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# The causal effect of a health treatment on beliefs, stated preferences and memories

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**Abstract**

The paper estimates the causal effect of a health treatment on patients' beliefs, preferences and memories about the treatment. It exploits a natural experiment which occurred in the United Kingdom during the COVID-19 vaccination campaign. UK residents could choose to opt into the vaccination program, but not which vaccine they received. The assignment to a vaccine offered little objective information for learning about its qualities, but triggered strong psychological demand for reassuring beliefs. We surveyed a sample of UK residents about their beliefs on the different COVID-19 vaccines *before* and *after* receiving their jab. *Before* vaccination, individuals exhibit similar prior beliefs and stated preferences about the different vaccines. *After* vaccination, however, they update their beliefs overly optimistically about the safety and effectiveness of the vaccine they received, state that they would have chosen it if they could, and have distorted memories about their past beliefs. These results cannot be explained by conventional experience effects. At the aggregated level, they show that random assignment to a health treatment predicts a polarization of opinions about its quality. At the individual level, these findings provide evidence in line with the predictions of motivated beliefs and over-inference from weak signals in a real-world health setting.

*Keywords:* Natural experiment | Behavioral health economics | COVID-19 | Motivated beliefs | Motivated memory | Over-inference
*JEL:* I12, I18, D91

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## 1. Introduction

Beliefs are powerful predictors of decisions. This is true also in the health sector, where patients' beliefs about a health treatment predict their subsequent decisions of taking or avoiding it. Evidence abounds across a wide range of treatments, from Type II diabetes to HIV, from depression to asthma (see Horne et al., 2013, for a meta-analytic review). Overall, beliefs play a bigger role in the adherence to a treatment than demographic and clinical factors (Horne and Weinman, 1999), and even unintentional non-adherence (due to forgetting or carelessness) can be predicted by patients' beliefs about how safe and effective their treatment is (Gadkari and McHorney, 2012).

Little is known, however, about the converse: how does a health treatment influence subsequent beliefs? Investigating this question is not trivial. When confronted with important health decisions, people typically have agency and choose what they believe to be the best option for them. Undergoing a specific treatment is thus an endogenous choice, with self-selection problems that prevent causal identification. To make progress, we exploit a natural experiment which occurred in the UK during the COVID-19 pandemic, where individuals were *exogenously* assigned either the Pfizer or the Moderna vaccine. We use this random variation to study the causal effect of getting a vaccine on patients' beliefs, preferences and memories about that vaccine.

We find that, after vaccination, individuals exhibit optimistic beliefs about the characteristics of their own vaccine, compared to those who received another vaccine. When asked to make hypothetical choices, many change them in favor of their own vaccine.[1] When asked about what they used to think before receiving the vaccine, they tend to distort their memories in favor of the vaccine they were assigned to. These effects can be causally attributed to the injection of a specific vaccine. At the aggregated level, this asymmetric updating (each group updates beliefs about its own vaccine in an overly optimistic way) generates a dynamic of belief divergence and thereby shows that beliefs polarization can emerge as a consequence of exogenous assignment of individuals to different treatments.

This study was made possible by a particular institutional setting in the UK during the COVID-19 vaccination campaign. UK residents could choose to opt into the vaccination program, but not which vaccine they received. Once age and health restrictions taken into account, the assignment to a specific vaccine was exogenous. Although the majority of people declared that they would choose a type of vaccine (Pfizer) if they had the choice, about 20% of them were assigned to another one (Moderna). This event was likely to trigger strong psychological needs, that pointed in different directions according to the received vaccine. We interviewed 640 UK residents about their beliefs on the different COVID-19 vaccines *before* and *after* receiving their jab, and study how people who received Moderna (treatment group) update their beliefs compared to those who received Pfizer (control group). We focus on two dimensions of the Moderna vaccine: its safety –is it dangerous?–, and its effectiveness –is it useful?–; as well as on its desirability as perceived ex-ante and ex-post.

We document three main results. First, we observe that individuals overly optimistically update their beliefs about the vaccine they received. *Before* vaccination, individuals hold similar prior beliefs about the different vaccines. *After* vaccination, however, those who received Moderna believe it to be safer and more effective than they used to think, and more so than those who received Pfizer. Such asymmetric updating is observed also when controlling for personal experience and socio-demographic characteristics.

[1] The questions were "If you had the choice, which vaccine would you choose to receive?" (Wave 1) and "If you have had the choice, which vaccine would you have chosen to receive?" (Wave 2). Although economists typically favor data derived from incentivized choices, our analysis relies on stated preferences elicited from hypothetical scenarios. This represents a limitation of our approach, as stated and actual choices might differ, but it was the only implementable option in this context. See Benjamin et al. (2012) for a honest discussion of the limits and potentials of hypothetical choices in surveys.

It is not explained by some peculiarities of the Moderna vaccine, as beliefs about Pfizer's safety display a similar (reversed) pattern, and no difference emerges for beliefs about vaccines that were not assigned in our sample, i.e. AstraZeneca and Janssen. Second, we show that this observed asymmetric updating is driven by individuals who were particularly skeptical about a vaccine but then were assigned to it, and by individuals who were particularly keen on a vaccine but then did not receive it. This is more than an instance of simple regression-to-the-mean: even among people exhibiting low (resp. high) priors, we observe a significant asymmetry between those who received different vaccines. Third, we find that people adapt not only their beliefs, but also their hypothetical choices and the memory of their past beliefs. Before vaccination, only 7% of people declare that they would choose Moderna. Later on, about 25% of those who received Moderna state that they would have chosen this vaccine if they have had the choice. Moreover, after vaccination, those who received Moderna recall it to be safer and more effective than those who received Pfizer.

These results meet the predictions of Caplin and Leahy (2019)'s model, according to which individuals' desires causally impact their beliefs, and thus a divergence in desires will result in a divergence in beliefs. In sum, people seem to believe what they would like to be true. This phenomenon, known as *motivated beliefs* (Kunda, 1990; Bénabou, 2015; Zimmermann, 2020; Möbius et al., 2022) or *wishful thinking* (Mayraz, 2011; Engelmann et al., 2019; Caplin and Leahy, 2019; Mayraz, 2019) appears whenever individuals update their beliefs in a fashion that is overly favorable for themselves given the available information.[2] Identifying motivated beliefs in the field −and particularly in the health domain−, is far from simple. First, because the desire for good health is innate and unchanging, it is almost impossible to observe a change in desires, and thus a change in beliefs. As a consequence, one can often only observe the resulting beliefs.[3] Second, because individuals decide according to their preferences, they have a priori no interest in changing their beliefs or memories. In our survey, *before* vaccination, individuals' desire for good health was likely not geared toward a specific vaccine. *After* vaccination however, it became vaccine-dependent. This exogenous event motivates beliefs in different directions, and offers a rare opportunity to testbed the predictions of motivated beliefs in the real world. We focus our analysis on Moderna because, among those who received it, only a minority (7%) would choose it ex-ante (we report the same analyses for Pfizer in the SI Appendix). To the best of our knowledge, this setting provides the closest replication of a treatment-control test of motivated beliefs in a real-world health setting.

Yet, there is actually another potential explanation for our findings: individuals may update their beliefs based on their (poorly informative) personal experience with their vaccine. The ambiguity in the interpretation of the underlying mechanism comes in part from the fact that beliefs and motivations are fundamentally unobservable, and in part from the main limitation of this study, i.e., that individuals in the treatment and control group arguably did not receive *exactly* the same information. In the weeks after the jab, participants might have actively looked for different information based on the vaccine that they received. Furthermore, they had some personal experience about the safety and effectiveness of one vaccine only. In the section "Mechanisms", we show that individuals do not display enhanced knowledge about the benefits of their own vaccine, nor they reveal a preference for reading about those benefits in an information-selection task. We also show that a mere Bayesian updating could not explain the size of the update. Since the mean prior subjective belief of experiencing severe side effects was 0.00001%, experiencing no severe side effects offers little

[2]That is, they are deluded in the perception of the situation and therefore evaluate their outcome as more favorable than an impartial observer would do. This process is akin to"desirability bias" (Krizan and Windschitl, 2009), "desirability effect" (Bar-Hillel and Budescu, 1995), the "good news-bad news effect"(Eil and Rao, 2011) and "rationalisation" (Elster, 1983). It encompasses "unrealistic optimism" (Weinstein, 1980) and "optimism bias" (Sharot et al., 2011), which refer to the wishful prediction of future events.

[3]See, for example, Weinstein et al. (2005); Jansen et al. (2011); Hanoch et al. (2019); Brnstrm and Brandberg (2010).

objective information for Bayesian updating. Nevertheless, we cannot rule out the possibility of some forms of purely cognitive (i.e., stripped of motivational factors) non-Bayesian update from their personal experience. This interpretation is motivated by recent evidence that people *over*-infer from weak signals (Augenblick et al., 2021). Over-inference might be enhanced by other contextual factors, such as the first-hand nature of information (Conlon et al., 2022), and the salience of the vaccination experience itself (Gennaioli and Shleifer, 2010; Bordalo et al., 2018, 2020).

In designing our study, we made a methodological decision that deserves discussion. We decided to focus on beliefs as the main variable of interest, and we carefully constructed the online questionnaire accordingly: we asked individuals about their beliefs at the beginning of the survey, about their memories just after and about their hypothetical choice later on. Beliefs, memories and preferences are deeply intertwined, and our design does not allow to pinpoint to what extent, say, motivated memory bent current beliefs or the other way round. Such mediation analyses have been explored elsewhere (Bordalo et al., 2022) and are beyond the scope of this study. Nevertheless, all reported effects can be causally associated to the administration of a specific vaccine.

This study belongs to the emerging field of behavioral health economics (Cox et al., 2016; Galizzi and Wiesen, 2018). The results reported herein contribute to identify the behavioural factors that impact the demand-side of health treatments. They do so in two ways.

First, they clarify the dynamic of beliefs formation about health treatments in general, and COVID-19 vaccines in particular. Two important differences are worth mentioning. With respect to medical choices, we differ from the literature that investigated how beliefs impact the willingness to get tested, cured, or vaccinated (Oster et al., 2013; Ganguly and Tasoff, 2017). Our study explores the *reversed* causality. We look at how the effect of getting vaccinated in turn impacts beliefs about vaccines. With respect to the burgeoning literature on beliefs about COVID-19 vaccines, we differ from the studies that identified the determinants of vaccination hesitancy (Jamieson et al., 2021; Kaplan and Milstein, 2021; Mahmud et al., 2021) and that compared various types of interventions to reduce it (Ashworth et al., 2021; Campos-Mercade et al., 2021; Schneider et al., 2023). Conversely, we look at the dynamic of beliefs as a *consequence* of COVID-19 vaccination. This was made possible by considering differences in individuals' beliefs about each specific vaccine, rather than studying beliefs toward COVID-19 vaccinations in general (all vaccines confounded).

Second, our results provide evidence in line with the predictions of motivated beliefs in a *real-world health setting*. When the answer to a medical question has different comforting properties to different people, beliefs are updated in the direction of the most reassuring option. Motivated beliefs have been documented as a potential cause of belief divergence either in artifactual situations (Schwardmann et al., 2022) or for individuals with different ex-ante beliefs, e.g. republican and democrats (Kahan, 2012; Levin et al., 2023). In the field, a few natural experiments documented that different beliefs tend to *converge* after a public event that affects everyone, e.g. an election (Beasley and Joslyn, 2001; Mullainathan and Washington, 2009). In contrast, we study a rare setting where people with *similar* beliefs are privately and randomly exposed to two *different* treatments, whose desirability depends on *public* (scientific) information. In this context, predictions of confirmation bias (Lord et al., 1979) and attribution theory (Bradley, 1978) do not apply, since individuals share similar priors and know that the vaccination outcome is outside of their control.[4]

There are very few studies that can identify a psychological mechanism by finding the data to be incon-

[4]These results were not trivial ex-ante, as motivated beliefs may seem unwarranted when individuals cannot choose their outcome and therefore bear no responsibility for what happens to them. Instead, theories of cognitive dissonance (Festinger, 1962; Suzuki, 2019) and of rationalization of past decisions (Eyster et al., 2021) relate to actual choices. For instance, Suzuki (2019, p.25) argues that "when there is no choice, the decision-maker has no room to experience post-decision dissonance as her choice cannot be 'wrong'".

sistent with all other potential explanations, and ours is no exception. As already mentioned, we explore the role of motivated beliefs since the vaccination plausibly triggered strong psychological demand for reassuring beliefs, but our results are also consistent with the hypothesis that individuals simply learnt too much from their positive vaccination experience.[5] Further research will be needed to pin down the psychological micro-foundation of the pattern that we document. Yet, the resulting beliefs are clear. We observe that when different people are assigned to different health treatments, beliefs tend to diverge. This divergence can be predicted, with corresponding implications for public policies, such as informing the debate on whether people should be able to choose the type of their vaccine during an epidemic.

We organize the paper as follows. In Section 2 we describe the natural experiment and the fundamental features of our longitudinal survey; we also spell out the identifying assumptions and test them. In Section 3, we describe the main results about beliefs updates, memories and states preferences. Section 4 discusses the potential mechanisms underlying the results and Section 5 concludes.

## 2. The natural experiment

### *2.1. Timeline*

The natural experiment consisted in two waves.

In Wave 1 (June-July 2021), we interviewed over 1,000 UK residents via Prolific (Palan and Schitter, 2018), based on the pre-screening criterion that they should not have received a vaccine yet. In the UK, the vaccination campaign had different rules based on age. We interviewed only people between 18 and 29 years old because they became eligible for vaccination in June 2021 (thus, mitigating self-selection problems), and because they were eligible for two vaccines only, Pfizer-BioNtech or Moderna (thus, reducing the dimensionality problem to one pairwise comparison). Participants had to answer a survey made of 3 blocks of questions. In the first block, they had to state their beliefs regarding the safety and effectiveness of each of the four vaccines that were available at that time in the UK (Pfizer-BioNtech, Moderna, Oxford-AstraZeneca, Janssen). Beliefs were elicited using cardinal probability scales and ordinal relative ranking. In the second block, participants were asked to report which vaccine they would choose to receive if they had the choice, as well as their estimated likelihood to receive each vaccine. Finally, the third block asked for demographic variables (age, gender, area of residence, health conditions, etc.).

In Wave 2 (November-December 2021), we asked the same participants to complete a second survey that consisted in answering the same blocks of questions. Thus, if we compare beliefs elicited in Wave 1 and in Wave 2 we can identify individuals who update their beliefs differently because they were assigned to different vaccines. We additionally asked participants: *(i)* to remember what they thought at the time of Wave 1; *(ii)* to report some details of their experience with COVID-19 and with the vaccine; *(iii)* to choose a piece of scientific information about vaccines that they wanted to read; and *(iv)* to take a short quiz designed to assess their general knowledge about COVID-19 vaccines. Figure 1 displays the timeline of the natural experiment. Table S1 in SI Appendix summarises the main variables that we measured in the two waves, and Tables S2-S5 in SI Appendix reports the complete questionnaires.

### *2.2. Identifying a causal effect of vaccine assignment on beliefs updating*

Unraveling a causal link between assignment to a specific vaccine and subsequent belief updating crucially depends on a *random* assignment of vaccines. "Random" in the sense that the assignment to a vaccine was uncorrelated with observable characteristics, ex-ante beliefs and stated preferences. In the UK, vaccines were

[5] 99% of the sample reported that they experienced no severe side effects.

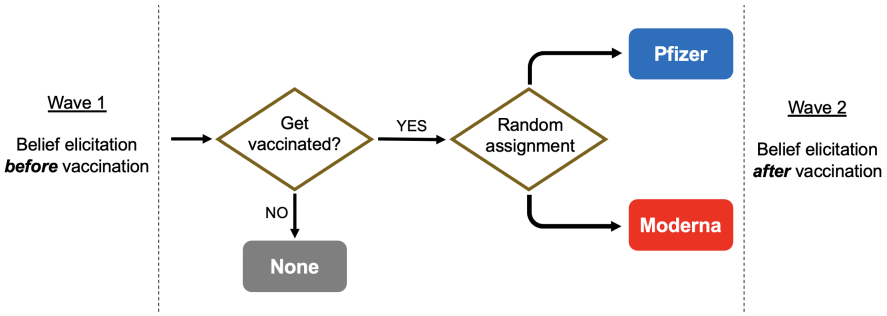


Figure 1: Timeline of the natural experiment

*Reading note:* UK residents could choose to get vaccinated or not, but not which vaccine they received. Pfizer and Moderna were randomly allocated. In Wave 1 (June-July 2021), we elicited beliefs about COVID-19 vaccines based on the pre-screening criterion that individuals should not have received a vaccine yet. In Wave 2 (November-December 2021), we asked the same participants to complete a second survey eliciting the same beliefs. Comparing beliefs elicited in Wave 1 and in Wave 2 allows identifying belief updating.

distributed subject to nationally and locally determined allocation principles, and to ensure equity in access (NHS England, 2021). No information was publicly disclosed regarding how many doses of which vaccine were delivered to a vaccination center. The same vaccination center could use different vaccines on the same day, and at the moment of booking an appointment, users had no information on which vaccine they will receive. On March 12th 2021, Professor Jonathan Van-Tam, Deputy Chief Medical Officer for England, made the following statement: "COVID vaccines are made at different speeds by different manufacturers. It is not possible for vaccination centers to choose the stock they are allocated and not possible for individuals to choose a vaccine."[6]

At the beginning of Wave 2, we asked participants whether or not they could choose the vaccine they received. There was no reason to lie since participants could complete the survey and receive payment regardless of their answer to this question. Overall, we drop from the analysis 65 participants who reported they could choose their vaccine (see SI Appendix, section A1 and Table S6 for details). In the UK, patients found out the type of their vaccine a few minutes *before* (and not after) the injection: in theory, they could refuse to complete the procedure, book another appointment, and try their chances again. In the survey, some participants took the time to explain why they could choose their vaccine, but none of them reported that they refused a vaccination. Among them, 12 could do so for medical reasons, while 7 went to a vaccination center where they expected to deliver only the vaccine that they wanted (leveraging information from peers or other unofficial sources). We suspect that not all the remaining 46 participants could actually choose their vaccine, and that such a high number was due to a misunderstanding in our questionnaire. Indeed, several respondents reported that they could "choose" in a certain sense, just because they were not eligible for all vaccines. For instance, participant n.954 wrote: "I was young for the Astrazeneca so that was partly a choice as I could refuse it but other than that I didn't get to choose". Regrettably, this was not the intended meaning of our question. Since most participants did not leave any further comment, we might have been unable to identify many of these cases.

As we will show in the Results section, we observe no difference in the ex-ante beliefs between the Pfizer group and the Moderna group. Although individuals' beliefs measured in Wave 1 could be slightly different from those on the day of the assignment to the treatment, the time lapse was reasonably short: over two-thirds of the vaccinated sample report that they got their first jab within five weeks from their participation

[6]Source: `https://healthmedia.blog.gov.uk/2021/03/12/covid19vaccines-faqs/`.

in Wave 1. In fact, the UK vaccination campaign was rolled out by age groups, and we fielded Wave 1 right after the under-30-year-old group became eligible for vaccination. Based on IP addresses, we also elicit longitude and latitude of every respondent and find no detectable geographical pattern in the assignment to a vaccine (Moran's I is statistically null).

### *2.3. Final sample*

Details of the study and procedures can be found in the SI Appendix, section A1. All of the participants gave their informed consent at the beginning of the study. The Research Ethics Committee of the Paris Institute of Political Studies reviewed and unanimously approved the procedures (n.2021-023). Subjects were recruited through Prolific and were informed that they may be recontacted to complete a second questionnaire a few months later. 1,285 individuals (458 males; mean age = 24.4) completed Wave 1; 951 completed Wave 2 (310 males; mean age = 23.4), and 856 (282 males, mean age = 23.3) passed the exclusions restrictions detailed in the SI Appendix, section A1. The statistical power analysis is described in the SI Appendix, section A8. Participants received £0.73 and £1.2 for their participation to Waves 1 and 2, respectively. These payments correspond to hourly rates of about £11 and are well above the average payment offered on Prolific.

Our final sample is made of 856 participants, which is relatively small but sufficient to detect a small-medium effect (see SI Appendix, section A8). 306 received no vaccine between Wave 1 and Wave 2. We refer to them as the group NONE. 457 received the vaccine Pfizer-BioNtech ("Pfizer" henceforth) and 93 received the vaccine Moderna. We refer to them as the groups PFIZER and MODERNA, respectively.[7] The NONE-PFIZER-MODERNA shares in our sample mirror the vaccination roll-out statistics in the UK population in the Fall 2021 (Rough and Powell, 2021).

In the analyses, we study how people who received MODERNA (treatment group) vs. PFIZER (control group) update their beliefs differently regarding Moderna. We focus on beliefs about Moderna because, ex-ante, only a minority would choose it, relative to Pfizer. The SI Appendix (section A2, Figures S1, S4 and Table S7) reports the same analyses regarding beliefs about Pfizer's vaccine. Note that NONE is neither a treatment nor a control since people self-selected into this group. We display the beliefs update of unvaccinated individuals with a descriptive purpose, and not for causal identification.

## 3. Results

Herein, we analyse how people who received different vaccines change their beliefs, stated preferences and memories. Leveraging on the exogenous allocation of the Pfizer and Moderna vaccines, we are able to causally identify the determinant of these asymmetric changes. We will focus on belief updating first.

### *3.1. Before vaccination, individuals exhibit similar beliefs about Moderna vaccine.*

In Wave 1, individuals do not know which vaccine they will be allocated to. Ex-ante, there is thus no reason to observe different beliefs between the PFIZER group and the MODERNA group. Importantly, this does *not* mean that the two vaccines should be considered equally good by the participants. It means that ex-ante beliefs about how good each vaccine is should not differ between the PFIZER group and the MODERNA group.

[7] Throughout the article, we will use small caps (PFIZER, MODERNA) to refer to the vaccine that individuals received, and standard typeface (Pfizer, Moderna) to refer to the vaccine that individuals expressed their beliefs, choices and memories about. Therefore, "PFIZER's beliefs about Moderna" should be understood as the beliefs about Moderna expressed by the group of individuals who received (or will receive) Pfizer.

Vaccines' safety was measured on a logarithmic scale, where people reported the incidence of significant side effects from 1 out of 10 (very unsafe) to 1 out of $10^7$ (very safe). Options were chosen on a labelled 1-7 Likert scale. According to scientific evidence at the time of the survey, the correct answer was around 4 for both vaccines (Baden et al., 2020; Polack et al., 2020). Vaccines' effectiveness was measured on a percentage scale, where people reported how effective they consider each vaccine, from 0% (completely ineffective against severe COVID-19 and death), to 100% (completely effective against severe COVID-19 and death). According to scientific evidence, the correct answer was around 95% for both vaccines (Bruxvoort et al., 2022; Tartof et al., 2021).

Figure 2 *left* displays the average reported beliefs about Moderna's safety. Before receiving a vaccine, the average belief of individuals regarding Moderna is not significantly different between individuals that *will* receive PFIZER ($Mean^{\text{PFI}}_{Mod,saf,1} = 5.27$) and individuals that *will* receive MODERNA ($Mean^{\text{MOD}}_{Mod,saf,1} = 5.30$, $p = 0.851$, t-test). Similarly, there is no significant difference between the two groups regarding the average reported beliefs about the effectiveness of Moderna (see Figure 2 *right*, $Mean^{\text{PFI}}_{Mod,eff,1} = 75.3$, $Mean^{\text{MOD}}_{Mod,eff,1} = 77.1$, $p = 0.365$, t-test). In both graphs, the group NONE reports much lower levels of perceived safety and effectiveness. This happens because individuals decide to get vaccinated or not, and those with lower confidence in the safety and/or effectiveness of (any type of) vaccination treatment in Wave 1 self-select out of the treatment itself in the following months.

These first results show that the groups PFIZER and MODERNA hold ex-ante identical beliefs about the characteristics of the Moderna vaccine, whether it be safety or effectiveness.

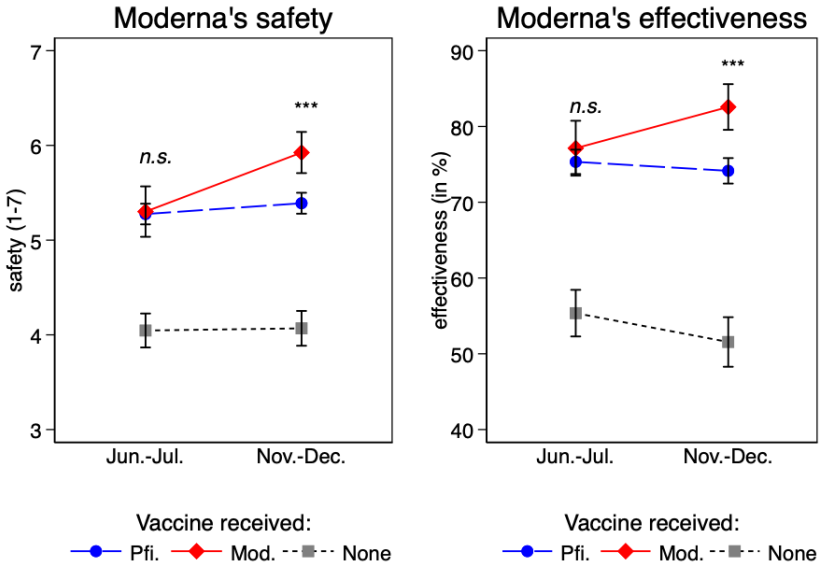


Figure 2: Beliefs about Moderna's vaccine

*Reading note:* Jun.-Jul. corresponds to belief elicitation *before* vaccination. Nov.-Dec. corresponds to belief elicitation *after* vaccination. Safety is measured on a labelled logarithmic scale, from 1 (incidence of significant side effects = 1 out of 10) to 7 (incidence of significant side effects = 1 out of $10^7$). Effectiveness is measured on a percentage scale, from 0% (completely ineffective against severe COVID-19 and death), to 100% (completely effective against severe COVID-19 and death). Error bars refer to 95% confidence intervals.

*3.2. After vaccination, individuals who received Moderna exhibit upward beliefs updating about the safety and the effectiveness of Moderna vaccine. This is not the case of individuals who received Pfizer.*

In Wave 2 (Figure 2 *left*), the average beliefs of individuals regarding Moderna's safety is significantly higher for individuals who received MODERNA ($Mean^{\text{MOD}}_{Mod,saf,2} = 5.92$) than for individual who received PFIZER ($Mean^{\text{PFI}}_{Mod,saf,2} = 5.39$, $p < 0.001$, t-test). A similar asymmetric pattern is observed regarding the effectiveness of the vaccine (see Figure 2 *right*). *After* vaccination, the average beliefs of individuals regarding Moderna's effectiveness is significantly higher for individuals who received MODERNA ($Mean^{\text{MOD}}_{Mod,eff,2} = 82.6$) than for individuals who received PFIZER ($Mean^{\text{PFI}}_{Mod,eff,2} = 74.1$, $p < 0.001$, t-test).

These results are supported by the regression analyses illustrated in Table 1. We regress the posterior belief about Moderna on the treatment variable (treatment = MODERNA), the prior belief, and a set of covariates, including experiencing severe COVID-19 and severe side effects from the vaccine. When only two points in time are available, this estimation with lagged-dependent-variable adjustment is a common alternative to difference-in-differences. While difference-in-differences relies on the parallel trend assumption (which is very likely to hold, but not testable, in our two-wave panel), the causal identification of our lagged model relies on the assumption of ignorability conditional on past outcomes. That is, in the absence of treatment, the outcomes for both the treated and control groups would exhibit the same (conditional) distributions given the prior (Ashenfelter, 1978; Ding and Li, 2019).[8]

Between Wave 1 and Wave 2, people who received MODERNA update their beliefs about Moderna's safety more positively (+0.52, $p < 0.001$; t-test) than those who received PFIZER, and this conditional on having the same initial belief, on not having experienced side effects and a set of other control variables which could plausibly affect belief updating. The same pattern is observed regarding Moderna's effectiveness. Those who received MODERNA update their beliefs about Moderna's effectiveness more positively (+6.32, $p < 0.001$; t-test) than those who received PFIZER, and this conditional on having the same initial belief and other covariates. More details are reported in SI Appendix, section A3.

Evidence of asymmetric belief updating is also observed when considering ordinal (rather than cardinal) measures of safety and effectiveness. Respondents were asked to rank vaccines from the safest to the least safe, and from the most to the least effective. This question enables to elicit which vaccine was considered *better*, independently of how *good* it was considered. Figure 3 *(left)* compares the fraction of respondents who consider Moderna safer than Pfizer (and vice versa). In Wave 2, the percentage of participants who ranked Moderna as safer is much higher among individuals who received MODERNA than among those who received PFIZER (-0.45, $p < 0.001$, t-test). In contrast, there is no statistical difference in Wave 1 (-0.03, $p = 0.412$, t-test). Figure 3 *(right)* displays a similar pattern for Moderna's effectiveness. Said differently, while about only 1 respondent in 8 considered Moderna to be safer or more effective than Pfizer ex-ante, about half of those who received MODERNA consider it the safest and most effective option ex-post.

Looking at the whole distribution of beliefs (rather than the mean) corroborates that individuals disproportionately shifted their beliefs upward about the vaccine they received. Figure 4 reports the cumulative distribution of beliefs about the safety and effectiveness of Moderna. The figure shows that, in Wave 2, MODERNA group's beliefs about Moderna first-order stochastically dominate PFIZER group's beliefs ($p < 0.001$, Somers' D). In contrast, in Wave 1, the distributions were almost identical ($p = 0.738$ for safety and $p = 0.313$ for effectiveness, Somers' D). Concretely, it means that a randomly selected respondent who received MODERNA is 27% more likely to have a higher belief about Moderna's safety and 30% more likely to have a higher belief about Moderna's effectiveness, than a randomly selected respondent who received PFIZER.

[8]Incidentally, if the ignorability condition is violated (but the parallel trend hypothesis is valid), the regression coefficient associated with the treatment variable would *under*-estimate the true effect (see Angrist and Pischke, 2009, p.184).

Table 1: Regressions of the posterior beliefs about Moderna with lagged-dependent-variable adjustment

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Dep.var.: safety | | Dep.var.: effectiveness | |
| Treatment = Moderna | 0.54*** | 0.52*** | 8.43*** | 6.32*** |
| | (0.13) | (0.13) | (2.02) | (1.91) |
| Male | | 0.15 | | 3.50** |
| | | (0.11) | | (1.61) |
| Age | | -0.02 | | 0.02 |
| | | (0.02) | | (0.25) |
| Student | | 0.14 | | 1.70 |
| | | (0.10) | | (1.59) |
| Pregnant/health conditions | | 0.21 | | -0.23 |
| | | (0.19) | | (2.83) |
| Vaccine quiz score | | 0.15** | | 1.31 |
| | | (0.07) | | (1.13) |
| Hospitalized because of COVID-19 | | -0.11 | | 2.84 |
| | | (0.14) | | (2.14) |
| Tested positive after vaccine | | -0.40** | | -4.93* |
| | | (0.18) | | (2.76) |
| Had severe side effects | | -0.59 | | -4.28 |
| | | (0.40) | | (6.03) |
| Prior | | 0.37*** | | 0.36*** |
| | | (0.04) | | (0.04) |
| Time dummies | | ✓ | | ✓ |
| Geographical dummies | | ✓ | | ✓ |
| Constant | 5.39*** | 3.43*** | 74.14*** | 43.13*** |
| | (0.06) | (0.52) | (0.83) | (8.16) |
| N | 550 | 545 | 550 | 545 |
| $R^2$ | 0.028 | 0.242 | 0.031 | 0.234 |

*Reading note:* Linear regressions of posterior belief on the treatment and other covariates. Columns (1)-(2) refer to beliefs about safety; columns (3)-(4) refer to beliefs about effectiveness. Standard errors are in parentheses. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$. Specifications (2) and (4) include the following covariates: dummies = 1 if knows someone who had severe side effects / tested positive after the (same) vaccine, weekly time dummies for the date of participation in Wave 2, monthly time dummies for the date the last dose was received, and geographical dummies for the country of residence (England, Scotland, Wales or Northern Ireland).

When we replicate the analysis for beliefs about Pfizer, we find evidence of asymmetric belief updates about its safety, but not about its effectiveness (see SI Appendix, section A2). This result should be interpreted in light of the timing of Wave 2: the hit of the COVID-19 omicron variant in November-December 2020 infected many vaccinated people and could have compressed the belief premium in Pfizer's effectiveness, since beliefs about Pfizer's effectiveness were, ex-ante, higher. Section A2, in the SI Appendix, presents a more thorough discussion.

Finally, section A4 and Figure S6 in the SI Appendix shows that ex-post beliefs about AstraZeneca and Janssen are not significantly different between the Moderna and Pfizer groups. There is a slight update between Wave 1 and Wave 2, but this update is common to the Moderna and Pfizer groups. This placebo test corroborates that belief divergence about Moderna can be causally attributed to the fact of receiving that specific health treatment.

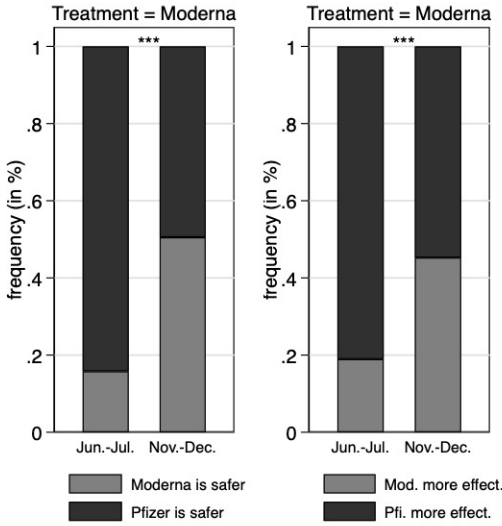


Figure 3: Relative Safety and Effectiveness: Moderna vs Pfizer

*Reading note:* The *left* part of the figure shows the share of individuals who ranked Moderna as safer than Pfizer (or vice versa), based on the answers to the question: "According to you, which one of the vaccines is the safest? Please move the items below to rank them from the safest (1) to the least safe (4) vaccine". The *right* part of the figure shows the share of individuals who ranked Moderna as more effective than Pfizer (or vice versa), based on the answers to the question: "According to you, which one of the vaccines is the most effective? Please rank them from the most effective (1) to the least effective (4)".

### *3.3. Asymmetric belief updating is driven by individuals who experienced a mismatch between their initial priors and the vaccine they received.*

The belief updating of individual who received Moderna vs. Pfizer shows that the received vaccine predicts belief updating. We now investigate the role of priors *within* each treatment group. We start by using regression analysis and run the same analysis described in Table 1, but adding an interaction term between priors and treatment. Table 2 reports a summary of the results for four linear regressions (safety and effectiveness, with and without controls). In all specifications, the estimated coefficient associated with the interaction term is significant, thus indicating that the slope of the relationship between prior and posterior depends on the treatment. Said differently, individuals with different priors update differently depending on having received the Moderna or the Pfizer vaccine. The estimated coefficient associated with the treatment is positive (indicating that the treatment is associated with a higher posterior), the one associated

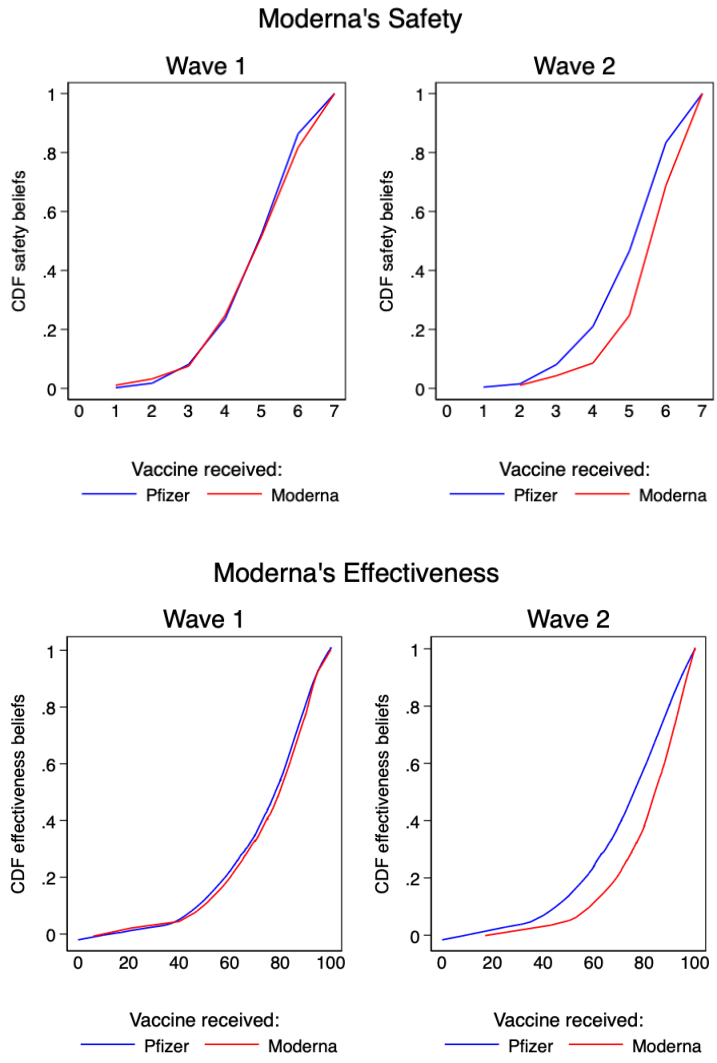


Figure 4: Cumulative density function of beliefs about Moderna

*Reading note:* The figure compares the cumulative distributions of beliefs of the Moderna and Pfizer groups before and after receiving the vaccine.

with the prior is also positive (indicating that, on average, a higher prior is associated with a higher posterior), and the one associated with the interaction term is negative (indicating that this relationship is weaker for the treated group). This suggests that a relatively low prior is more easily associated with a relatively high posterior in the Moderna group than in the Pfizer group.

To clarify the role of high and low priors, we classify an individual as having *low priors* about the vaccine he will receive if he belongs to the 50% of individuals who had the lowest beliefs about its safety (resp. effectiveness) in Wave 1. Otherwise, the individual is classified as having *high priors*.[9] This classification allows identifying four subgroups: individuals with *high* (1) vs. *low* (2) priors about a vaccine they will receive; and individuals with *high* (3) vs. *low* (4) priors about a vaccine they will *not* receive. Ex-post, prior

[9]Our results are robust to alternative classifications, with the threshold set either at the lower quartile or at the upper quartile (see SI Appendix, Figure S7).

beliefs *match* the received vaccine for categories (1) and (4). However, for categories (2) and (3), there is a *mismatch* between prior beliefs and the received vaccine.

Figure 5 reproduces Figure 2 separating between people who experienced a *match* or a *mismatch* between their prior beliefs and the vaccine they actually received. This decomposition highlights two patterns. First, individuals with *low* priors about their vaccine disproportionately update their beliefs upward, compared to those who did not receive that vaccine. Second, individuals with *high* priors about a vaccine they did *not* receive negatively update their beliefs about that vaccine, while we do not observe significant updating for individuals who received the vaccine they had high priors about. These patterns are observed whether we consider Moderna's safety or effectiveness.

Overall, this decomposition shows that asymmetric belief updating is driven by individuals who are the most at risk of experiencing a discrepancy between their prior beliefs and the vaccine they received.

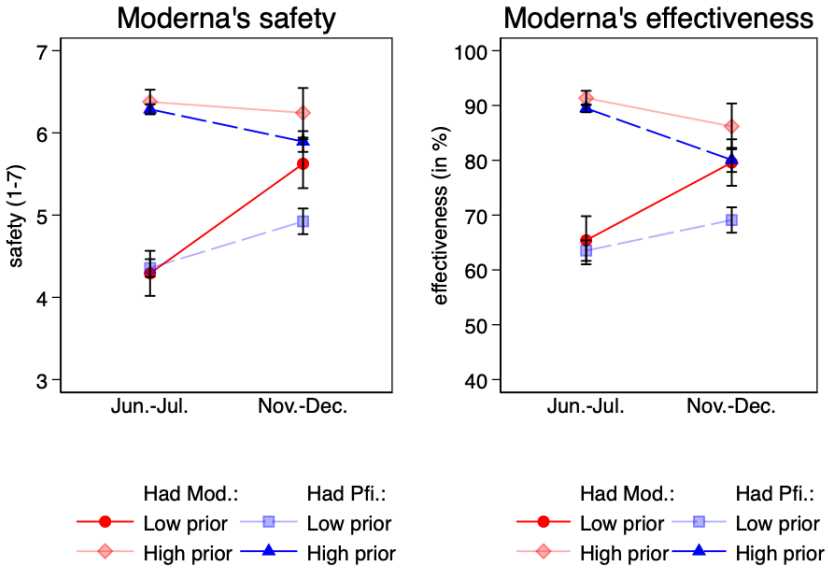


Figure 5: Beliefs about Moderna's vaccine, by priors

*Reading note:* Jun.-Jul. corresponds to belief elicitation *before* vaccination. Nov.-Dec. corresponds to belief elicitation *after* vaccination. An individual is classified as having Low priors about the vaccine he will receive if he belongs to the 50% of individuals who had the lowest beliefs about its safety (resp. effectiveness) in Wave 1. Otherwise, the individual is classified as having High priors. Error bars refer to 95% confidence intervals.

### *3.4. Individuals not only shift their beliefs but also their memories and stated preferences according to the vaccine they received.*

In Wave 2, individuals were asked to recall how safe and effective they used to think each vaccine was about five months earlier. While in Wave 1 there was no difference in beliefs between the Moderna and Pfizer groups, in Wave 2 we observe a significant difference in memories between the two groups: Moderna recall higher beliefs than Pfizer, both about safety ($Mean^{\text{Mod}}_{Mod,saf,rec} - Mean^{\text{Pfi}}_{Mod,saf,rec} = 0.40$, $p < 0.001$, t-test) and effectiveness ($Mean^{\text{Mod}}_{Mod,eff,rec} - Mean^{\text{Pfi}}_{Mod,eff,rec} = 6.44$, $p < 0.001$, t-test), as displayed in Figure 6. Ex-post memories shift in a similar fashion as beliefs (see also SI Appendix, section A9, Figure S9). This pattern is related to, but different from, hindsight bias (i.e., the tendency to recall the past as more predictable than it actually was), that we also observe in our sample (see SI Appendix, section A7, Table S9).

Table 2: Regressions of the posterior beliefs about Moderna on prior, treatment and their interaction

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Dep.var.: safety | | Dep.var.: effectiveness | |
| Treatment = Moderna | 1.83*** | 1.73*** | 30.23*** | 26.24*** |
| | (0.52) | (0.54) | (8.38) | (8.66) |
| Prior | 0.46*** | 0.42*** | 0.44*** | 0.41*** |
| | (0.04) | (0.04) | (0.04) | (0.05) |
| Prior × Treatment | -0.25** | -0.23** | -0.29*** | -0.26** |
| | (0.10) | (0.10) | (0.11) | (0.11) |
| Controls | | ✓ | | ✓ |
| N | 547 | 545 | 546 | 545 |
| $R^2$ | 0.205 | 0.250 | 0.186 | 0.242 |

*Reading note:* Linear regressions of posterior belief on the treatment, the prior, their interaction and other covariates. Columns (1)-(2) refer to beliefs about safety; columns (3)-(4) refer to beliefs about effectiveness. Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Specifications (2) and (4) include the following covariates: gender, age, student status, health status, vaccine quiz score, dummies = 1 if (i) hospitalized because of COVID-19, (ii) tested positive after vaccine, (iii) had severe side effects, (iv) knows someone who had severe side effects / tested positive after the (same) vaccine, weekly time dummies for the date of participation in Wave 2, monthly time dummies for the date the last dose was received, and geographical dummies for the country of residence (England, Scotland, Wales or Northern Ireland).

Regarding individuals' hypothetical choices, we measured how they shifted following the vaccination. In Wave 1, individuals were asked which vaccine they would choose to receive if they had the choice. In Wave 2, they were asked which vaccine they would have chosen to receive if they have had the choice. Here again, we observe a strong asymmetry conditional on the received vaccine. In Wave 1, before knowing which vaccine they will receive, the percentage of participants who would choose to receive Moderna is about the same between the two groups Moderna and Pfizer (0.01, p=0.634, t-test). In contrast, in Wave 2, people who received Moderna are significantly more likely to report that they would have chosen to receive Moderna all along (0.25, p<0.001, t-test). Similar effects appear when comparing the stated preference for Pfizer between groups in Wave 1 (0.05, p=0.321, t-test) and in Wave 2 (0.30, p<0.001, t-test). Figure 7 summarizes these findings.

## 4. Mechanisms

In the following sections, we explore different psychological mechanisms of how individuals may update their beliefs. We show that our results can neither be explained by conventional experience effects nor by some enhanced knowledge about the benefits of one's own vaccine. Instead, they are consistent with the predictions of motivated beliefs as well as a model of over-inference from weak signals.

### *4.1. Bayesian updating cannot rationalize the observed asymmetric updating pattern.*

Isn't all this rational? People are likely to exploit observations from their personal experience to infer the general properties of their vaccine, as predicted by the theory of Bayesian inference. To get a sense of the extent to which Bayesian updating descriptively fits the data, we look at the size of the update among those who experienced no severe side effects (99% of the sample).[10] When we make a parametric estimation of the

[10]We also look at the update of the 8 individuals who declared that they experienced severe side effects (what should be considered as "severe side effects" was left to the participant's interpretation): 2 of them revised their beliefs *downward*, other 2 revised *upwards* and the remaining 4 did not update their beliefs.

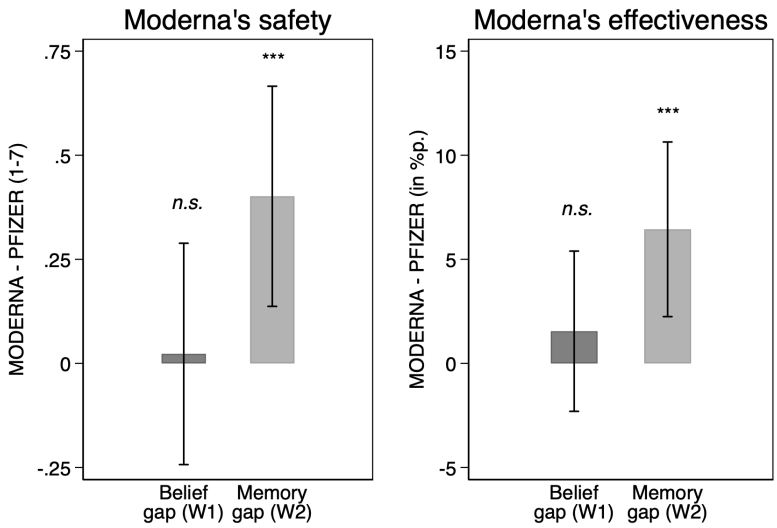


Figure 6: Difference in beliefs and memories about Moderna's vaccine

*Reading note:* In each figure, the left bar (i.e., belief gap) represents the difference between the *beliefs* reported in Wave 1 by the groups Moderna and Pfizer. The right bar (i.e., memory gap) represents the difference between the *memories* reported in Wave 2 by those two groups. *Before* vaccination, there is no significant difference in beliefs about Moderna's safety and effectiveness. *After* vaccination, those who received Moderna recall it to be safer and more effective than those who received Pfizer. Error bars refer to 95% confidence intervals.

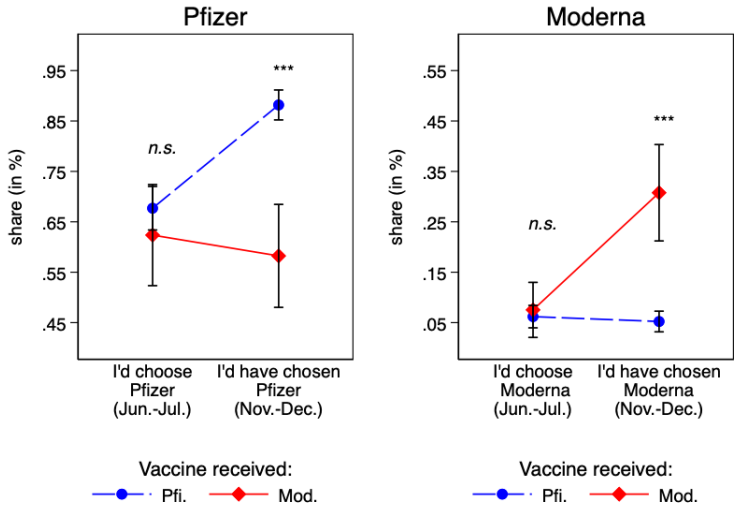


Figure 7: Stated preferences for vaccines

*Reading note: Before* vaccination, participants were asked to state among all vaccines the one that they would choose to receive if they had the choice. *After* vaccination, participants were asked to state among all vaccines the one that they would have chosen to receive if they have had the choice. Jun.-Jul. corresponds to belief elicitation *before* vaccination. Nov.-Dec. corresponds to belief elicitation *after* vaccination. Note that y-axes are re-scaled for readability. Error bars refer to 95% confidence intervals.

exact posterior predicted by Bayesian updating (details of the computation are in the SI Appendix, section A5), we find it to be inconsistent with the observed results. Individuals exhibit upward belief updating that exceeds by far the update predicted by Bayesian updating.

The order of magnitude is akin to someone drawing a green ball from an urn where they expect to have one million green balls and one black ball, and subsequently thinking that there must be *two* million green balls (and one black) in the urn. In the case of long-term side effects (arguably the strongest factor of vaccine hesitancy in our sample, see ONS, 2021), there was no feedback at all, since individuals were interviewed only a few weeks after their injection.

Overall, despite the fact that people might use the outcome of their vaccination to update their beliefs, conventional Bayesian inference cannot explain the large size of the updates that we observe.

### *4.2. There is no clear evidence that individuals either prioritize positive information or are better informed about their own vaccine.*

Individuals were interviewed during a period where immense amount of information about vaccines was available, and was, sometimes, contradictory. In this context, people must decide what they wish to know (see Golman et al., 2017; Sharot and Sunstein, 2020), and the vaccine they received could impact this attitude toward information.

Different elements allow us to investigate the potential role played by information seeking. First of all, at the end of our survey in Wave 2, we gave each individual the possibility to read information regarding COVID-19 vaccines. They had to choose whether they wanted to read a piece of information about the 'advantages' or 'disadvantages' of the vaccine they did or did not receive (see SI Appendix, section A6).[11] We indeed observe an asymmetry in preferences for information, but it is between own vs. other vaccine, rather than between favorable vs. unfavorable information. Around 90% of vaccinated individuals chose to read a piece of information related to the vaccine they received. About half chose to read about its relative advantages, and about half preferred to read about its relative disadvantages (see Figure S8 in SI Appendix). When given the choice, individuals did not actively select favorable information. However, since most scientific public information about vaccines was positive, seeking more information about one's own vaccine could lead individuals to form more optimistic beliefs about it. If individuals were more optimistic about their vaccine because they were more informed, we should observe that beliefs about their own vaccine selectively converge toward the state of scientific knowledge. That is, we should observe negative updating for individuals who ex-ante overshoot the safety and the effectiveness of the vaccine they received. This is not the case: optimistic updating is observed even if most individuals already overshoot the safety of the vaccine they will receive (scientific evidence suggests safety to be around 4/7 on the Likert scale, i.e. one severe side effect every $10^4$ vaccines, see Polack et al., 2020; Baden et al., 2020). In other words, individuals do *not* hold more accurate beliefs about their vaccine *after* receiving it than *before*. Finally, our survey in Wave 2 also included a short quiz designed to measure individuals' general knowledge about COVID-19 vaccines. Variations in the size of belief update are uncorrelated with the participants' score (Pearson correlation coefficient of 0.05 or lower), nor the score variable helps explain beliefs variations in the regressions with lagged-dependent-variable adjustment (see Table 1).

Overall, we observe information seeking behavior to correlate with the treatment (Pfizer or Moderna), but we do not observe signs indicating that individuals prioritize positive information about their own vaccine, are better informed and/or hold more accurate beliefs about it.

[11] The incentives to seek information right after vaccination and at the time of Wave 2 were somewhat different, as information on short-term side-effects was now redundant. However, other potential information (about medium-to-long-term side effects, e.g., infertility; about the length of the protection against severe/fatal forms of COVID-19 and against new COVID-19 variants) was still valuable at the time of Wave 2.

*4.3. People update their beliefs in a fashion consistent with motivated beliefs.*

In our survey, individuals were interviewed about a topic with a clearly desirable outcome for their current and future health: the safer and the more effective their vaccine, the better. Once the individual has received a specific vaccine, there is no going back. The vaccine injection is definitive, with potentially large long-term benefits/costs. Insofar as the assignment to a specific vaccine makes its safety and effectiveness much more desirable for the patient, one might expect that this change in desires will result in more optimistic beliefs. This is the core prediction of motivated beliefs.

*Motivated beliefs* (Kunda, 1990; Bénabou, 2015; Zimmermann, 2020; Möbius et al., 2022), aka *wishful thinking* (Mayraz, 2011; Engelmann et al., 2019; Caplin and Leahy, 2019; Mayraz, 2019), refer to people's tendency to believe what they would like to be true. The literature has abundantly shown than people's desire for good health can affect their beliefs (see, e.g., Weinstein, 1980, 1982; Jansen et al., 2011; Hanoch et al., 2019; Brnstrm and Brandberg, 2010) and the natural experiment that we study seems to confirm it.

The three main results presented in Section 3 are in line with the predictions of motivated beliefs.[12] First, individuals who now have an interest in their vaccine being safer and more effective than they used to think, end up changing their mind in this direction. That is, diverging wishes generate diverging beliefs, as predicted by Caplin and Leahy (2019). Second, those who had high priors about a vaccine that they did *not* receive deflate their beliefs about that vaccine, while those who had low priors about their vaccine update their beliefs overly optimistically. These two patterns are in line with, respectively, a *sour grape effect* and *sweet lemon effect*,[13] i.e., two strategies to reduce cognitive dissonance (Kay et al., 2002), that have potentially far-reaching economic consequences (Dalton et al., 2016). Third, individuals who received Moderna tend to recollect their past beliefs as more favorable to Moderna than they actually were, consistently with self-serving motives (Zimmermann, 2020; Müller, 2021), in particular avoiding regret. Regret avoidance is intimately related to the sour grape effect, as someone recalling that they thought well of Moderna is also someone who is justifying their past self for making a responsible decision (see Sugden, 1985, for a discussion). Finally, we observe that many individuals shift their stated preferences according to the vaccine they received, consistently with adaptive preferences (Elster, 1983).[14]

Overall, individuals update beliefs, memory and stated preferences in a fashion that is overly favorable for their current situation.

*4.4. Results can be rationalized by alternative non-Bayesian mechanisms.*

We find that people's beliefs react strongly to their assignment to a vaccine, although their personal experience is poorly informative about unlikely events. This pattern might seem at odds with the well-established and well-replicated finding that humans tend to *under-infer* from signal(s), compared to the Bayes benchmark (see the review by Benjamin, 2019). Recently, however, Augenblick et al. (2021) has rightly pointed out that this literature has looked almost exclusively at highly informative signals. When weak signals are considered instead, people tend to over-react to new information relative to Bayes theorem,

[12] In the previous section, we presented no evidence of motivated information seeking. By itself, this does not undermine the motivated nature of belief formation, but it sets a limit to its scope (i.e., through information processing only, and not information seeking).

[13] The sour grape effect refers to people's tendency to devalue something they desire but cannot have; the sweet lemon effect refers to the converse, i.e. the tendency to positively reappraise something that is attainable or attained, even if it was initially undesirable. The name "sour grape" comes from Aesop's fable "The Fox and the Grapes", popularized by La Fontaine.

[14] In practice, it is very hard to disentangle to what extent either the change in preferences trickled down on beliefs or the other way round. Elster (1983, p.124) notices that the difference is so subtle that in the French version of La Fontaine's tale about sour grapes the fox is deluded in his perception of the vermilion grapes, and wrongly believes that they are green. In the English version, he wrongly believes that they are sour, i.e., a matter of preferences rather than beliefs.

both in the lab and in the field. They propose a model of cognitive imprecision, in which people are unsure about the informativeness of the signal they receive, and therefore inflate how much they can learn from poorly informative events. Our results about belief updating can be accommodated within this non-Bayesian framework.

The source of information, i.e. first-hand experience, might play a role too. In a series of experiments, Conlon et al. (2022) document a general tendency to over-infer personal information compared to other sources. In all their treatments, Conlon et al. (2022) find that people better recall the information from their own experience than some equally well-observed and informative signals from others. The salience of the vaccination experience could also exacerbate over-inference, as predicted by diagnostic expectations (Gennaioli and Shleifer, 2010; Bordalo et al., 2018, 2020). According to this model, people over- or under-estimate probabilities according to how easily information comes to mind. In the case of the personal experience with the vaccine, we can reasonably assume that patients use their personal experience as highly representative when accessing information from memory.

Diagnostic expectations could also explain the memory asymmetry that we observe, but a more general explanation is possible. Even if participants cannot recall exactly what they used to think about vaccines, they probably have a general idea, that they adjust based on the relevant information they have available at the moment. Their current beliefs are among this relevant information. This heuristic process could explain why we observe a recall bias in the direction of inflated memories for one's own vaccine, on top of inflated beliefs. A similar process could explain the bias in stated preferences.

Overall, the pattern of beliefs updating that we document could be explained by some non-Bayesian mechanisms, whereby individuals learned too much from their own experience.

## 5. Conclusions

Our study identifies the causal effect of vaccine assignment on beliefs updating, stated preferences and memory distortions. We showed that, *before* vaccination, individuals exhibit similar beliefs and similar stated preferences about the different vaccines. *After* vaccination however, they exhibit upward beliefs updating about the safety and the effectiveness of the vaccine they received. When asked to recall their past opinions, they tend to wrongly remember that they thought well of their vaccine all along. When asked what they would have chosen to receive, they are more likely to cite their vaccine than those who received another one.

Overall, our results are consistent with a pattern of motivated beliefs, where individuals seem to update beliefs to convince themselves that they are in the best state of the world. Receiving a vaccine is likely to impact beliefs via the change in desires, over and above the purely informational content of the post-vaccination experience and the effect of skewed information seeking. These results are also consistent with a cognitive model of over-inference, where people learn too much from their experience and therefore end up being overly optimistic about their own vaccine. While the former interpretation has the advantage of accounting for the psychological needs for self-reassurance that probably occurred in this specific context, the latter has the advantage of being more parsimonious, as it relies on purely cognitive mechanisms. Importantly, there is little reason to think that motivational and cognitive mechanisms are mutually exclusive, while it is plausible that they both intervene in the formation of beliefs (Melnikoff and Strohminger, 2023; Gilovich, 2008, p.80).

Optimistic belief updating can be either harmful or beneficial. On the one hand, optimistic beliefs about COVID-19 vaccines could act as a "belief trap" (Scheffer et al., 2022) potentially leading to harmful behaviors (e.g. non-compliance with safety rules). On the other hand, they may protect individuals' well-being by reducing fear and anxiety, especially given the irreversible nature of vaccine injection (Jefferson et al., 2017). More empirical evidence is needed to establish the precise psychological mechanism and assess the relative

costs and benefits. Yet, our results can inform the debate about whether individuals should be able to choose which health treatment they receive (including which COVID-19 booster jab, see Kramer et al. 2021).[15] The natural experiment that we investigate clearly shows that individuals form optimistic beliefs about the treatment they receive, even when they cannot choose it.

[15]Many other factors matter, of course. While giving vaccination choice respects the principle of patient self-determination and may increase overall vaccination acceptance, accommodating individual vaccine preferences would exacerbate current inequities in vaccine administration and potentially cast doubt on the fact that each authorized vaccine works. Additionally, choice of the vaccine may become a target of misinformation campaigns from vaccine companies or social media.

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## Appendix

*A1: Method*

In the first wave of the survey, participants were UK residents recruited via Prolific based on the pre-screening criterion that they should not have received a vaccine yet and that they should be between 18 and 29 year-old. After reading and approving the consent form, they had to answer the questions listed in Table S2. In the second wave of the survey, we re-invited all participants that answered that they were *not* vaccinated in Wave 1 to complete a second survey. After reading and approving the consent form, they had to answer the questions listed in Tables S3-S5.

*Final sample*: 951 individuals participated in both waves. We drop 95 participants who did not pass the exclusion restrictions (see Table S6 for a summary of attrition and exclusions). 5 respondents provided inconsistent Prolific identifiers, 10 respondents reported in Wave 2 that they started the vaccination cycle before June 2021, 15 respondents had at least a dose of another vaccine (for instance, if they got vaccinated abroad). 65 participants claimed that they could choose their vaccine. Among them, 12 could do so for medical reasons, 7 used feedback from peers, the others reported different or no explanation. We suspect that a sizeable share said that they could choose their vaccine because they were eligible for two vaccines only, because of their age. This was not the intended meaning of our question, but we drop these participants from the analysis as a precaution. Including those participants in our data analysis does not significantly change the results.

*A2: Beliefs about Pfizer's vaccine*

This section replicates the analysis conducted in the main text, but using beliefs about Pfizer instead. Therefore, Moderna should be considered as the control group and Pfizer as the treatment group. For beliefs about Pfizer's safety, we observe a similar dynamic than the one documented about Moderna's safety, albeit less polarized. In Wave 2 (see Figure S1 *left*), the average beliefs of individuals regarding Pfizer's safety is significantly higher for individuals who received Pfizer ($Mean^{\text{Pfi}}_{Pfi,saf,2} = 6.17$) than for those who received Moderna ($Mean^{\text{Mod}}_{Pfi,saf,2} = 5.74$, $p < 0.001$, t-test). Between Wave 1 and Wave 2, people who received Pfizer update their beliefs more positively ($+0.43, p < 0.001$; t-test) than those who received Moderna, and this conditional on having the same initial belief (see Table S7). For beliefs about Pfizer's effectiveness, we observe essentially no update (see Figure S1 *right*).

The absence of update should consider the timing of our survey. Wave 1 was fielded at the beginning of the 2021, when many people expected vaccines to protect against any form of COVID-19. Wave 2 was fielded at the end of the Fall 2021, when the omicron variant started spreading and it quickly became clear that vaccination does not protect against infection. Arguably, beliefs about Moderna's effectiveness were less affected because priors were lower and people did not expect nor preferred to receive that vaccine.

The latter remark is important, as our focus on Moderna's beliefs is motivated by the fact that most participants expected and preferred to receive Pfizer. The good news-bad news asymmetry (Eil and Rao, 2011; Zimmermann, 2020) typically arises in contexts where people receive undesirable news, and receiving Pfizer was good news for 4 people out of 5 (see figure 3). Of course, those people still had an incentive toward believing that Pfizer is safe and effective, but the extent of the motivational incentive was probably smaller.[16] In theory, beliefs about Pfizer should undergo similar shifts as beliefs about Moderna only insofar

[16] An example in a similar context might help. Imagine that you must undergo some surgery, and there are two possible types of interventions, one that you were told is safe and the other that you were told is significantly more dangerous. Eventually, the doctor tells you that the safe one will be implemented. Your need for self-reassurance would probably be drastically smaller than if you had been assigned to the alternative.

as the psychological need for self-reassurance was the same in the two cases. As we have no direct measure of such psychological need, and the predictions of motivated beliefs are somewhat ambiguous in this context, we cannot but acknowledge that further investigation is needed and refrain from speculating about these results.

*A3: Regression analysis*

In this section, we describe more in detail our lagged-dependent-variable-adjusted estimations. We run the following linear estimation:

$$y_{it} = \alpha + \beta y_{it-1} + \gamma T_i + X'_{it}\delta + \epsilon_{it}. \tag{A1}$$

Our dependent variable $y_{it}$ is the belief in Wave 2 about safety / effectiveness; $y_{it-1}$ is the lagged dependent variable, i.e., the belief in Wave 1; $T_i$ is the treatment (Moderna or Pfizer), and $X_{it}$ is a matrix of independent covariates; $\epsilon_{it}$ is the normally distributed error term. For details about this specification, see Angrist and Pischke (2009, chap. 5.3). Our independent variables can be categorized in five groups: (1) *Main variables*: the treatment, and the belief level in Wave 1. (2) *Socio-demographic*: gender, age, employment status (student or not), health pre-conditions (including pregnancy), and area of residence. (3) *COVID-19 variables*: knowledge about COVID-19 (as measured in a quiz); having being hospitalized because of COVID-19 (either the respondent or a close one); having tested positive to COVID-19 after the vaccine; having experienced severe side effects after the COVID-19 vaccine, knowing someone who experienced severe side effects after a COVID-19 vaccine, knowing someone who tested positive after a COVID-19 vaccine. (4) *Time variables*: date (week) in which the individual participated in Wave 2; date (month) in which the respondent received their first dose of vaccine. Table 1 reports coefficients from the lagged-dependent-variable-adjusted estimations of the beliefs about Moderna. Between Wave 1 and Wave 2, people who received Moderna update their beliefs about Moderna's safety (+0.52, $p < 0.001$; t-test) and Moderna's effectiveness (+6.32, $p < 0.001$; t-test) more positively than those who received Pfizer, and this conditional on having the same initial belief, on not having experienced side effects and a set of other control variables described above. The last coefficient refers to the relationship between the priors and the posterior. Among the other independent variables, the only ones that reach conventional levels of statistical significance are the vaccine quiz score, that predicts higher confidence in Moderna's safety, and having tested positive after the vaccine, which reduces beliefs about both safety and effectiveness. Table S7 presents the lagged-dependent-variable-adjusted estimations of the beliefs about Pfizer. The assignment to Pfizer predicts higher posterior beliefs about its safety (+0.45, $p < 0.001$; t-test), but not about its effectiveness (+1.32, $p = 0.455$; t-test). Instead, beliefs about effectiveness are significantly affected by having tested positive after the vaccine.

*A4: Beliefs about other vaccines (Janssen and AstraZeneca)*

We elicited individuals' beliefs about the safety and effectiveness of the vaccines Oxford-AstraZeneca and Janssen for two main reasons. First, since it was impossible to anticipate accurately which vaccine were going to be distributed in which proportion, we had to elicit beliefs regarding the four vaccines available in the UK at that time (Pfizer, Moderna, Astrazeneca, Janssen). Second, measuring beliefs on vaccines that both groups (Pfizer and Moderna) did *not* receive provides a placebo test for the causal identification of the effect we studied. And indeed, we do not observe significantly different updates between the two groups, Pfizer and Moderna, whether considering the safety or the effectiveness of AstraZeneca and Janssen vaccines (see Figure S6).

*A5: Computation of Bayesian Updating*

To study the extent to which Bayesian update descriptively fits with the data, we use self-reported information about having experienced severe side effects (for beliefs about safety) and about having tested positive after the vaccine (for beliefs about effectiveness). Intuitively, the Bayesian process is akin to the

textbook example of an urn problem, where the decision maker has a prior about the proportion of balls of two colors in the urn, and drawing a ball offers useful information to update the prior. Similarly, people might use the outcome of their vaccination to update their beliefs about the likelihood of adverse side effects (safety) and post-vaccination severe COVID-19 (effectiveness). This calculation disregards two important facts. First, the feedback received by the individuals was partial. Indeed, individuals were interviewed only a few months or weeks after their injection, so that they had no personal experience about long-term side effects or about the probability of experiencing severe forms of the disease in the future. Second, the topic and period of study were characterised by a rich descriptive information environment, where official statistics were available and salient, and one's social circle was likely to be exposed to various vaccines. In this context, updating one's own belief based solely on one's own experience would be a blinkered strategy. Individuals' beliefs update was probably determined by some combination of one's own personal experience with the vaccination and the public available information about vaccines quality. This section shows that, holding the latter constant, one's own personal experience cannot explain the patterns that we observe, thus suggesting that, beyond Bayesian updating, some psychological forces skewed the updating process in favor of the vaccine that one received.

*Safety*: We study the size of the update among those who experienced no severe side effects (i.e. 99% of the sample). Individuals were asked to report the probability of experiencing severe side effects on a logarithmic scale, from 1/10 to $1/10^7$. Average ex-ante beliefs are $Mean^{\text{Mod}}_{Mod,saf,1}|no\ side\ eff. = 5.36$ and $Mean^{\text{Pfi}}_{Pfi,saf,1}|no\ side\ eff. = 5.91$. If individuals interpreted the scale in the way it was labelled (i.e., from 1/10 to $1/10^7$), having experienced no side effects was poorly informative and it is hard to qualify any positive update as Bayesian. The intuition is the following. If severe side effects are believed ex-ante to be very rare events (in the order of one out of 100,000), then getting no short-term side effects from one or two jabs offers a tiny (trivially negligible) sample to justify a positive belief update along the scale.

It is possible, however, that individuals interpreted the scale as linear. In that case, ranking a vaccine as 6/7 instead of 5/7 would means that people judge it about 15 percentage points (1/7) safer, rather than 10 times safer. The Bayesian posterior depends on the latent distribution of the priors (i.e., the level of subjective uncertainty), but we observe only the mean value of this distribution (i.e., the stated belief in Wave 1). To get around this problem, we use the observed belief update about Pfizer to infer the second moment of the distribution of the priors about Moderna. In other words, we assume that individuals are equally *uncertain* about the "true" safety of the two vaccines. We can then formally describe the experience of getting vaccinated as a Bernoulli process $X|p \sim Bernoulli(n, p)$, where $n$ corresponds to the number of trials (i.e. 1 or 2) and the parameter p represents the "true" probability of experiencing side effects in any of the two doses. This parameter $p$ is itself a random variable $p \in [0, 1]$, for which we observe the mean prior $\bar{p}$ and mean posterior $\bar{p*}$. We can describe both the prior and posterior distributions as following a Beta distribution, $p \sim Beta(a, b)$, where $a$ and $b$ are hyperparameters. The Bayesian posterior $\bar{p*}$ is therefore a function of the prior $\bar{p}$, and of the hyperparameters $a$ and $b$. We assume $a_{Mod} = a_{Pfi} = a$ and $b_{Mod} = b_{Pfi} = b$ and elicit $a$ and $b$ from observing beliefs update about Pfizer. Specifically, we elicit the dispersion of $p$ of the group Pfizer and infer $a$ and $b$ which correspond to this update. We can then deduce the Bayesian posterior of the group Moderna based on its prior beliefs and applying the same hyperparameters $a$ and $b$. According to this computation, Bayesian update would predict the mean posterior about Moderna to be 5.48, i.e. well below the value that we observe in the sample (5.97, p-value $< 0.001$, t-test).

Overall, individuals therefore exhibit an upward belief updating about Moderna's safety that largely exceeds the update predicted by Bayesian updating, and this is true even if we acknowledge that they might have misinterpreted the scale.

*Effectiveness*: Individuals were asked to report the effectiveness of each vaccine in preventing severe/critical disease and death. For this, they used a percentage scale. We can learn about Bayesian updating by comparing the size of the update among those who did not test positive after the vaccine (i.e. 92% of the

sample) and the few ones who did. In theory, based on the observed average prior and posterior beliefs about Moderna, we can estimate the hyperparameters of the distributions of the prior, and use this estimation to predict how people who tested positive should *downward* update their beliefs. Bayesian update can hardly explain the updates that we observe. Indeed, even those who tested positive after the vaccine tend to positively update their beliefs about Moderna's effectiveness, from 80% to 86%. Similarly, beliefs about Pfizer's effectiveness cannot be rationalized by the extra personal information learned from testing positive (or not) after the vaccination. Among those who received Pfizer, the point estimate of the mean belief is higher *before* vaccination than *after* vaccination, even among those who have not tested positive at the moment of Wave 2. The difference is not significantly different from zero, thus suggesting that there was essentially no update for beliefs about Pfizer's effectiveness. Overall, as for safety, the dynamic of beliefs about effectiveness is not properly described by a Bayesian updating process based on personal experience with the vaccine.

*A6: Information selection*

In Wave 2, individuals had to choose whether they wanted to read a piece of information about the vaccine they received or about the vaccine they did not receive, and whether they wanted to read a piece of information about the relative 'advantages' or 'disadvantages' of this vaccine. There were no opt out option: individuals had to choose one and only one of the four pieces of information. The four pieces of information were: "Pfizer-BioNtec is the most effective vaccine ever created at preventing laboratory-confirmed infection with COVID-19 virus." Source: National Center for Immunization and Respiratory Diseases (NCIRD) (2020). "Compared to Moderna, Pfizer-BioNtec triggers a substantially lower anti-body response, which might offer a relatively shorter protection against the virus." Source: Steensels et al. (2021); "Compared to Pfizer-BioNtec, Moderna triggers a substantially higher anti-body response, which might offer a longer protection against the virus." Source: Steensels et al. (2021). "Compared to BioNtec-Pfizer, Moderna is associated with relatively higher rates of heart inflammations (myocarditis and/or pericarditis)." Source: Naveed et al. (2022). The share of decisions of the Pfizer and Moderna groups are presented in Figure S8. Each column shows the percentage of subjects who chose to read one of the four pieces of information among those who received Pfizer (left-hand side) or Moderna (right-hand side). Therefore, the four columns on the left hand-side sum up to 100% and so do the four columns on the right hand-side. Participants reveled a stark preference for reading about their own vaccine vs the other vaccine, but no preference for reading about its advantages vs disadvantages.

*A7: Hindsight bias*

When recalling past predictions, individuals integrate current information about the known outcome. Therefore, they tend to recall their past as more predictable than it actually was. Table S9 reports the predicted likelihood (foresight) and the recalled likelihood (hindsight) of receiving a certain vaccine. Those who received Moderna recall that they considered receiving Moderna as more likely than they actually did; similarly, those who received Pfizer recall that they considered receiving Pfizer as more likely than they actually did.

*A8: Statistical power analysis*

No existing study provided an indication on which effect size to expect for the comparison between beliefs of participants that received Moderna *vs.* Pfizer vaccine. To be on the conservative side, we determined the sample size hypothesizing a small-medium effect size (Cohen's d = 0.35). Assuming a type-I error rate of 0.05, a power level of 0.8, and an allocation ratio of $\frac{1}{5}$ between the two vaccines (based on past injections, we expected Pfizer to be injected five times more than Moderna), the number of observations per treatment required to detect such effect is 61 for Moderna and 305 for Pfizer. With 93 participants in the Moderna

treatment (152% of the required sample size) and 457 participants in the Pfizer treatment (149%), we had enough observations to detect such effect.

*A9: Memory update*

Ex-post memories shift in a similar fashion as beliefs (see Figure S9). People who received MODERNA recall that they thought it to be safer and more effective than they actually did, and the recall error is highly correlated with the belief update. Similarly so for those who received PFIZER.

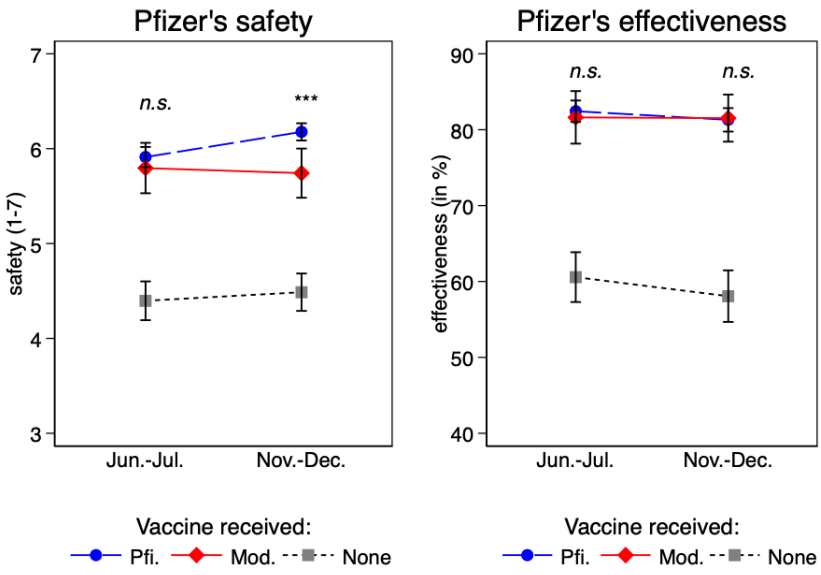


Figure S1: Beliefs about Pfizer's vaccine

*Reading note:* Vaccines' safety is measured on a logarithmic scale, where people report the incidence of significant side effects from 1 out of 10 (very unsafe) to 1 out of $10^7$ (very safe). Options were chosen on a labelled 1-7 Likert scale. Vaccines' effectiveness is measured on a percentage scale, where people report how effective they consider each vaccine, from 0% (0% effectiveness against severe Covid-19 and death), to 100% (100% effectiveness against severe Covid-19 and death). Jun.-Jul. corresponds to belief elicitation *before* vaccination. Nov.-Dec. corresponds to belief elicitation *after* vaccination. Error bars refer to 95% confidence intervals.

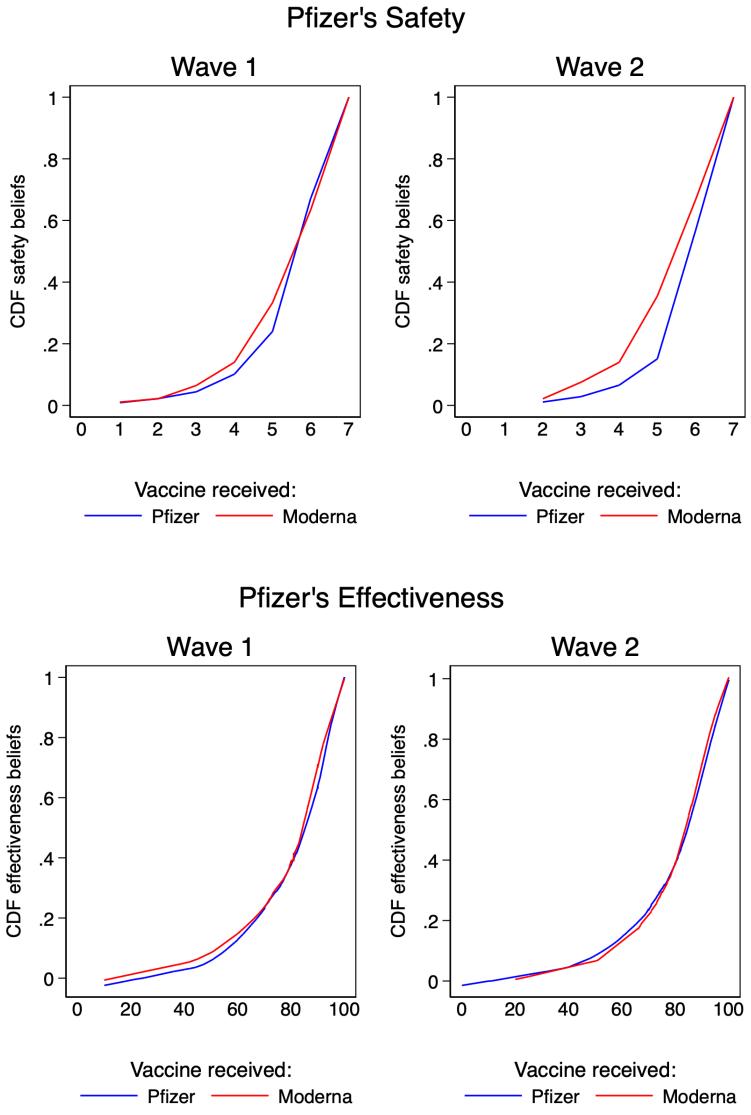


Figure S2: Cumulative density function of beliefs about Pfizer

*Reading note:* The figure compares the cumulative distributions of beliefs of the Moderna and Pfizer groups before and after receiving the vaccine.

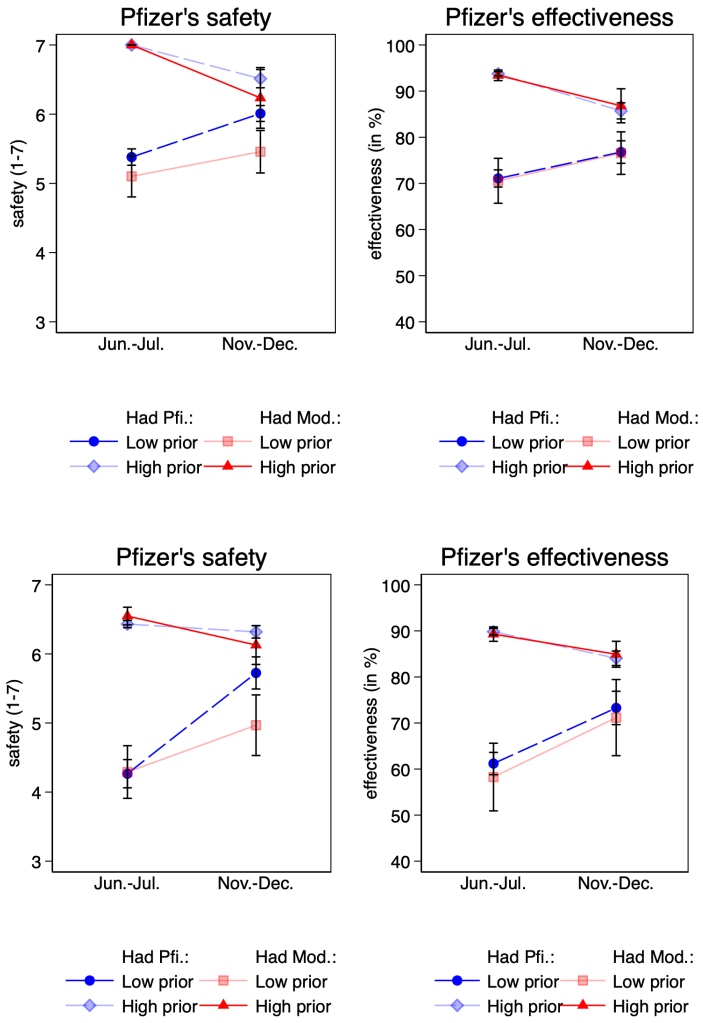


Figure S3: Beliefs about Pfizer's vaccine by priors, using alternative definitions of *Low* vs. *High* prior beliefs

*Reading note:* On the top panel, an individual is classified as having Low priors about the vaccine he will receive if he belongs to the 50% of individuals who had the lowest beliefs about its safety (resp. effectiveness) in Wave 1. Otherwise, the individual is classified as having High priors. On the bottom panel, an individual is classified as having Low priors about the vaccine he will receive if he belongs to the 25% of individuals who had the lowest beliefs about its safety (resp. effectiveness) in Wave 1. Otherwise, the individual is classified as having High priors. We do not calculate the split at the 75th percentile because there is no variation between beliefs in Wave 1 and 2 for this split. The Vaccines' safety is measured on a logarithmic scale, where people report the incidence of significant side effects from 1 out of 10 (very unsafe) to 1 out of $10^7$ (very safe). Options were chosen on a labelled 1-7 Likert scale. Vaccines' effectiveness is measured on a percentage scale, where people report how effective they consider each vaccine, from 0% (0% effectiveness against severe COVID-19 and death), to 100% (100% effectiveness against severe COVID-19 and death). Jun.-Jul. corresponds to belief elicitation *before* vaccination. Nov.-Dec. corresponds to belief elicitation *after* vaccination. Error bars refer to 95% confidence intervals.

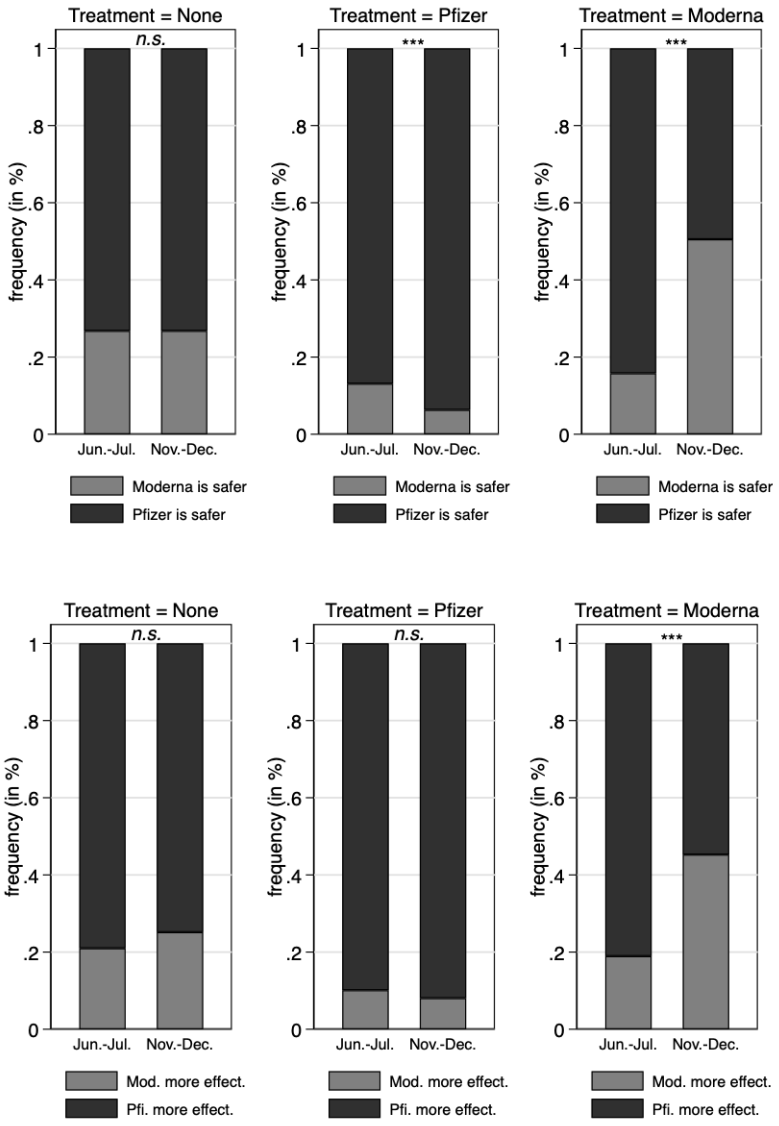


Figure S4: Relative Safety and Effectiveness

*Reading note:* The *top* part of the figure shows the share of individuals who ranked Moderna as safer than Pfizer (or vice versa), based on the answers to the question: "According to you, which one of the vaccines is the safest? Please move the items below to rank them from the safest (1) to the least safe (4) vaccine". The *bottom* part of the figure shows the share of individuals who ranked Moderna as more effective than Pfizer (or vice versa), based on the answers to the question: "According to you, which one of the vaccines is the most effective? Please rank them from the most effective (1) to the least effective (4)".

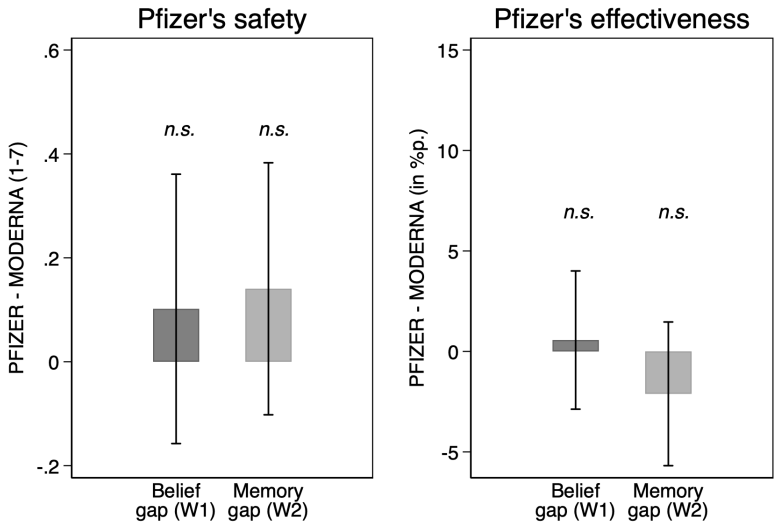


Figure S5: Difference in beliefs and memories about Pfizer's vaccine

*Reading note:* In each figure, the left bar (i.e., belief gap) represents the difference between the *beliefs* reported in Wave 1 by the groups Moderna and Pfizer. The right bar (i.e., memory gap) represents the difference between the *memories* reported in Wave 2 by those two groups. We find no evidence of a memory gap among those who received Pfizer. Error bars refer to 95% confidence intervals.

Table S1: Variables measured

| *Blocks* | Wave 1 | Wave 2 |
|---|---|---|
| *Beliefs* | Safety of $\mathcal{V}$<br>Effectiveness of $\mathcal{V}$<br>% pop. who received $\mathcal{V}$<br>Most-to-least safe<br>Most-to-least effective | Safety of $\mathcal{V}$<br>Effectiveness of $\mathcal{V}$<br>% pop. who received $\mathcal{V}$<br>Most-to-least safe<br>Most-to-least effective |
| *Memory* | | Recalled safety of $\mathcal{V}$<br>Recalled effectiveness of $\mathcal{V}$<br>Recalled likelihood of $\mathcal{V}$ |
| *Expectations* | Likelihood of receiving $\mathcal{V}$ | |
| *Stated preferences* | Hypothetical choice | Hypothetical choice |
| *Experience* | | Experienced safety<br>Experienced effectiveness |
| *Demand for info.* | | Which piece of news would you like to read? |
| *Quiz* | | Questionnaire to assess knowledge about COVID-19 vaccines |
| *Other* | Health condit., response time, demographics | Health condit., response time, demographics |

*Note*: $\mathcal{V}$ = Pfizer, Moderna, Astrazeneca, Janssen.

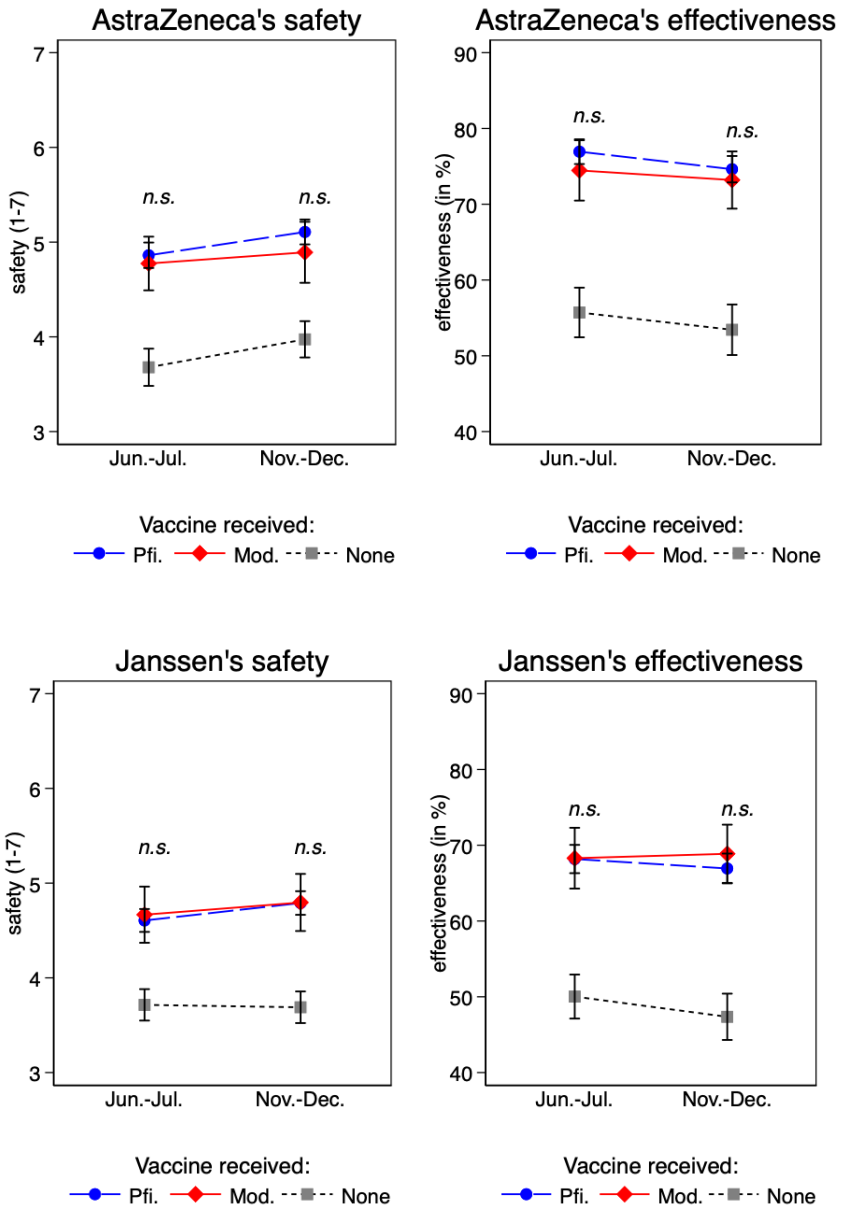


Figure S6: Beliefs about AstraZeneca's and Janssen's vaccines

*Reading note:* Vaccines' safety is measured on a logarithmic scale, where people report the incidence of significant side effects from 1 out of 10 (very unsafe) to 1 out of $10^7$ (very safe). Options were chosen on a labelled 1-7 Likert scale. Vaccines' effectiveness is measured on a percentage scale, where people report how effective they consider each vaccine, from 0% (0% effectiveness against severe COVID-19 and death), to 100% (100% effectiveness against severe COVID-19 and death). Jun.-Jul. corresponds to belief elicitation *before* vaccination. Nov.-Dec. corresponds to belief elicitation *after* vaccination. Error bars refer to 95% confidence intervals.

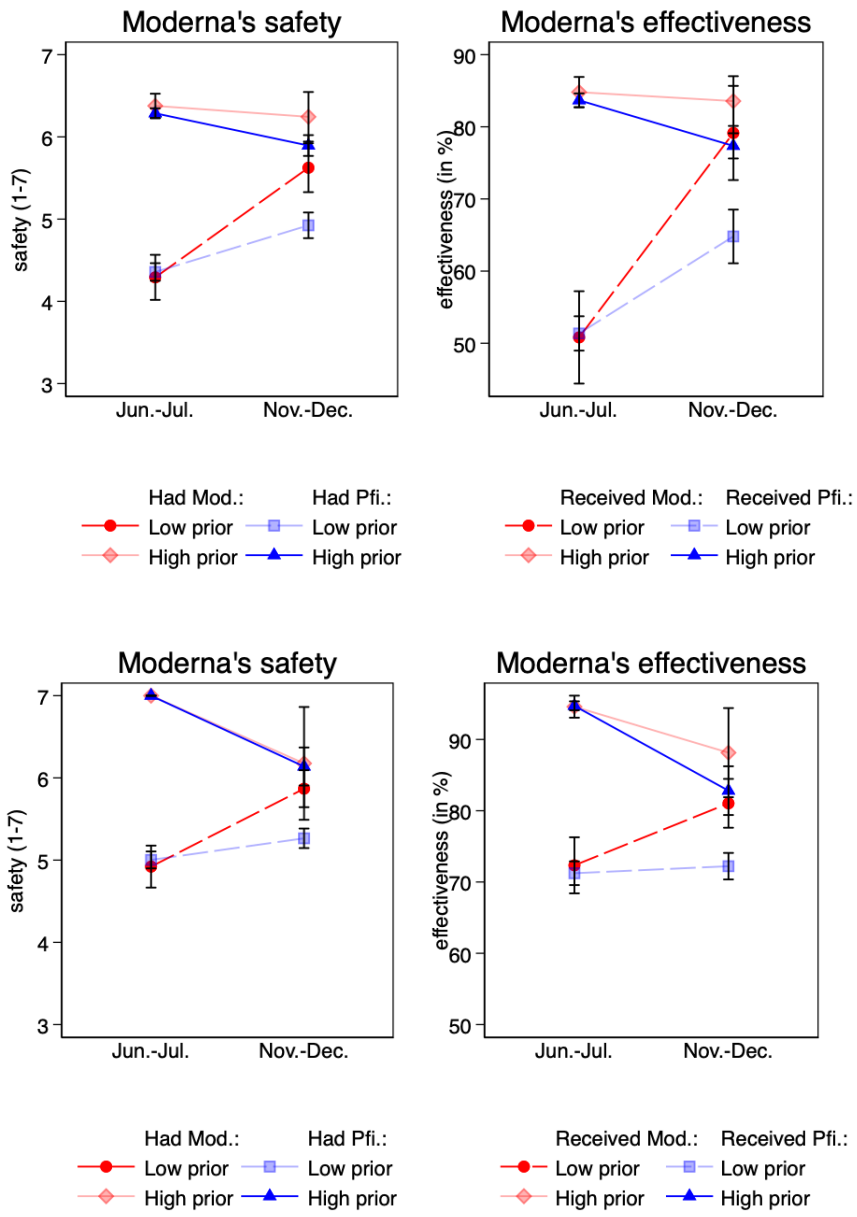


Figure S7: Beliefs about Moderna's vaccine by priors, using alternative definitions of *Low* vs. *High* prior beliefs

*Reading note:* On the top panel, an individual is classified as having Low priors about the vaccine he will receive if he belongs to the 25% of individuals who had the lowest beliefs about its safety (resp. effectiveness) in Wave 1. Otherwise, the individual is classified as having High priors. On the bottom panel, an individual is classified as having Low priors about the vaccine he will receive if he belongs to the 75% of individuals who had the lowest beliefs about its safety (resp. effectiveness) in Wave 1. Otherwise, the individual is classified as having High priors. Vaccines' safety is measured on a logarithmic scale, where people report the incidence of significant side effects from 1 out of 10 (very unsafe) to 1 out of $10^7$ (very safe). Options were chosen on a labelled 1-7 Likert scale. Vaccines' effectiveness is measured on a percentage scale, where people report how effective they consider each vaccine, from 0% (0% effectiveness against severe Covid-19 and death), to 100% (100% effectiveness against severe Covid-19 and death). Jun.-Jul. corresponds to belief elicitation *before* vaccination. Nov.-Dec. corresponds to belief elicitation *after* vaccination. Error bars refer to 95% confidence intervals.

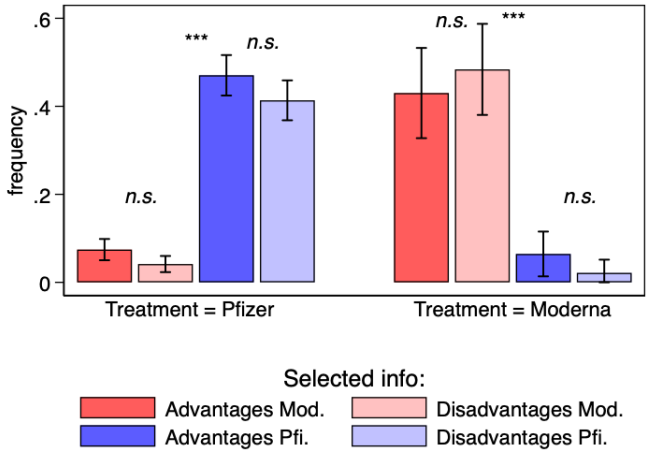


Figure S8: Share of individuals choosing to read about advantages / disadvantages of each vaccine

*Reading note:* The two red bars on the left-hand side of the graph represent the proportion of individuals who chose to read information about Moderna, among those who received Pfizer. The two blue bars on the left-hand side represent the proportion of individuals who chose to read information about Pfizer, among those who received Pfizer. A darker color refers to positive information about the vaccine (i.e., its advantages), while a lighter color refers to negative information (i.e., its disadvantages). Among those who received Pfizer, about 90% preferred to read some information about Pfizer, but similarly distributed between those who decided to read about its advantages and its disadvantages. The interpretation is similar, *mutatis mutandis*, for the four bars on the right-hand side of the graph. Error bars refer to 95% confidence intervals.

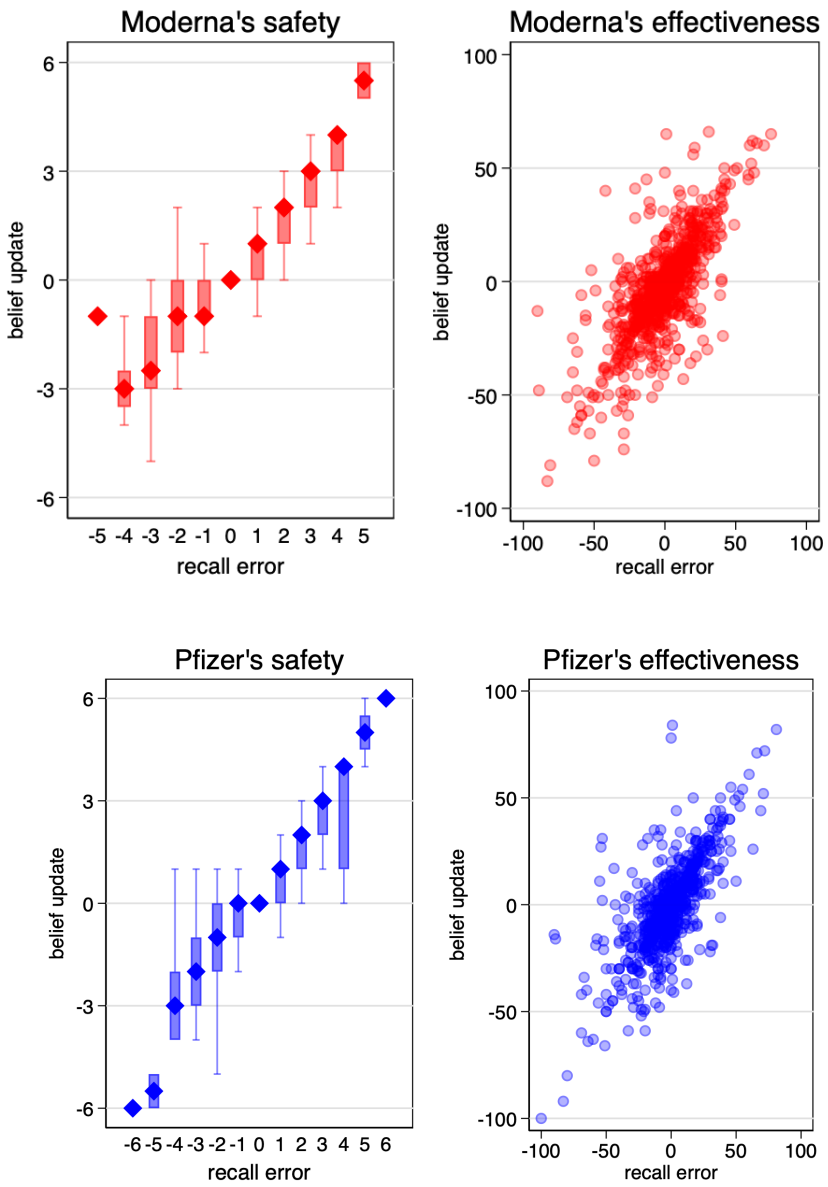


Figure S9: Relationship between recall errors and belief updates

*Reading note:* Recall errors are defined as the difference between the retrospective belief reported in Wave 2 and the actual belief reported in Wave 1. Belief update is defined as the difference between the beliefs reported in Wave 1 and Wave 2. In the box plots, the diamonds indicate the median, while the whiskers indicated the top and bottom quartile.

Table S2: Survey - Wave 1

| | |
|---|---|
| **Vaccination** | Have you received a coronavirus (COVID-19) vaccination? ☐ Yes *(A)* ☐ No *(B)* |
| **Safety** | Currently, in the UK, 4 types of vaccines are distributed: Pfizer-BioNTech, Oxford-AstraZeneca, Moderna, Janssen. Some scientists think that the vaccines to prevent COVID-19 spread are safe. Other scientists are worried that they could have significant side effects. What is your opinion? |
| Ordinal | According to you, which one of the vaccines is the safest? Please move the items below to rank them from the safest (1) to the least safe (4) vaccine. |
| Cardinal | Please rate on a scale from 1-7 the safety of each vaccine, where 1 is totally unsafe (1 case of significant side effects out of 10 vaccinated people) and 7 is totally safe (1 case out of 10 million). |
| Confidence | How confident are you in your answers above? (Likert scale from 1: not confident at all, to 10: very confident) |
| **Effectiveness** | Scientists are also debating the effectiveness of each vaccine in preventing severe disease and death. What is your opinion? |
| Ordinal | According to you, which one of the vaccines is the most effective? Please rank them from the most effective (1) to the least effective (4). |
| Cardinal | How effective do you consider each vaccine? 0 = Not effective at all (0% effectiveness against severe COVID-19 and death), 100 = Very effective (100% effectiveness against severe COVID-19 and death) |
| Confidence | How confident are you in your answers above? (Likert scale from 1: not confident at all, to 10: very confident) |
| **Expectations** | Do you plan to receive a vaccine within the coming months? ☐ Yes *(C)* ☐ No *(D)* |
| Ordinal | *If (C):* According to you, which one of the vaccines are you the most likely to receive? Please rank them from the most likely (1) to the least likely (4). *If (D):* If vaccination became mandatory, according to you, which one of the vaccines would you be most likely to receive? Please rank them from the most likely (1) to the least likely (4). |
| Cardinal | According to you, what is the likelihood that you will receive each vaccine? (the likelihoods must total 100%). |
| **Stated preferences** | If you had the choice, which vaccine would you choose to receive? |
| **Allocation** | According to you, among the vaccinated population in the UK, what is the share who received each vaccine? (the total must sum up to 100%) |
| **Demographics** | What is your country of residence? Are you pregnant or do you have any underlying health condition? If you would like to let us know anything else, please type your feedback below. |

Table S3: Survey - Wave 2

| | |
|---|---|
| **Safety** | Currently, in the UK, 4 types of vaccines are distributed: Pfizer-BioNTech, Oxford-AstraZeneca, Moderna, Janssen. Some scientists think that the vaccines to prevent COVID-19 spread are safe. Other scientists are worried that they could have significant side effects. What is your opinion? |
| Ordinal | According to you, which one of the vaccines is the safest? Please move the items below to rank them from the safest (1) to the least safe (4) vaccine. |
| Cardinal | Please rate on a scale from 1-7 the safety of each vaccine, where 1 is totally unsafe (1 case of significant side effects out of 10 vaccinated people) and 7 is totally safe (1 case out of 10 million). |
| Confidence | How confident are you in your answers above? (Likert scale from 1: not confident at all, to 10: very confident) |
| **Effectiveness** | Scientists are also debating the effectiveness of each vaccine in preventing severe disease and death. What is your opinion? |
| Ordinal | According to you, which one of the vaccines is the most effective? Please rank them from the most effective (1) to the least effective (4). |
| Cardinal | How effective do you consider each vaccine? 0 = Not effective at all (0% effectiveness against severe COVID-19 and death), 100 = Very effective (100% effectiveness against severe COVID-19 and death) |
| Confidence | How confident are you in your answers above? (Likert scale from 1: not confident at all, to 10: very confident) |
| **Memory** | At the beginning of last summer (end of June 2021), we asked you the same kind of questions regarding the safety and efficiency of COVID-19 vaccines. |
| Safety - Ord. | Back then, which one of the vaccines did you think was the safest? Please move the items below to rank them from the safest (1) to the least safe (4) vaccine. |
| Safety - Card. | Back then, how did you rate on a scale from 1-7 the safety of each vaccine, where 1 was totally unsafe (1 case of important collateral effects out of 10 vaccinated people) and 7 was totally safe (1 case out of 10 million) |
| Safety - Conf. | How confident are you about your memories on this topic? 0 = Not confident at all, 100 = Very confident. |
| Effectiveness - Ord. | At the beginning of last summer, which one of the vaccines did you think was the most effective? Please rank them from the most effective (1) to the least effective (4). |
| Effectiveness - Card. | Back then, how effective did you consider each vaccine? 0 = Not effective at all (0% effectiveness against catching COVID-19), 100 = Very effective (100% effectiveness against catching COVID-19) |
| Effectiveness - Conf. | How confident are you about your memories on this topic? 0 = Not confident at all, 100 = Very confident. |

Table S4: Survey - Wave 2 (continued)

| | |
|---|---|
| **Memory** | At the beginning of last summer (end of June 2021), we asked you the same kind of questions regarding the safety and efficiency of COVID-19 vaccines. |
| Expectations | At the beginning of last summer, were you planning to receive a vaccine? ☐ Yes *(G)* ☐ No *(H)* |
| Expectations - Ord. | *If (G)* Which one did you expect to receive? Please rank them from the most likely (1) to the least likely (4). |
| Expectations - Card. | And what did you think was the likelihood to receive each vaccine? (the likelihoods must total 100%). |
| **Choice** | Normally, UK residents cannot choose the type of vaccine that they receive. However, a few exceptions apply. What about you, could you choose the vaccine that you received? ☐ Yes, exceptionally I could choose. *(a)* ☐ It's complicated *(b)* ☐ *No, I could not choose. (c). If (a)* Could you tell us why you could choose? ☐ I have some specific medical conditions (e.g. allergies, pregnancy) ☐ I experienced some side effects after the first dose ☐ Other ☐ I could not choose the vaccine. *If (b)* Please explain. |
| **Stated preferences** | *If (c)* If you have had the choice, which vaccine would you have chosen to receive? |
| **Allocation** | Today, according to you, among the vaccinated population in the UK, what is the share who received each vaccine? (the total must sum up to 100%) |
| **Information selection** | Scientists from all over the world are monitoring the potential long-term risks and benefits related to the vaccines. Below you can read some of the latest news about the Pfizer-BioNtec and Moderna vaccines. Please click on one of the buttons below to display the piece of news you would like to read about. Each piece of news consists in a short sentence that summarizes results of a scientific study. ☐Pfizer-BioNtec: Advantages of receiving Pfizer-BioNtec vaccine compared to other vaccines ☐Pfizer-BioNtec: Disadvantages of receiving Pfizer-BioNtec vaccine compared to other vaccines ☐ Moderna: Advantages of receiving Moderna vaccine compared to other vaccines ☐ Moderna: Disadvantages of receiving Moderna vaccine compared to other vaccines |
| **Experience** | Did you experience any side effect after receiving a dose of vaccine against COVID-19? ☐ No ☐ Yes, but only mild side effects ☐ Yes, I experienced serious side effects. Do you know of anyone who experienced serious side effects after receiving a dose of vaccine against COVID-19? ☐ No / only from the media *(d)* ☐ Yes, a friend of a friend *(e)* ☐ Yes, a relative or a close friend *(f). If (e) or (f)* Did any of them receive the same vaccine that you received? Have you tested positive for COVID-19 infection at any point after your vaccine? ☐ No ☐ Yes, after the first dose ☐ Yes, after the second dose. Have any of your relatives or close friends tested positive after their vaccine? ☐ No *(g)* ☐ Yes, 1 or 2 *(h)* ☐ Yes, 3 or more *(i). If (h) or (i)* Did any of them receive the same vaccine that you received? Have you or any of your relatives and close friends been hospitalized after contracting the COVID-19 virus? |

Table S5: Survey - Wave 2 (continued)

| | |
|---|---|
| **Quiz** | For each of the following questions, please check the answer that you consider correct. You can still get COVID-19 even if you have received a COVID-19 vaccine. Some COVID-19 vaccines can affect your DNA. Pfizer-BioNTech and Moderna vaccines recorded a 100% efficacy against hospitalization and death from COVID-19. Side effects from COVID-19 vaccines are more common in older adults. In the U.K., to be eligible for a COVID-19 vaccine you must be 18 or older. |
| **Demographics** | What is your country of residence? Are you pregnant or do you have any underlying health condition? If you would like to let us know anything else, please type your feedback below. |

Table S6: Summary of sample composition, attrition and exclusions.

| | |
|---|---|
| Initial sample (Wave 1) | 1,285 |
| Attrition | 334 |
| Unmatched | 5 |
| Chose their vaccine | 65 |
| Inconsistent date of vaccination | 10 |
| Different second dose | 4 |
| Vaccine other than Pfizer or Moderna | 11 |
| Unvaccinated | 306 |
| Pfizer | 457 |
| Moderna | 93 |

Table S7: Regressions of the posterior beliefs about Pfizer with lagged-dependent-variable adjustment

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Dep.var.: safety | | Dep.var.: effectiveness | |
| Treatment = Pfizer | 0.44*** | 0.45*** | -0.23 | 1.32 |
| | (0.12) | (0.11) | (1.88) | (1.76) |
| Male | | 0.15 | | 1.95 |
| | | (0.09) | | (1.47) |
| Age | | -0.04** | | -0.04 |
| | | (0.02) | | (0.24) |
| Student | | 0.16* | | 0.41 |
| | | (0.09) | | (1.46) |
| Pregnant/health conditions | | 0.09 | | -2.11 |
| | | (0.17) | | (2.61) |
| Vaccine quiz score | | 0.04 | | 0.45 |
| | | (0.07) | | (1.04) |
| Hospitalized because of COVID-19 | | -0.24* | | 1.58 |
| | | (0.13) | | (1.97) |
| Tested positive after vaccine | | -0.02 | | -6.02** |
| | | (0.16) | | (2.53) |
| Had severe side effects | | -0.33 | | 3.01 |
| | | (0.35) | | (5.57) |
| Prior | | 0.27*** | | 0.39*** |
| | | (0.04) | | (0.04) |
| Time dummies | | ✓ | | ✓ |
| Geographical dummies | | ✓ | | ✓ |
| Constant | 5.74*** | 4.78*** | 81.53*** | 49.53*** |
| | (0.11) | (0.51) | (1.71) | (8.07) |
| N | 550 | 545 | 550 | 545 |
| $R^2$ | 0.024 | 0.208 | 0.000 | 0.218 |

*Reading note:* Linear regressions of posterior belief on the treatment and other covariates. Columns (1)-(2) refer to beliefs about safety; columns (3)-(4) refer to beliefs about effectiveness. Standard errors are in parentheses. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$. Specifications (2) and (4) include the following covariates: dummies = 1 if knows someone who had severe side effects / tested positive after the (same) vaccine, weekly time dummies for the date of participation in Wave 2, monthly time dummies for the date the last dose was received, and geographical dummies for the country of residence (England, Scotland, Wales or Northern Ireland).

Table S8: Regressions of the posterior beliefs about Pfizer on prior, treatment and their interaction

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Dep.var.: safety | | Dep.var.: effectiveness | |
| Treatment = Pfizer | 0.68 | 0.68 | -4.34 | -0.75 |
| | (0.52) | (0.54) | (8.79) | (8.92) |
| Prior | 0.35*** | 0.31*** | 0.37*** | 0.37*** |
| | (0.08) | (0.08) | (0.09) | (0.10) |
| Prior × Treatment | -0.05 | -0.04 | 0.05 | 0.03 |
| | (0.09) | (0.09) | (0.11) | (0.11) |
| Controls | | ✓ | | ✓ |
| N | 547 | 545 | 546 | 545 |
| $R^2$ | 0.152 | 0.208 | 0.148 | 0.218 |

*Reading note:* Linear regressions of posterior belief on the treatment, the prior, their interaction and other covariates. Columns (1)-(2) refer to beliefs about safety; columns (3)-(4) refer to beliefs about effectiveness. Standard errors are in parentheses. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$. Specifications (2) and (4) include the following covariates: gender, age, student status, health status, vaccine quiz score, dummies = 1 if (i) hospitalized because of COVID-19, (ii) tested positive after vaccine, (iii) had severe side effects, (iv) knows someone who had severe side effects / tested positive after the (same) vaccine, weekly time dummies for the date of participation in Wave 2, monthly time dummies for the date the last dose was received, and geographical dummies for the country of residence (England, Scotland, Wales or Northern Ireland).

Table S9: Beliefs about likelihood of receiving a vaccine

| *Vaccine* | Wave 1 (Foresight) | Wave 2 (Hindsight) | W2-W1 | *p-value* | N |
|---|---|---|---|---|---|
| *Treatment = Moderna* | | | | | |
| Moderna | 21.3 | 30.9 | 9.6 | *0.001* | 80 |
| Pfizer | 55.3 | 45.5 | -9.7 | *0.003* | 80 |
| AstraZeneca | 16.8 | 18.4 | 1.5 | *0.535* | 80 |
| Janssen | 6.5 | 5.1 | -1.4 | *0.176* | 80 |
| *Treatment = Pfizer* | | | | | |
| Moderna | 18.7 | 14.4 | -4.35 | *0.001* | 376 |
| Pfizer | 56.5 | 61.1 | 4.55 | *0.005* | 376 |
| AstraZeneca | 17.4 | 19.5 | 2.0 | *0.118* | 376 |
| Janssen | 6.0 | 5.0 | -0.9 | *0.111* | 376 |

*Reading note*: A positive value in the W2-W1 column indicates hindsight bias (aka, knew-it-all-along effect). Individuals treated with Moderna displays hindsight bias for the likelihood of receiving Moderna (p-value = 0.001) and individuals treated with Pfizer displays hindsight bias for the likelihood of receiving Pfizer (p-value = 0.005). The number of observations is smaller than the size of the sample because of non-response.