm). We substantially increased the sample size for the German experiment to ensure sufficient statistical power to allow for the testing of four distinct information treatments. We defined participants' willingness to get vaccinated against COVID-19 as the outcome variable and estimated a logistic regression model including stratification variables (gender, age, education) as well as sub-national regions as controls to estimate the treatment effects.

Lastly, we examined heterogeneity in treatment effects by using a non-parametric model-based recursive partitioning approach.[32,33] Building on the parametric logistic regression model from the primary outcome analysis, the recursive partitioning algorithm creates different versions of the estimations to split participants – based on combinations of gender, age, education, employment, and target country – into subgroups (also referred to as “nodes”) with statistically significant different values of the explanatory variables.

Analyses were carried out in Stata SE 17.1 and R 4.1.0. The survey experiment and the corresponding pre-analysis plan were registered on the Open Science Foundation platform (accessible here: https://osf.io/53zdk/).

Ethics Review for Human Subject Research

The study received approvals from the ethics committees of the medical faculty at the Technical University of Munich (TUM, IRB 227/20 S) and the ethics board at the University of Trento (Trento, IRB 2021-027), and also complies with the LSE research ethics policy (https://info.lse.ac.uk/staff/divisions/research-and-innovation/research/ research-ethics/research-ethics).

Tables

Table 1. Treatment Effects on Vaccine Willingness

	Bulgaria	France	Germany	Italy	Poland	Spain	Sweden	UK
COVID-19 Risk Reduction	1·46 0·73 – 2·95	1·06 0·64 – 1·78	**1·46*** **1·09 –1·97**	0·75 0·51 – 1·10	0·90 0·54 – 1·50	**0·66*** **0·46 – 0·96**	1·16 0·81 – 1·67	0·88 0·58 – 1·33
Vaccination Certificate	1·58 0·77 – 3·25	0·87 0·52 – 1·45	**1·45*** **1·09 – 1·95**	1·02 0·71 – 1·49	0·97 0·56 – 1·61	0·97 0·66 – 1·41	0·92 0·64 – 1·31	**1·51*** **1·02 – 2·24**
Hedonistic Benefits	1·25 0·62 – 2·55	1·45 0·88 – 2·39	**1·43*** **1·06-1·93**	0·77 0·52 – 1·12	0·96 0·57 – 1·61	1·00 0·69 – 1·46	0·90 0·63 – 1·29	1·19 0·81 – 1·77
Altruistic Benefits	-	-	1·32 0·99 – 1·77	-	-	-	-	-
N	**1069**	**1108**	**2323**	**1087**	**1104**	**1102**	**1097**	**1205**

Notes: Coefficients are odds ratios (95% CI) based on logistic regressions. All treatment arms compared to the control arm. All analyses control for stratification variables and region to account for potential variations in COVID-19 infection rates. Outcome is an indicator variable of vaccine willingness, which equals 1 if the respondents reported that they would definitely get vaccinated and 0 otherwise.

Table 2. Model-Based Recursive Partitioning Approach: Heterogeneity in Treatment Effects on Vaccine Willingness

Subgroup composition	OR [95% CI]	Probability of willingness to get vaccinated relative to control group	p-value
Treatment: Individual Medical Risk Reduction			
Spanish, not employed	0·49 [0·25-0·93]	-52%	0·030
Italian & German, female, not employed	0·38 [0·17-0·83]	-62%	0·015
Italian & German, female, employed, primary or secondary education	2·23 [1·02-4·90]	+123%	0·045
Treatment: Exclusive Non-Medical Benefits			
Italian & Swedish & German, primary or secondary or further education, 18-24 or 65+ years	3·15 [1·56-6·36]	+250%	0·001
Italian & Swedish & German, higher education, 35-44 or 65+ years	2·76 [1·53-4·98]	+176%	0·001

Notes: 95% CIs are Wald confidence intervals.

Figures

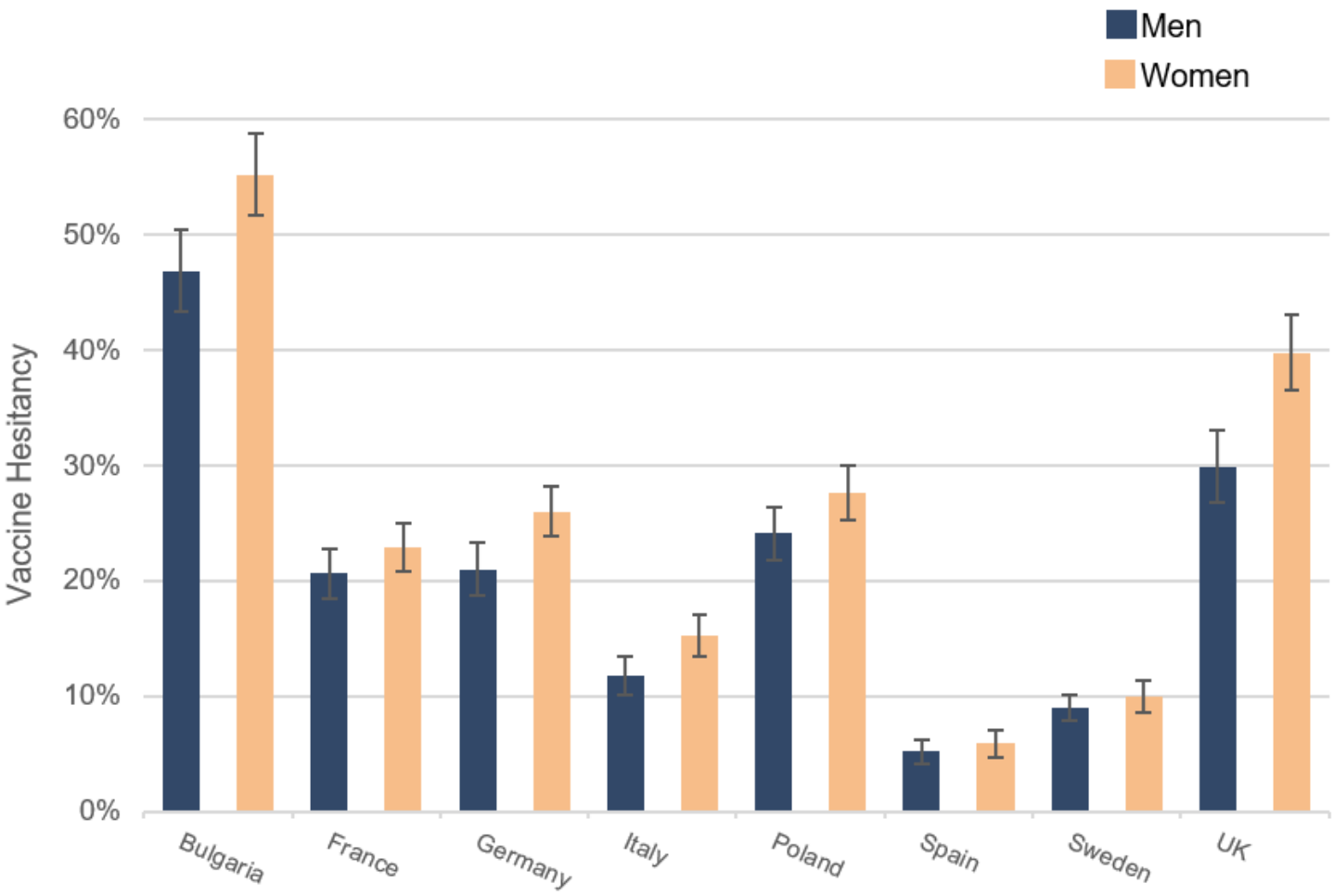

Figure 1

COVID-19 Vaccine Hesitancy by Gender. Notes: This includes all 21,982 respondents, whether vaccinated or not. (i) Participants were considered vaccine hesitant if they reported being either unsure whether they would get vaccinated against COVID-19 or certain that they would not get vaccinated. (ii) Participants who had already received one or two vaccine shots were coded as not hesitant.

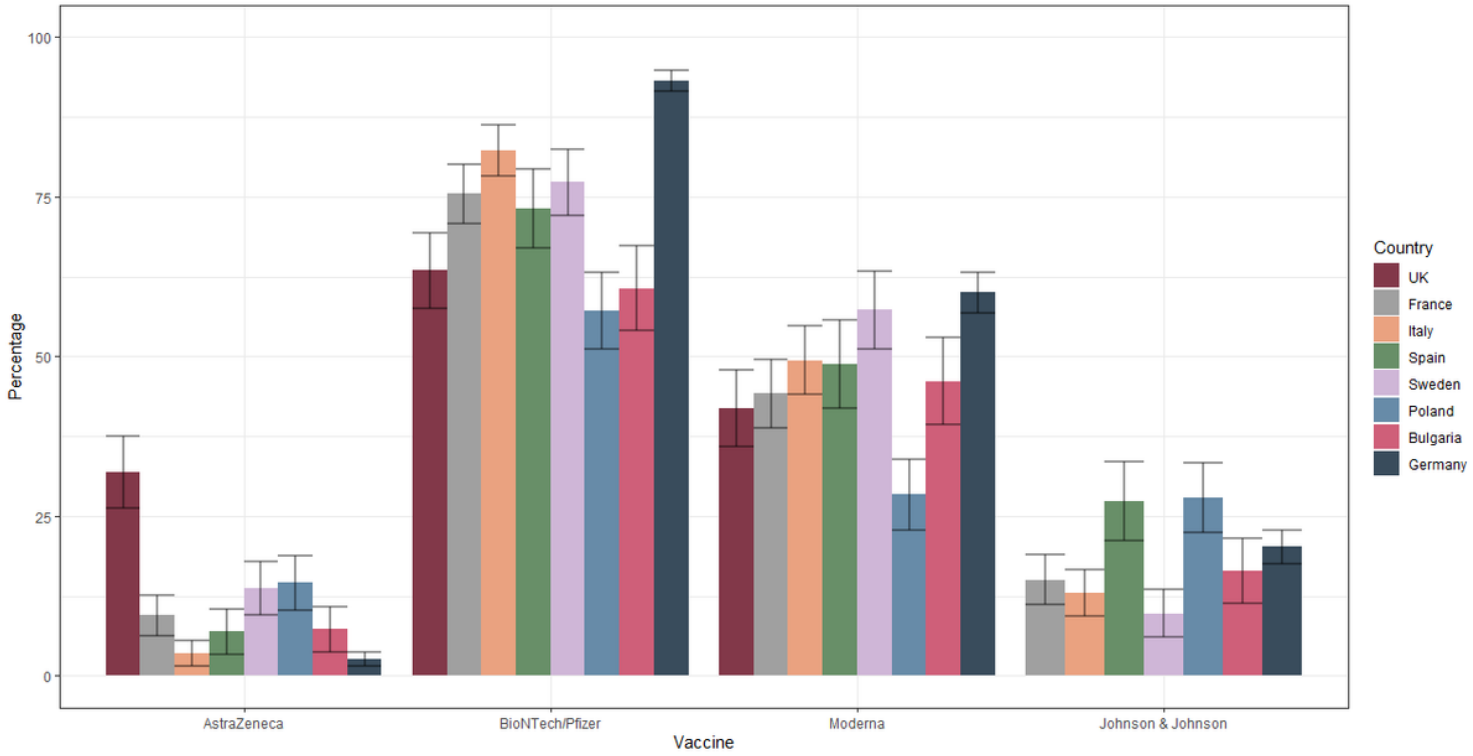

Figure 2

Acceptance of Different COVID-19 Vaccines Among Unvaccinated Participants with Conditional Willingness.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFiles.docx