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A Lack of Perceived Benefits and a Gap in Knowledge Distinguish the Vaccine Hesitant from Vaccine Accepting during the COVID-19 Pandemic

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Keyword(s): COVID-19; Vaccine Intention; Behavioural Science

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Abstract: The current strategy to end the COVID-19 pandemic is to achieve herd immunity through mass vaccination. This relies on individuals' willingness to take a vaccine. Yet little is known about how people perceive the risks and benefits of the COVID-19 vaccine. This paper reports the results of a series of interactive tasks that were given to a nationally representative sample of the population to assess how people prioritise risks and benefits, and how much they know about the COVID-19 vaccines. Most individuals see some risks to vaccination, but many hesitant individuals fail to see any benefits. Vaccine hesitant individuals are less knowledgeable about the vaccine, and knowledge is associated with how people perceive benefits and what risks are most salient to them. These differences have a stronger association with intention to be vaccinated than sociodemographic characteristics. Public health communications may need to consider an education campaign to address a significant gap in knowledge.

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Since January 2020, the main line of defence against COVID-19 has been radical changes to everyday behaviour. National lockdowns and collective adherence to public health guidelines kept the virus under control in many countries, while the global effort to find a vaccine was underway. There has now been regulatory approval of eight vaccines worldwide meaning that vaccination has begun in some parts of the globe.[1] Yet the challenge of mass vaccination is dependent not only on having the vaccine available, but on the willingness of people to take it, and in sufficient numbers that it will provide herd immunity. Somewhere between 60-90% of populations will need to be immune to the virus to stop the spread.[2] Ending this pandemic is therefore largely reliant on human behaviour.

Current estimates suggest that around 32% of people worldwide are hesitant or resistant to taking a COVID-19 vaccine.[3] Vaccine hesitancy is therefore likely to have a substantial impact on the vaccine's success. Many surveys have identified sociodemographic subgroups who may be more hesitant about the vaccine. Younger adults, women, those with children and minority ethnicity groups (BAME) are all less likely to say they intend to the take the vaccine.[4-17] Some studies find that those with lower levels of education and income are less likely to take the vaccine, but these effects are less consistent.[4, 9-11, 13, 15-19]

Other studies have explored psychological reasons for hesitancy. People who believe that they are not at great risk of getting COVID-19, or of being severely ill if they do get it, are less willing to take the vaccine.[5, 8, 10, 12, 20, 21] Other factors associated with increased hesitancy include mistrust in scientific information, the government and health professionals and lower levels of analytic reasoning.[6, 11, 13, 15, 22-25] Some of these psychological variables appear to be more strongly associated with vaccine hesitancy than sociodemographic characteristics, which implies limits to the effectiveness of communication strategies based on targeting by social group.[9, 11, 13, 25] Other studies, including one recently published in Lancet Public Health on the French population, have found that features of the vaccines themselves may induce hesitancy. Vaccines that are made in the UK and America, that have higher reported efficacy and fewer reported side effects, were more palatable to the French participants.[26]

People's reasons for hesitancy about the vaccine are not necessarily unreasonable, irrational, or misinformed. Many who say they will take the vaccine may also be aware of potential side effects of the vaccine. Their ultimate decision will be influenced by how they trade these risks off against the benefits. Most decisions that involve making a choice between options necessitate a trade-off. A large literature on risk-benefit trade-offs suggests that people do not always assess risks and benefits accurately, but instead give weight to risks and benefits in part through the emotions they induce. This is termed the affect heuristic. In some circumstances, it can lead people to find an inverse relationship between risks and benefits, even when risks and benefits are in fact positively correlated.[27] People who see higher risks to an activity, also tend to see fewer benefits, while those who see higher benefits tend to see fewer risks. This has a strong influence on the outcome of the trade-off. From what is known about the COVID-19 vaccines to date, the benefits of protection against severe COVID-19 are likely stronger than the risks of severe side effects. However, this previous literature suggests that people may vary substantially in their perceptions of the benefits and risks, given likely variation in experiences of the pandemic and emotional responses to it.

The present study investigates the risk-benefit trade-off at the heart of the vaccine decision. Previous surveys and qualitative explorations have asked people to list the reasons why they are hesitant to take the COVID-19 vaccine. The most common are fear of side effects, belief that the vaccine is not necessary, perceived lack of efficacy, and worry about the development process or novelty of the vaccine.[7, 8, 15, 17, 18, 21] This research is useful for getting a broad overview of concerns, however, there is no research that we are aware of that has explored how people trade off different types of risks and

benefits when thinking about the COVID-19 vaccine. This is an important gap in our understanding. For instance, while someone may report that side effects are a risk they have considered, they may also perceive them to be a lesser risk relative to getting COVID-19. Similarly, the benefit of protection against COVID-19 may be perceived to be greater than the risk of the side effects. It is how people trade-off these risks against other risks and benefits that is likely to influence their final decision, rather than whether they perceive the risk or benefit alone. In addition, trade-offs are often influenced by the level of expertise in the decision.[28] Some research has shown that knowledge about COVID-19 predicts intention to get the COVID-19 vaccine.[15, 22, 23] However, we are not aware of research that has investigated how knowledge about the COVID-19 vaccines themselves influences risk perception or intention to get vaccinated. This gap may be because much of the research on vaccine intention was carried out in 2020, before much was known about the vaccines that would later be approved. Educational attainment has been sometimes taken as a proxy for knowledge in previous studies but in a global pandemic, where people are surrounded by information on COVID-19, it may not be a good proxy, given the inconsistent pattern of findings for education in predicting vaccine hesitancy.

This paper reports the results of a survey experiment, which used an interactive computerised environment to assess how people perceive and trade off the different risks and benefits when thinking about the COVID-19 vaccine. Across multiple sequential tasks, we systematically manipulated the types of factors that participants were asked to consider. We gathered open text responses about risks and benefits of the vaccine, had participants rank risks and benefits, and asked them to complete a test of knowledge about the COVID-19 vaccines. Participants could spend as much time as necessary engaging with each task and could undo and redo responses during each task. The study addressed the following questions:

1) What risks and benefits of the COVID-19 vaccine are most salient to individuals when not prompted by specific questions?
2) How do individuals prioritise risks associated with COVID-19 and the COVID-19 vaccine?
3) How do individuals rank risks and benefits?
4) How do individuals balance their greatest perceived risk and benefit?
5) What are the strongest rationales for getting vaccinated?
6) How much do individuals know about the COVID-19 vaccine?
7) How do these decision-making factors relate to intention to take the COVID-19 vaccine?

By breaking down the components of the decision into succinct tasks, and allowing participants to interact with each in turn, we uncover new findings about how people perceive risks and benefits, and how these influence the decision. The study was carried out on a nationally representative sample in Ireland. Research questions, methods and hypotheses were pre-registered on Open Science Framework prior to data collection.[1] The research was funded by the Government of Ireland Department of Health to inform policy around COVID-19 vaccine communications.

Methods

Study Sample

A sample of 1,600 adults living in the Republic of Ireland was recruited from a market research agency panel to take part in a 20-minute online survey experiment about COVID-19 vaccination intention. Data collection ran from 21 to 27 January 2021, during Ireland's third national lockdown. The sample size was set to ensure a sufficient number of vaccine hesitant and vaccine resistant participants, who accounted for an estimated 25% and 5% of the population at the time of data collection.[29] Recruitment

[1] Link to OSF here: https://osf.io/43xeg/?view_only=14d58b273c57422fb0866d1bdb2fc87a

was stratified to be representative of the population in terms of age, sex, region of residence and socio-economic status. Participants gave informed consent before beginning the experiment and were paid €4 upon completion.

Survey Experiment

Participants completed a series of interactive tasks to assess how intentions to accept a COVID-19 vaccine relate to the most prominent perceived benefits and risks of the COVID-19 vaccine and general knowledge about COVID-19 vaccines. A full list of these tasks is shown in Table 1. In the same study, participants saw one of eight posters related to COVID-19 vaccination, but the results of this study are reported separately for reasons of space and will be released in a forthcoming paper. The responses to the tasks reported in this paper were not influenced by whether participants saw the posters before or after answering these questions.

Following an initial question about vaccine intention, participants were invited to write down risks and benefits of the COVID-19 vaccine in open text boxes. This allowed us to identify thoughts before participants were potentially primed by any survey items.

Participants then ranked several risks and benefits of the COVID-19 vaccine in order of personal importance to them, leaving unranked any item they deemed unimportant. The order of the risk/benefit rankings was counter-balanced and the order of the individual items were randomised for each individual. Participants were then shown their top risk and top benefit and indicated which would be more influential in their decision about whether to take the COVID-19 vaccine.

Participants completed a binary choice task to assess risk of the COVID-19 vaccine compared to other risks. They saw five choices in randomised order in which they indicated whether they were more worried about getting the COVID-19 vaccine or the other risk (see Table 1). Participants then indicated their level of agreement with several rationales for accepting the COVID-19 vaccine using a 7-point Likert scale.

Finally, 13 multiple-choice questions that tested objective knowledge of the COVID-19 vaccine and its development were administered. These were designed to have intermediate levels of difficulty to avoid floor or ceiling effects.

Standard demographic variables including age, gender, ethnicity, educational level, and employment status were collected. Since a large number of studies have found that women express greater vaccine hesitancy than men and that women are on average more risk averse than men, the General Risk Propensity Scale (GRiPS) was also administered to assess whether higher vaccine hesitancy reports from women could be explained by lower levels of risk propensity.[30, 31]

Table 1: Tasks within each stage of the experiment

Stage 1. Open Text Responses	
Some people think that vaccines only have risks, some people think vaccines only have benefits, and some think they have both. In the box below, please write down the first risk or benefit that you think of when you think about the COVID-19 vaccine. Please only write down one. When you have written one, a new box will appear. You may write down as many or as few as you like.	
Stage 2. Ranking Tasks	
Benefits	**Risks**
The vaccine will reduce the number of cases of COVID-19.	We don't know what effect the vaccine has in all groups of the population.
The vaccine will allow the economy to recover.	The vaccine was developed very quickly.
The vaccine will stop me spreading COVID-19 to others, including my friends and family.	We don't know the long-term side effects of the vaccine.
Getting the vaccine means that I will help to protect people who can't get the vaccine from COVID-19.	This type of vaccine is new.
The vaccine will protect me from getting sick with COVID-19.	Rare serious side effects from the vaccine
The vaccine will allow normal life to restart.	Common mild side effects from the vaccine (e.g. tiredness for 1-2 days)
The vaccine will protect me from possible long term effects of COVID-19.	I am afraid of needles.
Stage 3. Risk Prioritization Task	
Being vaccinated with the COVID-19 vaccine	Getting COVID-19
Being vaccinated with the COVID-19 vaccine	Spreading COVID-19 to someone else
Being vaccinated with the COVID-19 vaccine	Living in lockdown for a long time
Being vaccinated with the COVID-19 vaccine	Getting the annual flu vaccine
Being vaccinated with the COVID-19 vaccine	Getting the flu
Stage 4. Vaccination Rationale Rating Task	
If I get vaccinated, it will be to protect close friends and family from getting COVID-19.	
If I get vaccinated, it will be to protect the healthcare system.	
If I get vaccinated, it will be to protect myself from getting COVID-19.	
If I get vaccinated, it will be to do a good thing for society.	
If I get vaccinated, it will be to end restrictions and get back to normal.	
Stage 5. Test of Knowledge	
Q1	COVID-19 vaccine efficacy level
Q2	What is known about transmission reduction induced by COVID-19 vaccines
Q3	What is known about COVID-19 vaccine side effects
Q4	Reasons for quick development of COVID-19 vaccines
Q5	Whether mRNA vaccination is a new technology
Q6	How much of the population needs to be vaccinated to stop COVID-19 spread
Q7	Whether or not you can get COVID-19 from the vaccine
Q8	Whether or not the COVID-19 vaccine can alter your DNA
Q9	Whether or not the COVID-19 vaccine implants a tracking chip
Q10	Whether or not you will have to pay out of pocket for the vaccine
Q11	Whether formaldehyde, mercury and aluminium are safe vaccine ingredients
Q12	Whether previous vaccines have had serious side effects
Q12	How often the regular influenza vaccine is administered

Vaccine intention

An important measure was participants' intention to accept a vaccination against COVID-19. This was taken at baseline before participants were exposed to the interventions or any other survey content that may have influenced their intention level. They indicated whether they definitely would, probably would, probably would not or definitely would not get the vaccine. There was also an option for those unable to take the vaccine for medical or religious reasons.

Statistical Analysis

Our analysis strategy was to compare performance on each of the five stages separately by respondents' level of intention to be vaccinated (definitely yes, probably yes, probably no or definitely no). In Stage 1, we assess whether vaccine hesitant and vaccine resistant respondents list risks and benefits differently to vaccine accepting respondents in open text responses. In Stage 2, we assess whether vaccine hesitant and resistant respondents give different relative rankings to risks of the COVID-19 vaccine and to benefits of the COVID-19 vaccine compared to vaccine accepting respondents. In Stage 3, we asked respondents to confront the risk of the COVID-19 vaccine compared to other related risks and assess whether vaccine hesitant and vaccine resistant respondents differ in their prioritisation of risk compared to vaccine accepting respondents. In Stage 4 we check whether the rationales for vaccination differ among vaccine hesitant, resistant, and accepting respondents. In Stage 5, we assess whether there are differences in objective knowledge between vaccine hesitant, resistant, and accepting respondents. Finally, we model intention to be vaccinated by sociodemographic characteristics, perceived severity of COVID-19, perceived susceptibility to COVID-19 infection, perceived risks of vaccination, perceived benefits of vaccination and knowledge of the COVID-19 vaccines to determine how strong these associations are.

Open text responses were classified into categories according to a coding framework (available on OSF). Coding was carried out independently by two investigators achieving an initial inter-rater reliability of 74% (Cohen's kappa = .73). Following discussion, agreement was reached on all divergent items.

Quantitative analyses were performed using logistic regression or ordinal logistic regression (OLR) where appropriate. Where the Brant test of proportional odds indicated that the proportional odds assumption of OLR was violated, generalized ordered regression was used instead.

Results

Characteristics of the sample are shown in Table 2.

Table 2: Sociodemographic descriptives for full sample and by intention to take the vaccine

	All	Definitely Yes	Probably Yes	Probably No	Definitely No
Gender (Female)	792 (49.9%)	493 (46.0%)	199 (58.9%)	62 (62.0%)	42 (53.2%)
Age					
<30	244 (15.3%)	174 (16.2%)	44 (13.0%)	16 (16.0%)	10 (12.7%)
30-39	309 (19.4%)	174 (16.2%)	71 (21.0%)	37 (37.0%)	27 (34.2%)
40-49	296 (18.6%)	165 (15.4%)	78 (23.1%)	27 (27.0%)	26 (32.9%)
50-59	289 (18.2%)	200 (18.6%)	72 (21.3%)	10 (10.0%)	7 (8.9%)
60-69	305 (19.2%)	231 (21.5%)	57 (16.9%)	8 (8.0%)	9 (11.4%)
70+	147 (9.3%)	129 (12.0%)	16 (4.7%)	2 (2.0%)	0 (0%)
Region					
Connacht/Ulster	317 (19.9%)	196 (18.3%)	79 (23.4%)	20 (20.0%)	22 (27.9%)
Leinster – Dublin	430 (27.0%)	296 (27.6%)	88 (26.0%)	31 (31.0%)	15 (19.0%)
Leinster – Outside of Dublin	418 (26.3%)	288 (26.8%)	92 (27.2%)	23 (23.0%)	15 (19.0%)
Munster	425 (26.7%)	293 (27.3%)	79 (23.4%)	26 (26.0%)	27 (34.2%)
Employed	863 (54.3%)	563 (52.5%)	194 (57.4%)	55 (55.0%)	51 (64.6%)
Locality (Urban)	989 (62.2%)	669 (62.4%)	207 (61.2%)	66 (66.0%)	47 (59.5%)
Nationality (Irish)	1376 (86.5%)	967 (90.1%)	288 (85.2%)	72 (72.0%)	49 (62.0%)
Education (Degree+)	671 (42.2%)	470 (43.8%)	126 (37.3%)	46 (46.0%)	29 (36.7%)
Reduced work due to restrictions	114 (7.2%)	70 (6.5%)	25 (7.4%)	10 (10.0%)	9 (11.4%)
Children	870 (54.7%)	576 (53.7%)	193 (57.1%)	52 (52.0%)	49 (62.0%)
Usually get the flu vaccine					
Never	846 (53.2%)	483 (45.0%)	210 (62.1%)	82 (82.0%)	71 (89.9%)
Some years	223 (14%)	156 (14.5%)	53 (15.7%)	9 (9.0%)	5 (6.3%)
Yes - most years	521 (32.8%)	434 (40.5%)	75 (22.2%)	9 (9.0%)	3 (3.8%)

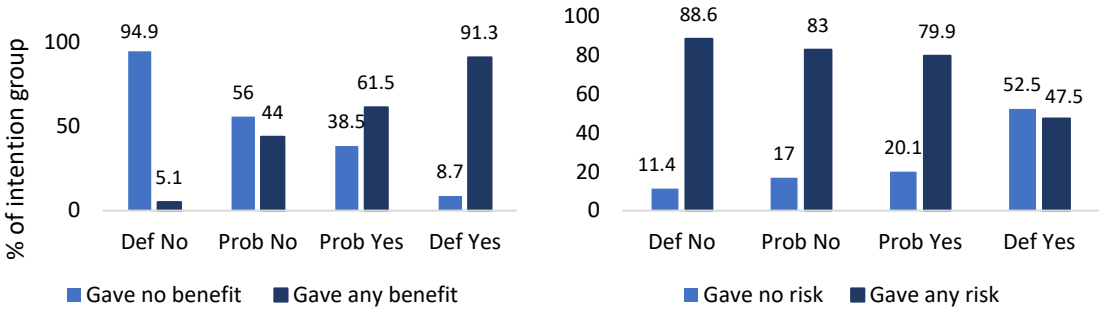
When queried about willingness to accept a COVID-19 vaccine, 67% reported that they would definitely accept it, 21.1% leaned towards yes, 6.2% leaned towards no, 4.9% said they definitely would not, and the remainder reported that they were unable to take the vaccine. These participants were excluded leaving a sample size of N=1,590.

Stage 1. Open Text Responses

Most people listed at least one benefit of the vaccine (77.7%) or at least one risk (58.7%) in the open text responses. Figure 1 shows the breakdown by intention to be vaccinated. Participants who were more vaccine hesitant were less likely to list any benefit, even in this task that asked them to write down any of the risks and benefits of the COVID-19 vaccine that they could think of. The size of the effect was substantial. Of the most vaccine accepting group, 91% reported at least one benefit of the vaccine, compared to only 5% in the most hesitant group. Even in the most accepting of the hesitant groups – those who said they probably would take the vaccine - more than a third failed to report any benefit of the vaccine. The top 3 most frequently mentioned risks and benefits are shown for each intention group in Supplementary Material (Table S1). Concerns about side effects were frequently mentioned by all groups, regardless of intention to be vaccinated, but vaccine accepting participants cited protection from COVID-19 and life returning to normal as benefits more often than vaccine hesitant participants. Protection from COVID-19 is arguably the most obvious benefit of the vaccine

and while 59% of respondents who said they would definitely get the vaccine mentioned protection from COVID-19 as a benefit, only 33% of those in the 'probably yes' category did and only 24% of those in the 'probably no.'

Figure 1. Proportion of participants listing risks and benefits in unprompted open text.



The majority gave a benefit of the vaccine as their first answer (67.8%), suggesting that benefits may be more cognitively available than risks, at least to the majority of accepting participants. However, participants who were more vaccine hesitant were more likely to list a risk than a benefit as their first thought and vice versa ($\chi^2(6) = 474.15$, $p < .001$). This is despite counterbalancing the question instructions between participants so that half were asked to write down "the first risk or benefit" and half "the first benefit or risk."

Only 39.8% of participants reported both benefits and risks even though the average number of thoughts listed was 2.8 (Table 3 for average number of risks and benefits). In the whole sample, when participants listed both risks and benefits, they reported feeling more strongly about benefits (M = 6.22, SD = 0.98, median = 6.5, range = 1-7, N = 633) than risks (M = 4.81, SD = 1.67, median = 5, range = 1-7, N = 631), $Z = -15.78$, $p < .001$. They also reported having thought more about benefits (M = 6.14, SD = 1.11, median = 6.5, range = 1-7, N = 633) than risks (M = 5.24, SD = 1.62, median = 5.5, range = 1-7, N = 631), $Z = -11.92$, $p < .001$.

Table 3: Number of Risks and Benefits mentioned across vaccination intention groups

	Number of Benefits	Number of Risks
Definitely Yes	1.98	0.64
Probably Yes	.96	1.38
Probably No	0.55	1.67
Definitely No	0.06	2.24

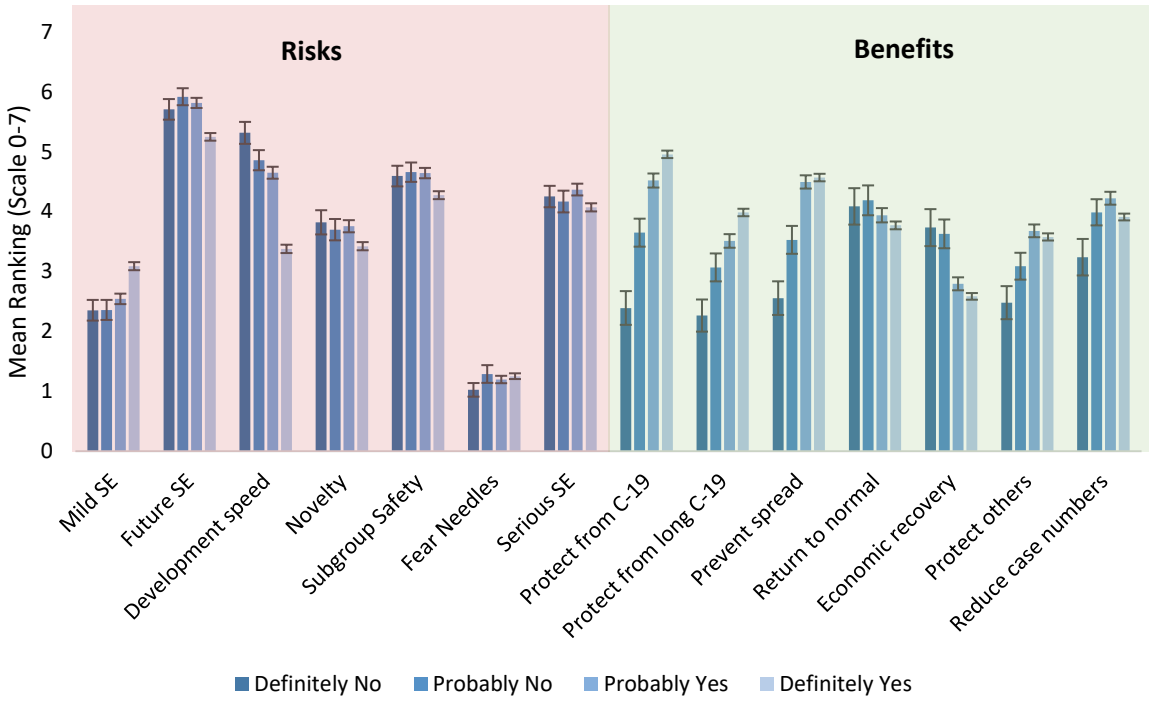
Overall, the open text responses produced an interesting and perhaps unexpected finding. Much news coverage has focused on potential risks associated with taking the vaccine. Yet we record greater divergence between those who say they will take the vaccine and those who are more hesitant, in listing benefits than listing risks.

Stage 2. Ranking Tasks

In Stage 2, respondents ranked seven risks and seven benefits separately in order of personal priority. The aim of this stage was to determine whether vaccine resistant, hesitant, and accepting participants differ in their relative ranking of types of risks and benefits. Ranking of risks was largely consistent across vaccination intention groups with all reporting fear of future side effects as the greatest risk ($M_{whole\ sample} = 5.43$, SD = 1.94, range 0-7) and fear of needles as the least ($M_{whole\ sample} = 1.23$, SD = 1.46,

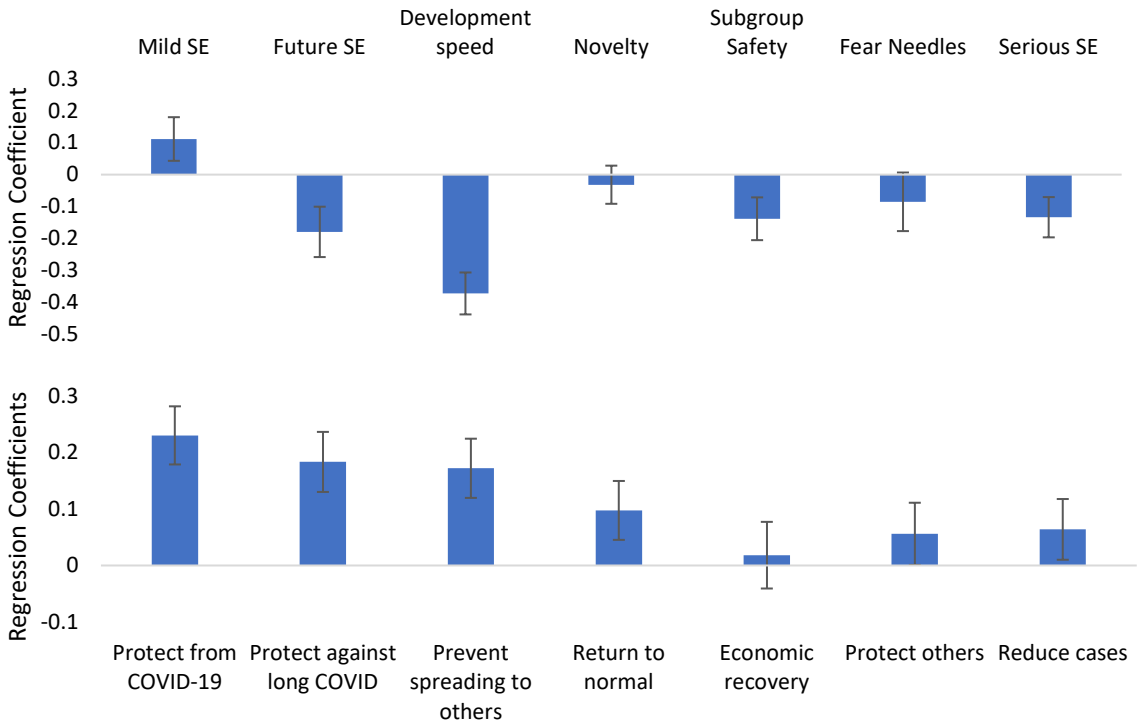
range 0-7). The exception was concern about the speed of vaccine development, which was ranked higher by the vaccine hesitant (Figure 2). This was confirmed in an ordinal logistic regression which found that the strongest predictor of being in a more vaccine hesitant group was giving a higher risk ranking to speed of development (Figure 3 and Table S2) – stronger than the ranking given to the risk of side effects.

Figure 2. Mean Ranking of Risks and Benefits by Intention



Note. Error bars are standard errors. Red shaded area covers risks and green shaded area covers benefits.

Figure 3. Coefficients and 95% confidence intervals from ordinal logistic regressions comparing ranking of risks and benefits by intention to be vaccinated



Note. SE = Side Effects. Negative coefficients indicate that a higher ranking is associated with a lower probability of being in a more vaccine accepting group. For the purposes of the graph the ordinal logistic regression is shown here. The results are the same as the generalised ordered logistic regression shown in Table S4.

The highest ranked benefit was protection from COVID-19 ($M_{whole\ sample}$ = 4.66, SD = 2.20, range = 0-7) and the lowest was economic recovery ($M_{whole\ sample}$ = 2.75, SD = 1.98, range = 0-7). A generalised ordered logistic regression found that the strongest predictor of intention to be vaccinated in this task was giving a higher ranking to protection from COVID-19 (Figure 3, Table S3). Results did not differ depending on whether participants ranked risks or benefits first.

When shown their top-ranked benefit and top-ranked risk, 77.4% of participants said the benefit would be more influential to their decision on whether to take the COVID-19 vaccine. This differed by intention group with only 6.3% of the definitely no group choosing their top benefit, 17% of the probably no group, 57.1% of the probably yes group and 94.6% of the definitely yes group, $\chi^2(3)$ = 696.75, $p < .001$.

This is potentially important when combined with the results of Stage 1 because most of the undecided but "probably yes" group said their top benefit would be more important than their top risk, even though this group was less likely to list benefits of the vaccine.

Stage 3. Risk Prioritization Task

Figure 3 shows the results of a binary choice task in which participants chose whether the COVID-19 vaccine was more or less concerning than getting COVID-19, spreading COVID-19, extended lockdown, getting the flu vaccine or getting the flu. To see whether vaccine hesitant, resistant, and accepting respondents differed in their risk prioritisation, we ran a generalised ordered logistic regression with intention to be vaccinated as the dependent variable and whether a participant chose the vaccine over the alternative risk as the five independent variables. The coefficients and 95% confidence

intervals from a generalised ordered logistic regression are shown in Figure 4 and the full regression table in Table S4. The analysis confirms the results seen in Figure 3; belief that the COVID-19 vaccine is more concerning than getting the flu vaccine or the flu does not reliably predict which intention group participants fell into except being in the "definitely yes" category. The strongest consistent predictor of hesitancy to take the vaccine was the perception that the COVID-19 vaccine is more concerning than getting COVID-19.

Figure 4. Proportion of participants who think the COVID-19 vaccine is more concerning than five related risks

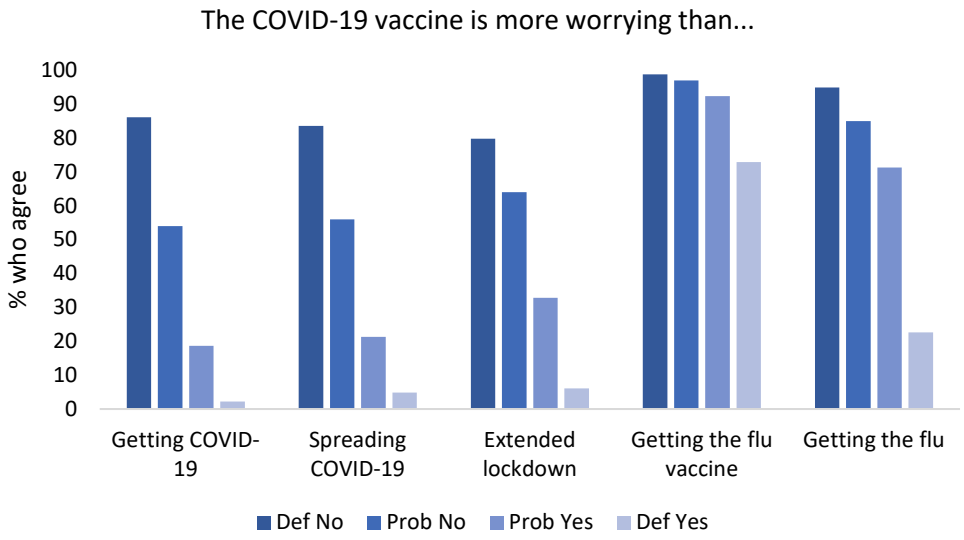
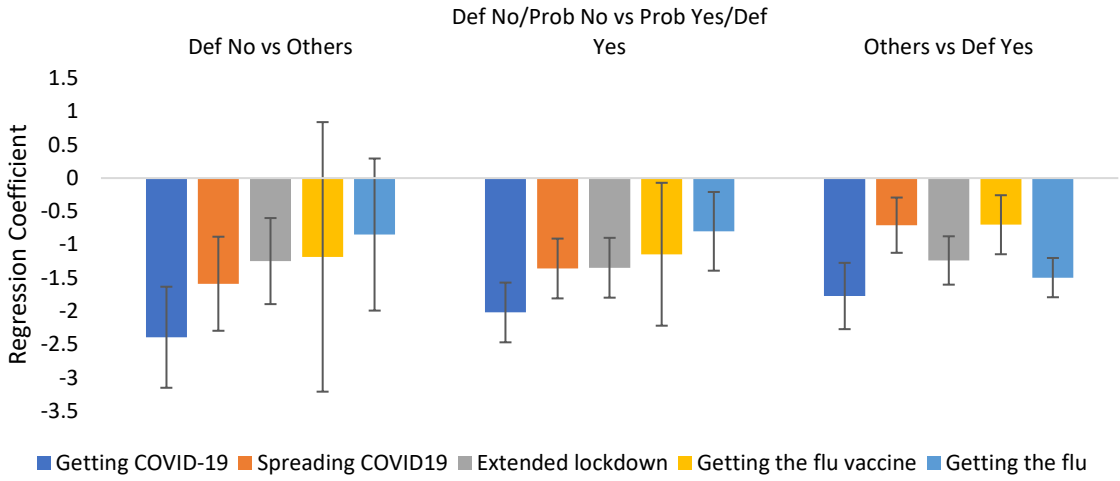


Figure 5. Coefficients and 95% confidence intervals from a generalised ordered logistic regression comparing risk prioritisation by intention to be vaccinated



Note. Negative coefficients indicate that participants who said the COVID-19 vaccine is more concerning than the alternative risk were less likely to be in a more vaccine accepting group.

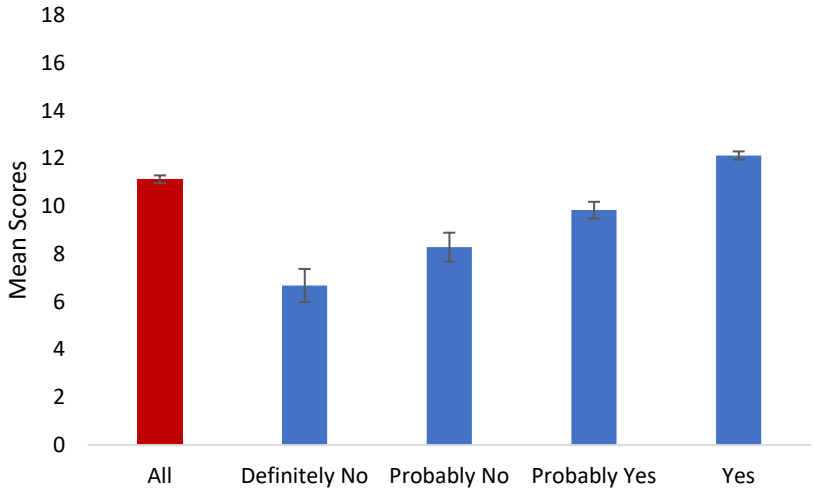
Stage 4. Vaccination Rationale Rating Task

We checked whether the rationale for vaccination differed by intention groups. Among specific vaccination rationales that were presented to participants, the most convincing was the protection of others (M = 6.27, SD = 1.34, range = 1-7) while the least convincing was that it would be a good thing for society (M = 5.78, SD = 1.58, range = 1-7). Vaccine accepting participants gave stronger scores for all five rationales than vaccine hesitant and resistant groups. There was little variation between rationales within the groups (Figure S1).

Stage 5. Test of Knowledge

Participants completed a 13-item multiple-choice test of knowledge about the COVID-19 vaccine and related issues. Some questions had "select all that apply" response options which meant that participants got one point for every correct option they selected or incorrect option they did not select. This generated a possible top score of 18. The total mean score was 11.13, equivalent to 62% (SD = 3.35, range = 1-18). There was substantial variation in knowledge by intention to be vaccinated with the most accepting participants getting an average of 67% correct compared to 37% for the most hesitant (raw mean scores in Figure 6). This trend was present in almost every individual question (see Figure S1).

Figure 6. Mean knowledge scores by intention to be vaccinated



We ran supplementary tests to check if scores on knowledge questions about specific risks and benefits relate to how those risks and benefits are viewed. We could do this for questions on efficacy, the speed of development and novelty of mRNA vaccines. In regression analyses (Table S5 to S7 in Supplementary Material), we find that respondents who could correctly answer questions about the development process of the vaccine were less likely to rank speed of development as a concern and were less likely to mention development as a concern in open text responses, even after controlling for intention. Respondents who correctly identified that the mRNA vaccine research had begun prior to the start of the pandemic gave a lower rank to novelty as a risk of the vaccine. Respondents who knew the efficacy of the Pfizer vaccine (the vaccine that was approved for use in Ireland at the time of data collection) were also more likely to mention protection from COVID-19 in open text responses. People who had higher knowledge scores were also more likely to give both risks and benefits in the open text task, compared to only risks or only benefits (Table S8).

Full Model

Finally, we ran a regression analysis to test for demographic differences between intention groups, and whether these could be explained by knowledge or the perception of risks and benefits of the COVID-19 vaccine. Table 4 shows the results of stepwise generalised ordered logistic regressions with intention to be vaccinated as the dependent variable. The proportional odds assumption was not met in an ordered logistic regression, so we carried out a generalised ordered logistic regression. For ease of interpretation, we combined the two "probably" categories into one to create a three-level variable consisting of will definitely not get vaccinated, will maybe get vaccinated and will definitely get vaccinated. The analysis shows the same sociodemographic differences that have been found in previous studies, namely that older adults, men, and those with higher levels of education are more likely to say they will take the vaccine. People with children and those of minority ethnicities (BAME) are less likely to. Employment status was not associated with intention. Perceived severity of COVID-19 was associated with a stronger intention to take the vaccine, but perceived susceptibility was not. The GRiPs scale for risk propensity was not associated with intention either. We then added in scores on the knowledge test. When knowledge was added to the regression model, the education and BAME effects were no longer statistically significant. In the fourth model, we added in whether respondents gave any risk or any benefit in the open text task as an indicator for how people perceive the trade-off between risks and benefits of the COVID-19 vaccine. When these variables were added to the model, the sociodemographic differences were greatly reduced and became mostly statistically non-significant. Having a child was associated with a slightly lower tendency to be in a probably or definitely yes category compared to the definitely no and being male was associated with a higher tendency to be in a definitely yes compared to a probably no or definitely no category. However, the size of the effect was reduced.

Table 4. Generalised ordered logistic regressions showing relationship between sociodemographic characteristics, knowledge and perception of risks and benefits, and intention to be vaccinated.

DV: Vaccine intention		(1) B (SE)	(2) B (SE)	(3) B (SE)	(4) B (SE)
Def No vs Others	Age (ref: under 40)				
	40-60	0.35 (0.26)	-0.11 (.27)	-0.06 (0.30)	0.16 (.33)
	60+	1.38 (0.40)**	0.67 (.38)	0.63 (0.42)	0.85 (0.48)
	Male	0.05 (0.24)	0.34 (.24)	0.23 (0.28)	-0.06 (0.31)
	Has child	-0.51 (0.25)*	-0.54 (.25)*	-0.62 (0.28)*	-0.63 (0.32)*
	Employed	-0.26 (0.25)	-0.18 (.25)	-0.19 (0.28)	-0.51 (0.31)
	High edu	0.37 (0.25)	0.32 (.25)	-0.27 (0.28)	-0.19 (0.31)
	BAME	-0.55 (0.43)	-0.10 (.45)	0.50 (0.48)	0.83 (0.53)
	Susceptibility		0.04 (.09)	-0.02 (0.10)	-0.01 (0.11)
	Severity		0.81 (.09)***	0.75 (0.11)***	0.69 (0.11)***
	Risk appetite		-0.14 (.13)	0.03 (0.15)	0.10 (0.18)
	Knowledge			0.36 (0.04)***	0.24 (0.05)***
	Gave any risk				-0.37 (0.45)
	Gave any benefit				3.55 (0.56)***
Others vs Def Yes	Age (ref: under 40)				
	40-60	0.08 (0.14)	-0.07 (0.14)	-0.22 (0.15)	-0.22 (0.17)
	60+	0.87 (0.17)***	0.53 (0.18)**	0.43 (0.19)*	0.35 (0.21)
	Male	0.46 (0.11)***	0.57 (0.12)***	0.54 (0.13)***	0.37 (0.14)**
	Has child	-0.30 (0.12)*	-0.35 (0.12)**	-0.32 (0.13)*	-0.28 (0.15)
	Employed	-0.11 (0.12)	-0.05 (0.12)	0.04 (0.13)	-0.04 (0.15)
	High edu	0.30 (0.12)**	0.33 (0.12)**	-0.20 (0.13)	-0.04 (0.15)

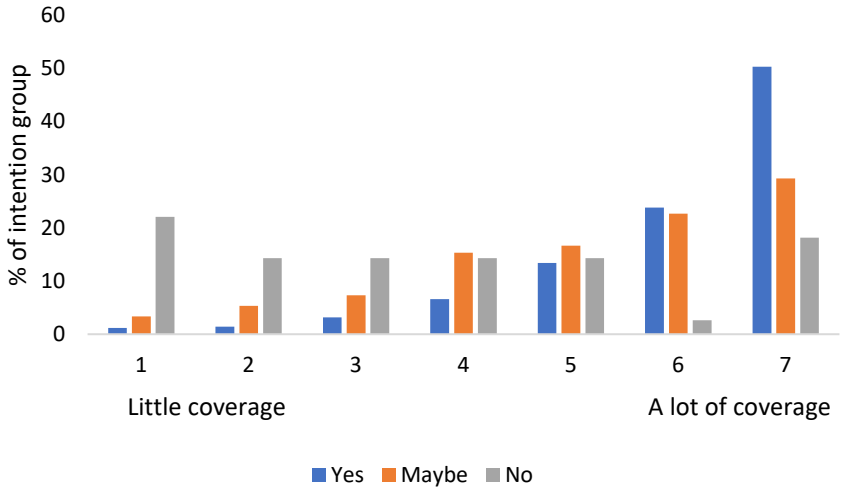
	BAME	-0.91 (0.25)***	-0.82 (0.26)**	-0.20 (0.28)	0.03 (0.33)
	Susceptibility		-0.04 (0.04)	-0.04 (0.05)	-0.03 (0.05)
	Severity		0.25 (0.04)***	0.22 (0.05)***	0.19 (0.05)***
	Risk appetite		-0.15 (0.06)*	-0.05 (0.07)	-0.08 (0.08)
	Knowledge			0.30 (0.02)***	0.28 (0.02)***
	Gave any risk				-1.49 (0.16)***
	Gave any benefit				1.47 (0.16)***

Note. ***p< .001, **p< .01, *p<.05. B = beta-coefficient, SE = standard error.

Additional Analysis

The above analysis reveals that individuals who are more hesitant about taking the vaccine are much less likely to recognise its benefits and have substantially lower levels of knowledge about the vaccine. Given this, we hypothesised that vaccine hesitancy might be associated with not (or no longer) paying attention to news coverage about COVID- The present dataset did not contain measure of media engagement, but we had access to another nationally representative sample of 1,000 participants collected just 2 weeks later. Respondents were asked questions about their daily activities in the previous week,[32] whether they intended to take the COVID-19 vaccine (yes, maybe, no) and how closely they had been following the latest news coverage about COVID-19 in Ireland (1-7 scale). Our hypothesis was confirmed by a very strong relationship between intention to be vaccinated and following news about COVID-19. Figure 7 displays the magnitude of this effect and a generalised ordered logistic regression confirms that the relationship between attending to coverage and vaccine intention is highly significant (maybe or yes versus no, B = 0.67, SE = 0.06, p < .001; no or maybe versus yes, B = 0.48, SE = 0.05, p < .001).

Figure 7. Relationship between watching news coverage on COVID-19 and intention to be vaccinated.



Discussion

This study identifies marked differences in how people who are vaccine hesitant perceive the risks and benefits of the COVID-19 vaccine, compared to those who are vaccine accepting. These differences in how people understand and trade off risks and benefits have a stronger association with intention to receive the vaccine than sociodemographic characteristics. Those who are vaccine hesitant are far less likely to perceive any benefit to the vaccine at all, health or otherwise. They score more poorly on an objective test of knowledge about the vaccine. They nevertheless weight the risk of the vaccine as overwhelmingly greater than other risks, including the risk of getting COVID-19. Furthermore, the

relationship between these assessments and intention is stepwise: people who say they definitely will not get vaccinated know less than those who say they probably will not, who know less than those who say they probably will, who know less than those who say they definitely will. Objective knowledge of the vaccine influences how people perceive the risk and the benefits. People who say they do not follow news coverage about Covid-19 are very much more likely to be hesitant.

Most medical decisions require finding the balance between the risks and the benefits. Often this is not a difficult decision, because a known and salient risk from an illness can be remedied by treatment (e.g., medication) that carries a lesser risk of harm. Vaccination is more psychologically complex because the intervention is preventive rather than curative. Most people who will be vaccinated are unlikely to have COVID-19, so they must decide on the balance between the relative risk of taking the vaccine and the risk of getting COVID-19. Because vaccination prevents harm that may or may not occur, some people see a greater risk and culpability in taking an action that incurs a risk (getting vaccinated) than in not taking an action, even when doing nothing also incurs a risk (i.e. not getting vaccinated and maybe getting COVID-19). This is a common psychological tendency known as omission-commission bias.[33] The bias may be related to our finding that people who say they do not want to be vaccinated perceive getting the COVID-19 vaccine to be more concerning than getting COVID-19, spreading COVID-19 to someone else, being in an extended lockdown, or contracting flu.

One notable finding in the paper was the strength of the relationship between perceiving benefits to the vaccine and intending to get vaccinated. Even one in three of those respondents who said they probably will get vaccinated listed no benefit to vaccination. This compares to only one in ten of those who said they definitely would get vaccinated.

The lack of perceived benefits in those who are more hesitant may be related to people's tendency to see an inverse correlation between risks and benefits. According to the affect heuristic, those who see a greater risk to vaccination, may be expected to see fewer benefits.[27] However, most people, regardless of their intention to be vaccinated, listed some risks to vaccination. This suggests there is an imbalance in how salient the risks of the COVID-19 vaccine are compared to the benefits. Previous work has shown that this can be causal; information that highlights the benefits of something decreases perceived risks and vice versa.[27] Information that highlights the benefits of vaccination increases intention to be vaccinated.[34] Interventions that artificially decrease perceived risk, where that risk does exist, may have ethical implications, but public health communications to balance awareness of the benefits of the COVID-19 vaccine with awareness of the risks may be called for. The argument for this is strengthened by the large knowledge gap that we find between those who are vaccine hesitant and those who are vaccine accepting, and the effect this has on perception of benefits. A public health education campaign focussing on the development process and benefits of the vaccine, particularly using non-traditional sources of media, may go some way to remedying this imbalance.

The strength of this study is the large nationally representative sample. The timing of data collection is also a strength as many previous studies on COVID-19 vaccine intentions were necessarily hypothetical as they were carried out before vaccines had been developed and approved. This research was carried out in January 2021, after vaccines had been approved by regulators in Europe and the United States, but before the full rollout had begun. A limitation of the study is that we are measuring intention and not behaviour. There may be barriers to vaccination that will influence behaviour, regardless of individuals' intentions. However, the size of the mass vaccination campaign is such that communications about the COVID-19 vaccine are needed well in advance of the full rollout and so understanding what influences intentions is useful. A second limitation is that the data is cross-sectional. We cannot determine if the relationships between knowledge, perceived benefits, and

intention are causal. Future research is needed to determine whether communicating benefits and increasing knowledge of the vaccine are effective interventions to increase uptake of the COVID-19 vaccines. Intention to take the vaccine has been increasing globally since the end of 2020.[35] It is possible that data about the real-world impact of the vaccine as well as personal exposure to friends and family taking the vaccine has increased acceptance, but this needs further research to determine the exact cause.

There are two main public health policy implications that result from this research. Firstly, knowledge of the COVID-19 vaccine is associated with greater intention to be vaccinated. Knowledge influences intention independently of education level. From a policy perspective, this is an important finding because it means that most people who plan to accept the COVID-19 vaccine are making an informed decision. We are not aware of any other study that has run a test of objective knowledge about the COVID-19 vaccine on the population. It suggests the need for communications campaigns to share factual information about these vaccines and how they were developed to fill a knowledge deficit in some parts of the population. The finding that people who more closely follow news coverage of COVID-19 are more likely to say they intend to be vaccinated has also been replicated in the U.K. and U.S in studies that were published since we ran this experiment.[36] Finding ways to disseminate information to people who may not watch mainstream news coverage is hence likely to be important. Secondly, many people who are hesitant about the COVID-19 vaccine do not recognise its benefits. There may be a tendency in current communications campaigns to focus on the relative risk of COVID-19 as a rationale for vaccination, but the more important message may be to focus on the benefits, such as that COVID-19 vaccines are effective, safe and will mean a return to normality, or as close as possible. As herd immunity by vaccination is the main goal for most countries, having a populace that can make an informed decision about whether to take the vaccine or not will be critical to its success. This study shows that knowing more about the vaccine, and accurately perceiving its benefits, is associated with a greater likelihood of accepting the vaccine, even while accepting that there are risks. Communicating scientific information accurately, succinctly and in an accessible manner may play a critical role in ensuring that there is sufficient uptake of the COVID-19 vaccine to end this pandemic.

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Supplementary Material

Table S1: Most frequent risks and benefits mentioned in the open text responses for each of the four intention groups

	Risk/Benefit	Percentage of subgroup mentioning it
Definitely Yes	Protection from COVID-19 **(B)**	59%
	Getting back to normality **(B)**	34.8%
	Side effects of the vaccine (non-specific) **(R)**	19.7%
Probably Yes	Side effects of the vaccine (non-specific) **(R)**	38.7%
	Protection from COVID-19 **(B)**	32.8%
	Getting back to normality **(B)**	16.5%
Probably No	Side effects of the vaccine (non-specific) **(R)**	39%
	Protection from COVID-19 **(B)**	24%
	Long-term side effects of the vaccine **(R)**	15%
Definitely No	Side effects of the vaccine (non-specific) **(R)**	36.7%
	Lack of testing of the vaccine **(R)**	27.8%
	General worry about authoritarian control **(R)**	21.15%

Note. B = Benefit and R = Risk.

Table S2. Ordinal Logistic Regression Showing Risk Ranking by Intention to Vaccinate

DV: Intention to be vaccinated	B(SE)
Subgroup safety	-0.14 (0.03)***
Serious side effects	-0.13 (0.03)***
Speed of development	-0.37 (0.03)***
Novelty of vaccine	-0.03 (0.03)
Fear of needles	-0.09 (0.05)
Mild side effects	0.11 (0.03)***
Future side effects	-0.18 (0.04)***

*p < .05, **p < .01, ***p < .001. B = beta-coefficient. SE = standard error.

Table S3. Generalised Ordered Logistic Regression Showing Benefit Ranking by Intention to Vaccinate

	Def No vs Others B(SE)	Def No/Prob No vs Prob Yes/Def Yes B(SE)	Others vs Def Yes B(SE)
Protection from COVID-19	0.33 (0.06)***	0.26 (0.04)***	0.18 (0.03)***
Protection against long COVID-19	0.18 (0.06)**	0.18 (0.04)***	0.15 (0.03)***
Prevent spread of COVID-19	0.24 (0.06)***	0.23 (0.04)***	0.12 (0.03)***
Return to normality	0.09 (0.05)‡	0.09 (0.04)*	0.06 (0.03)*
Economic recovery	0.01 (0.05)	-0.04 (0.04)	-0.001 (0.03)
Protect others	0.003 (0.06)	0.04 (0.04)	0.02 (0.03)
Reduce case numbers	0.13 (0.05)*	0.09 (0.04)*	0.01 (0.03)
Constant	-0.64 (0.44)	-1.20 (0.41)**	-1.51 (0.42)***

*p < .05, **p < .01, ***p < .001. B = beta-coefficient. SE = standard error.

Table S4: Generalised Ordered Logistic Regression Showing Prioritisation of Risk by Intention to be Vaccinated

DV: COVID-19 vaccine is more worrying than…	Def No vs Others B (SE)	Def No/Prob No vs Prob Yes/Def Yes B (SE)	Others vs Def Yes B (SE)
Getting COVID-19	-2.39 (0.39)***	-2.02 (0.23)***	-1.77 (0.25)***
Spreading COVID19	-1.59 (0.36)***	-1.36 (0.23)***	-0.71 (0.21)**
Extended lockdown	-1.25 (0.33)***	-1.35 (0.23)***	-1.24 (0.19)***
Getting the flu vaccine	-1.18 (1.03)	-1.14 (0.55)*	-0.70 (0.23)**
Getting the flu	-0.85 (0.58)	-0.80 (0.30)**	-1.50 (0.15)***
Constant	7.14 (1.10)***	5.23 (0.53)***	2.66 (0.21)***

*p < .05, **p < .01, ***p < .001. B = beta-coefficient. SE = standard error.

Table S5. Logistic regressions testing the effect of knowledge of development on the probability of ranking speed of development in top three risks and mentioning development as a concern in open text responses

	Speed of development ranked in top 3 B (SE)	Mentioned concerns about development in open text B (SE)
Answered Q Correctly (Correct ans.)		
More scientists worked on it (T)	-0.08 (0.12)	0.16 (0.20)
Parallel stages of testing (T)	-0.11 (0.11)	0.23 (0.19)
Large samples available (T)	-0.13 (0.11)	-0.21 (0.20)
Short term testing was reduced (F)	-0.43 (0.15)**	0.19 (0.24)
Long term testing was reduced (F)	-0.30 (0.11)**	-0.80 (0.18)***
Testing stages were skipped (F)	-0.01 (0.21)	0.33 (0.29)
Intention (ref. Def No)		
Prob No	-0.50 (0.33)	-0.95 (0.34)**
Prob Yes	-0.53 (0.29)‡	-1.76 (0.31)***
Def Yes	-1.36 (0.28)***	-2.83 (0.32)***
Constant	1.51 (0.30)***	-0.22 (0.33)

*p < .05, **p < .01, ***p < .001. B = beta-coefficient. SE = standard error.

Table S6. Generalised ordered logistic regression showing effect of answering a question on novelty correctly on the ranking of novelty of the vaccine as a risk

	Probability of ranking novelty as a risk at all B(SE)	Probability of ranking novelty higher than 1 B(SE)	Probability of ranking novelty higher than 2 B(SE)	Probability of ranking novelty higher than 3 B(SE)	Probability of ranking novelty higher than 4 B(SE)	Probability of ranking novelty higher than 5 B(SE)	Probability of ranking novelty higher than 6 B(SE)
Answered Novelty Q Correctly*	-0.33 (0.14)*	-0.42 (0.14)**	-0.25 (0.11)*	-0.32 (0.11)**	-0.13 (0.11)	-0.29 (0.14)*	-0.16 (0.19)
Intention (Ref. Def No)							
Prob No	-0.56 (0.72)	-0.02 (0.58)	-0.21 (0.37)	-0.12 (0.30)	-0.10 (0.33)	-0.15 (0.37)	-0.25 (0.52)
Prob Yes	-0.73 (0.63)	-0.39 (0.46)	-0.26 (0.31)	0.12 (0.25)	0.01 (0.27)	-0.11 (0.31)	-0.04 (0.42)
Def Yes	-1.82 (0.59)***	-1.20 (0.43)**	-0.76 (0.29)**	-0.05 (0.23)	0.17 (0.25)	0.07 (0.28)	-0.09 (0.39)
Constant	3.42 (0.59)***	2.72 (0.43)***	1.48 (0.28)***	0.16 (0.23)	-0.72 (0.25)**	-1.23 (0.28)***	-2.18 (0.29)***

*p < .05, **p < .01, ***p < .001. B = beta-coefficient. SE = standard error.

Table S7. Logistic regression showing effect of answering a question on efficacy correctly on the ranking of protection from COVID-19 and on spontaneous generation of protection from COVID-19 as a benefit in open text.

	Protection from COVID-19 or long COVID ranked in top 3 B (SE)	Mentioned protection from COVID-19 in open text B (SE)
Answered Q Correctly		
Efficacy is 90% (T)	0.18 (0.13)	0.34 (0.13)**
Intention (ref. Def No)		
Prob No	0.51 (0.31)	3.55 (1.03)***
Prob Yes	0.98 (0.26)***	3.84 (1.01)***
Def Yes	1.50 (0.25)***	5.08 (1.01)***
Constant	-0.45 (0.23)	-4.49 (1.01)***

*p < .05, **p < .01, ***p < .001. B = beta-coefficient. SE = standard error.

Table S8. Logistic regression showing likelihood of mentioning both risks and benefits in the open text task given scores on the objective knowledge task.

DV: Gave risk and benefit in open text	B (SE)
Knowledge score	0.12 (0.02)***
Intention (Ref: Def No)	
Prob No	2.33 (0.63)***
Prob Yes	2.71 (0.60)***
Def Yes	2.29 (0.60)***
Constant	-4.10 (0.61)***

*p < .05, **p < .01, ***p < .001. B = beta-coefficient. SE = standard error.

Figure S1. Rationale for vaccination by intention to be vaccinated

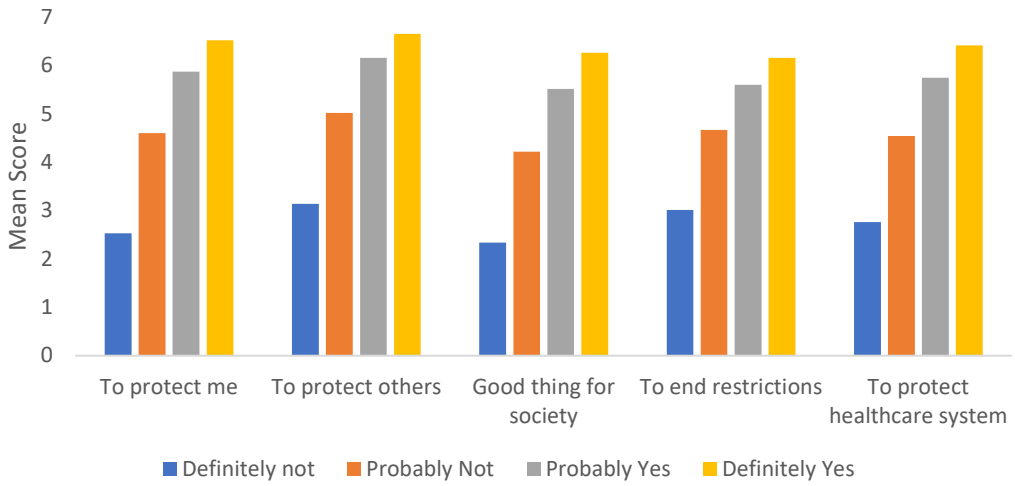

Figure S2. Scores on each question in the test of knowledge by intention