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How to reduce vaccination hesitancy? The relevance of evidence and its communicator ☆

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ABSTRACT

Even though the immediate urgency of the COVID-19 pandemic seems to have passed, many countries did not reach the vaccination rates they initially aimed for. The stagnation in vaccine uptake during the height of the pandemic presented policy makers with a challenge that remains unresolved and is paramount for future pandemics and other crises: How to convince the (often not insubstantial) unvaccinated proportion of the population of the benefits of a vaccination? Designing more successful communication strategies, both in retrospect and looking ahead, requires a differentiated understanding of the concerns of those that remain unvaccinated. Guided by the elaboration likelihood model, this paper has two objectives: First, it explores by means of a latent class analysis how unvaccinated individuals might be characterized by their attitudes towards COVID-19 vaccination. Second, we investigate to what extent (i) varying types of evidence (none/anecdotal/statistical) can be employed by (ii) different types of communicators (scientists/politicians) to improve vaccination intentions across these subgroups. To address these questions, we conducted an original online survey experiment among 2145 unvaccinated respondents from Germany where a substantial population share remains unvaccinated. The results suggest three different subgroups, which differ regarding their openness towards a COVID-19 vaccination: Vaccination *opponents (N = 1184)*, *sceptics (N = 572)* and those in principle *receptive (N = 389)* to be vaccinated. On average, neither the provision of statistical nor anecdotal evidence increased the persuasiveness of information regarding the efficacy of a COVID-19 vaccine. However, scientists were, on average, more persuasive than politicians (relatively increase vaccination intentions by 0.184 standard deviations). With respect to heterogeneous treatment effects among the three subgroups, vaccination *opponents* seem largely unreachable, while *sceptics* value information by scientists, particularly if supported by anecdotal evidence (relatively increases intentions by 0.45 standard deviations). *Receptives* seem much more responsive to statistical evidence from politicians (relatively increases intentions by 0.38 standard deviations).

1. Introduction

Despite sufficient vaccination capacity and evidence on vaccine efficacy [1], many countries around the world did not overcome the challenge of reaching vaccination rates sufficiently high to achieve community immunity during the peak of the COVID-19 pandemic. In autumn 2021 (during our data collection), Germany, among several other European countries, was hit strongly by the fourth wave of the pandemic and found itself struggling to find the right policies amidst the increased contagiousness of the Delta

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and Omicron variants. In response to the stagnating national vaccination rate, the government had introduced increasing restrictions on unvaccinated citizens. Nevertheless, at the time of writing (February 2023), the national vaccination rate remains at just above 75 % (i.e., those having received at least two doses [2]). To achieve community immunity, estimates of required vaccination rates range up to 90 %, underlining the importance of effective immunization campaigns [3]. Such a campaign, however, can only be created, if the needs and considerations of the unvaccinated, which have been dominated by concerns about vaccine safety and efficacy, are sufficiently understood [4–6]. Against this background, our paper engages in a differentiated classification of the unvaccinated population and builds on sociopsychological theory to assess how evidence regarding vaccine efficacy being presented through different communicators might increase vaccination willingness.

Existing research suggests that the judgment of information largely depends on the perception of trustworthiness and credibility of its communicator [e.g., 7]. Particularly for vaccinations, recent empirical evidence confirms the importance of a trustworthy communicator when it comes to the decision to get vaccinated [8,9]. To increase their trustworthiness, communicators may support their information with evidence [10,11]. An extensive literature on persuasion processes addresses the effects of information and information attributes on attitude change [see 12, for a review].

According to the dual-process theory of the Elaboration-Likelihood Model (ELM) [13], the processing of persuasive messages can occur through two distinct pathways. The first, known as the "peripheral route," runs through quick cognitive shortcuts, while the second, called the "central route," builds on more elaborate cognitive processing and deliberate reasoning [e.g., 14]. Thus, different types of evidence may align better with a certain processing path. Specifically, a distinction can be made between two forms of evidence: statistical and anecdotal. Previous research has shown that when subjects do not engage in deep elaboration, anecdotal evidence is more convincing [15,16] since it is more descriptive and easier to process via the peripheral route [17]. In contrast, statistical evidence is likely to be particularly compelling, if the respective population considers the subject to be prominent and engages via the central route.

Given heterogeneities in the population and their attitudes towards different communicators, we propose that communicators might be able to optimize the effectiveness of their message by choosing the evidence type that best complements their own credibility and aligns with the perspective of the recipient of the information. We examine these theoretical expectations within a unique sample of unvaccinated German citizens (N = 2145) who participated in an online survey experiment specifically targeting this critical share of the population.

The contribution of this paper is threefold. First, we engage in a latent class analysis to characterize unvaccinated individuals based on their attitudes towards the COVID-19 vaccination. In doing so, we conceptually rely on the 5C-scale of vaccination hesitancy [18]. Second, to determine the most effective strategies for increasing vaccination uptake, we combine our classification system with the theoretical framework of the ELM. Specifically, we experimentally examine how different types of evidence (none, statistical, anecdotal) and communicators (politicians, scientists) can be targeted to the respective subgroups that we have identified. We argue that treatment effects might vary significantly across subgroups if either the motivation or the ability in information processing also varies between them. To the best of our knowledge, this is the first study that considers the potential complementarity between communicator and evidence to increase messaging effectiveness and assesses treatment effect heterogeneity across different subgroups of unvaccinated respondents.[1]

The remainder of the paper is structured as follows: Section 2 briefly presents the utilized materials and methods, introduces the empirical strategy, and outlines the experimental approach. Subsequently, Section 3 presents the results of the latent class analysis and our experimental findings. Section 4 concludes with a brief discussion of the main findings and outlines avenues for future research.

2. Materials and methods

2.1. Setting and sampling

We conducted an online survey with a sample of 2,145[2] unvaccinated individuals from Germany between August 20 and September 16, 2021. Respondents were recruited from a German online access panel maintained by the survey company Bilendi & respondi, through which participants received an URL via email and could choose to participate in the survey using their own digital device. Individuals were eligible to participate in the study if they were at least 18 years old and had not yet been vaccinated against COVID-19 (not yet received the first dose). The survey covered socioeconomic characteristics, measures regarding respondents' elaboration likelihood to engage with information about COVID-19 vaccines, and their intentions to get vaccinated. Respondents received 'mingle points' (worth roughly 1 Euro) for participating in the survey, which they could redeem as cash, vouchers, or donations.[3]

2.2. Empirical strategy

2.2.1. Latent class analysis

According to the ELM, behavioural intentions are affected by one's motivation and ability, e.g., education [19], to engage with available information. Thus, to assess differences in the responsiveness to communicators and the effectiveness of evidence on COVID-19 vaccination intentions, we first classified and characterized different groups of unvaccinated respondents based on their attitudinal patterns towards COVID-19 vaccinations. For this purpose, we conducted a latent class analysis (LCA). This analysis was an explorative component of the information experiment as outlined in the Pre-Analysis-Plan.[4]

The purpose of LCA is to condense numerous observed ordinal

[1] For an overview of our proposed hypotheses, please see https://osf.io/vhjeg/. For specifications of pre-analysis plan deviations, see Appendix A.

[2] Please note that the actual number of observations might vary slightly in the results tables below due to missing values in socio-economic control variables. The number of missings is, however, very low (see below).

[3] We acknowledge that monetary incentives may have severe effects on the study results, if the financial incentives do influence the participation and/or response behaviour. The panel provider, *Bilendi & respondi,* places great importance on controlling the quality of the panellists through regular checks in order to assure high quality participants. This starts with the registration process and is continued during the lifetime of a panellist as well as in every survey participation. When registering for the panel, an automatic verification checks duplicate registrations with the same email address. During the registration process, the digital fingerprint highlights participants with identical IP addresses and browser configurations and automatically renders these respondents inactive. Furthermore, a double opt-in email with an invitation to complete the start questionnaire is sent to every new member straight after registration. Within the framework of *Bilendi & respondi's* quality strategy, the company does not use routing or river sampling in their controlling measures. The panellists are invited directly by email to *Bilendi & respondi's* client's questionnaire without being diverted to a router in between. This applies also to *Bilendi & respondi's* partners if the company needs additional purchase. Furthermore, *Bilendi & respondi* always clearly communicates the origin and proportion of external panellists to their clients.

[4] For the experimental protocol and the survey, please refer to the supplementary materials and the pre-analysis plan at https://osf.io/vhjeg/.

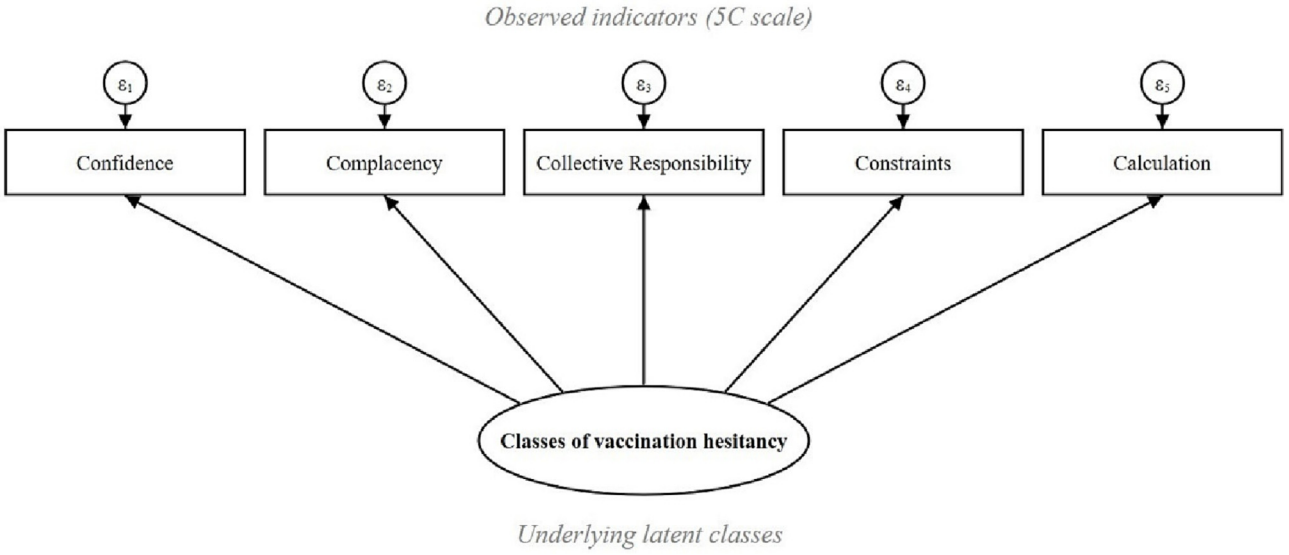

Fig. 1. LCA model: Identification of classes of vaccination hesitancy.

variables (reflective indicators) in order to assign probabilities of belonging to a smaller set of underlying, latent classes [20]. By reducing dimensionality, LCA facilitates subgroup analyses [21] which makes it particularly useful to assess heterogeneous effects in experiments [22]. As reflective indicators, we considered the extended COVID-19-adapted 5C scale by Betsch et al. [18]. Using three survey questions for each dimension, the scale captures five different aspects of vaccination intentions (namely: Confidence, Complacency, Collective responsibility, Constraints, and Calculation; see Section 2.3 and Table A15 for details), intended to proxy the motivation component of the elaboration likelihood of respondents. The LCA method assumes that the underlying latent class membership (i.e., here classes of vaccination hesitancy) induces differential response patterns in the reflective indicators (i.e., here the 5C scale questions). Thus, in the LCA, the 5C scale indicators are the dependent variables and the categorical latent class variable is the independent variable, as illustrated in Fig. 1 below. Based on this, we estimated a generalized structural equation model by means of an ordered logistic regression using maximum likelihood estimation.

2.2.2. Survey experiment

The second component of the empirical strategy comprised a survey experiment testing different information treatments about the benefits of a COVID-19 vaccination to identify persuasive communication strategies. Specifically, we first informed all participants about the current COVID-19 incidence in Germany (at the time of the survey) and described a hypothetical scenario in which a new COVID-19 vaccine had been developed and approved. In a second step, respondents were informed that this newly developed and approved vaccine is highly effective in reducing hospitalization following a COVID-19 infection. This second step was randomly varied regarding two components: (i) the profession of the communicator of this information and (ii) the type of evidence employed by the communicator. In our case, anecdotal evidence referred to a visit to an intensive care unit, while statistical evidence made reference to a clinical study on the efficacy of the new hypothetical COVID-19 vaccine. Appendix A provides the exact wording of the experimental treatments.

We estimated ordinary least squares (OLS) and ordered logit models to test the main hypotheses whether evidence increases vaccination willingness and whether heterogeneous messaging and respondent characteristics moderate this effect.

$$VI_i = \alpha_1 + \beta_1 Evi_i \times Com_i + \beta_2 Com_i + \beta_3 Evi_i + \beta_4 X' + \epsilon_i \quad (1)$$

VI_i in Equation 1 refers to the vaccination intentions of respondent i, Com_i, denotes whether a politician or scientist communicated the information treatment, Evi_i, refers to the type of provided evidence (none/anecdotal/statistical), X' refers to a vector of socioeconomic control variables, and ϵ_i is the error term.[5]

We also consider how the different subgroups of unvaccinated respondents (i.e., the identified classes of vaccination hesitancy) react to the differential messaging. For this purpose, we introduce interaction terms with LCA_i to Eq. (1):

$$VI_i = \alpha_1 + \beta_1 Evi_i \times Com_i + \beta_2 Com_i + \beta_3 Evi_i + \beta_4 X' + \beta_5 Evi_i \times LCA_i + \beta_6 Com_i \times LCA_i + \beta_7 Evi_i \times Com_i \times LCA_i + \beta_8 LCA_i + \epsilon_i \quad (2)$$

We later employ t-tests to assess if treatment effects across senders and evidence types differ by our assigned classes (LCA_i). Since there is uncertainty in the class assignment when using LCA, we employed a multiple imputation approach to address this (see Appendix A for further details in this regard).

2.3. Data and outcome variables

Beyond the information about treatment group assignment, the survey contained questions about the main dependent variable of interest: the intention to get vaccinated against COVID. We moreover collected information on additional explanatory variables, including demographic and socioeconomic characteristics of respondents. Question wording and summary statistics for the primary and secondary outcome variables as well as for selected control variables are provided in Table 1 below. A full list of all survey items is shown in Tables A1 and A15 in Appendix B.

2.3.1. Vaccination intention

The main outcome variable is respondents' intention to get vaccinated against COVID-19, measured on a 7-point Likert scale.

[5] To account for multiple hypothesis testing, we apply also sharpened q-values based on Stata code by Anderson [22] (see Tables A11 and A13 in Appendix B).

Table 1
Survey items, Question wording and Summary statistics.

Variable	Item/Question	Scale	Summary Stat.
Primary outcome variable:			
Vaccination willingness	How would you decide if you had the opportunity to get vaccinated against COVID-19 with this vaccine next week?	Scale from (1) I would definitely not get vaccinated to (7) I would definitely get vaccinated	Mean: 2.69 SD: 1.62
Secondary outcome variables (mediation analysis):	Please think about the new vaccine that was the subject of some of the previous questions. Now we would like to know how you assess the information provided by Ms. Sommer on this new vaccine. Please indicate to what extent you agree or disagree with the following statements:	Scale from (1) Strongly disagree to (7) Strongly agree	
Credibility	The information is credible.		Mean: 3.11 SD: 1.62
Relevance	The information is relevant for my decision to get vaccinated.		Mean: 2.80 SD: 1.79
Credible Source	Ms. Sommer is credible as the source of information.		Mean: 2.89 SD: 1.59
Controls			
Age	In which year were you born? (transferred to age)		Mean: 41.41 SD: 11.82
Gender	What gender do you identify with?	(1) Female (2) Male (3) Diverse (4) Prefer not to say	(1) 63.8 % (2) 36.0 % (3) 0.1 % (4) 0 %
Education	What is your highest level of education (educational qualification)?	(1) No school-leaving qualification (2) Elementary or secondary school leaving certificate without completed apprenticeship (3) Elementary or secondary school leaving certificate with completed apprenticeship (4) Secondary school leaving certificate, Realschulabschluss (5) Advanced technical college certificate (6)Abitur(general higher education entrance qualification) (7) University of applied sciences or university degree (Bachelor, Master, Magister, Diplom or Staatsexamen) (8) Doctorate/PhD (9) Other degree:	(1) 0.5 % (2) 3.0 % (3) 10.9 % (4) 35.6 % (5) 8.5 % (6) 17.4 % (7) 22.1 % (8) 1.3 % (9) 0.5 %
5C Vaccination attitudes		Scale from (1) Strongly disagree to (7) Strongly agree	
	The COVID-19 vaccinations are effective. (conf 1)		Mean: 3.09 SD: 1.78
	I have full confidence in the safety of COVID-19 vaccinations. (conf 2)		Mean: 2.29 SD: 1.74
	As far as COVID-19 vaccinations are concerned, I trust that government authorities will always decide in the best interest of the general public. (conf 3)		Mean: 2.56 SD: 1.80
	My immune system is so strong, it also protects me from contracting COVID-19. (comp 1)		Mean: 4.27 SD: 1.88
	Vaccination against COVID-19 is superfluous, since diseases against which one can be vaccinated are generally rare. (comp 2)		Mean: 3.23 SD: 1.82
	COVID-19 is not so bad that I need to be vaccinated against it. (comp 3)		Mean: 4.17 SD: 2.03
	It is costly for me to get vaccinated against COVID-19. (const 1)		Mean: 2.50 SD: 1.81
	My discomfort at doctor's appointments keeps me from		Mean: 2.47

(*continued on next page*)

Table 1 (*continued*)

Variable	Item/Question	Scale	Summary Stat.
	getting vaccinated against COVID-19. (const 2)		SD: 1.84
	Everyday stress keeps me from getting vaccinated against COVID-19. (cons 3)		Mean: 2.18 SD: 1.71
	I think very carefully about whether it makes sense for me to be vaccinated against COVID-19. (calc 1)		Mean: 5.98 SD: 1.56
	A full understanding of the issue of COVID-19 vaccination is important to me before I get vaccinated. (calc 2)		Mean: 5.67 SD: 1.58
	When I think about getting vaccinated against COVID-19, I weigh the benefits and risks to make the best possible decision. (calc 3)		Mean: 5.83 SD: 1.57
	If everyone is vaccinated against COVID-19, I don't need to get vaccinated too. (core 1, reverse coded)		Mean: 3.68 SD: 2.04
	I get vaccinated against COVID-19 because I can protect people with a weak immune system. (core 2)		Mean: 2.84 SD: 2.00
	Vaccination is a community measure to prevent the spread of COVID-19. (core 3)		Mean: 3.38 SD: 2.04

We elicited vaccination intentions by asking respondents the following question: *"How would you decide, if you had the opportunity to get vaccinated against COVID-19 with this vaccine next week?". Responses were measured on a scale from (1) "I would definitely not get vaccinated" to (7) "I would definitely get vaccinated.".*[6,7]

A broad psychological literature - largely based on the Theory of Planned Behavior [23] provides evidence that intentions are a relevant predictor of actual behaviour, for instance with respect to other health behaviours during the COVID-19 pandemic [24]. Nonetheless, we are aware that reported intended and actual vaccination decisions might differ [25–27]. Hence, we try to address this concern as follows: First, by sampling respondents with real-world hesitancy, we select the relevant target group for messaging campaigns (i.e., the approx. 25 % of the German population that indeed had not been vaccinated in September 2021 and is largely still unvaccinated today). Second, we include in our tested messaging recent information on the actual COVID-19 infection numbers at the time of the data collection. Third, we used messaging as employed by politicians/scientists [e.g., 28]. We deliberately did not refer to any of the existing COVID-19 vaccines in the experiment to avoid potential difficulties resulting from vaccine-specific (negative or positive) associations (e.g., with AstraZeneca), which would most likely systematically bias reactions to the employed messages in unintended ways. The indicated efficacy of the hypothetical new vaccine, however, matches the efficacy of the preferred vaccines which were used in Germany at that time (BioNTech and Moderna). Finally, the approval of a new vaccine was not an unrealistic prospect at the time of the survey, since new vaccines were still under development (which is even currently still the case, e.g., for variant-specific vaccines). We recognize that it would be valuable to conduct future research to measure the impact of messaging campaigns on actual vaccination decisions.

2.3.2. COVID-19 vaccination attitudes and elaboration likelihood

As outlined above, we employed the 5C scale by Betsch et al. [18] as reflective indicators for the LCA. We adjusted this scale, initially designed for general vaccination attitudes, to fit a COVID-19 specific application based on Betsch et al. [9]. The scale aims to elicit five central aspects of attitudes towards vaccination, namely (i) Confidence in the COVID-19 vaccines and their endorsers (this captures both safety and effectiveness concerns of the vaccines as well as confidence in the entities producing, administering, and encouraging vaccinations), (ii) Complacency (not perceiving the virus as a serious risk), (iii) Collective responsibility (willingness to protect others), (iv) Constraints (structural and psychological barriers), and (v) Calculation (extensive information searching for weighing costs and benefits) [18]. We employed the full extended scale, which consists of three items for each aspect (see Table A15 in Appendix B for a list of the 15 questions and the exact wording).

[6] For the exact wording of the other survey items, please see Table A15 in Appendix B.

[7] At the time of the data collection (mid-August-mid-September 2021), COVID-19 vaccines were still scarce in Germany, but the initially high demand for vaccine shots had largely passed. Approx. 61 % of the population were already vaccinated twice and not yet eligible for the booster vaccination (Impfdashboard, Bundesministerium für Gesundheit, 2023). During this time, the centralized online system and practitioners were no longer overwhelmed and citizens could mostly schedule their appointments for a vaccine without complications. While it was rather unlikely to book an appointment within a timeframe as short as one week (though it did occasionally happen that appointments were cancelled and citizens were offered their appointment on short notice), we chose this wording of our outcome variable as to more adequately elicit participants' vaccination intentions (i) independent of extreme scarcity considerations and (ii) to provide a more concrete time frame for respondents when making the decision. In doing so, we hoped to make the question more precise and viable for respondents and minimize potential biasing effects of its inherent hypothetical nature.

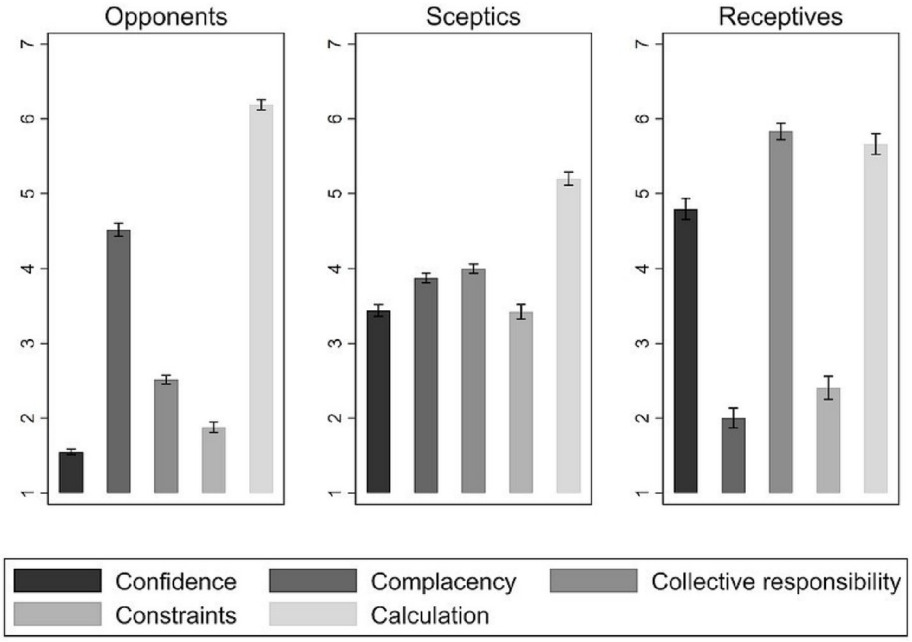

Fig. 2. Classes of vaccination hesitancy: Identification via the 5C scale. *Notes:* Results refer to mean values of the 5C scale for vaccination attitudes, separately for each class as identified by the LCA. The mean values shown here are those of the initial 5C scale, measured on a 7-point Likert scale. See Tables A3-A5 in Appendix B for the condensed scale. Values of the 15 5C items (three items for each aspect) were averaged for each of the five aspects of vaccination hesitancy that we aim to capture. See Figure A1 in Appendix B for the same graphic with all 15 items. In order to better illustrate class differences regarding the 5C vaccination hesitancy scale, the graph employs a definite class assignment where respondents were assigned to the class with the maximum predicted probability.

Moreover, the survey collected information to validate whether the LCA class assignment, in fact, captures the elaboration likelihood with which respondents take up the different information treatments. Specifically, we elicited trust in politicians and scientists (a proxy for motivation to engage with the provided information) and the perceived value and understanding of anecdotal and statistical evidence (a proxy for ability to engage with the provided information), all measured on a 7-point Likert scale. Besides building on the previously validated survey items in the respective cited works above, we piloted (soft-launched) our survey with a sample of 110 respondents to validate our outcomes and covariates.

3. Results

3.1. Latent class analysis: Not one, but many publics

The results of the LCA suggest the existence of three underlying classes of vaccination hesitancy in our sample.[8] The classes are characterized and distinguishable by differential response patterns to the COVID-19 adjusted 5C scale (see Fig. 2 below and Tables A2-A5 in Appendix B).[9] Given these differing response patterns to the 5C scale, we expect members of the three classes to have coherently varying attitudes towards getting vaccinated against COVID-19 and have therefore labelled the three classes as opponents, sceptics and receptives. The following paragraphs explain these differences by describing response patterns to the 5C scale (see Fig. 2) and stated intentions to get vaccinated against COVID-19 across classes (employed as an accuracy check of these labels, see Table 2). We further contrast socioeconomic characteristics across classes.

The first class, vaccination opponents, had the largest prevalence in our sample (55.14 %). This class was characterized by relatively low confidence levels in vaccine safety and efficacy, the system that delivers them, and the (motivations of the) actors deciding on the need for vaccines (Mean = 1.55). Similarly, vaccination opponents expressed high levels of complacency (perceived invulnerability towards the COVID-19 virus) (Mean = 5.52) and low levels of collective responsibility (Mean = 2.52), which may make them more susceptible to 'vaccination free-riding'. Finally, the aspect of calculation (i.e., in terms of careful searching for information to weigh infection and vaccination risks and benefits) was a highly important factor (Mean = 6.19), whereas practical constraints or inconveniences such as geographical accessibility did, on average, not seem to present a substantial barrier to vaccination in this identified subgroup (Mean = 1.88). In light of these characteristics, the class of opponents seems to have opposing attitudes towards a COVID-19 vaccination.

The second class with contrary characteristics, vaccination receptives, had the smallest prevalence in our sample (18.24 %). While levels of (i) vaccine confidence and (ii) collective responsibility in getting vaccinated were on average relatively high (Confidence: Mean = 4.80; Collective responsibility: Mean = 5.83), the degree of (iii) complacency was relatively low compared to the values in the class of vaccination opponents (Mean = 2.00). Practical constraints to getting vaccinated were slightly more important among vaccination receptives (Mean = 2.41), while calculation aspects were slightly less important than they were among vaccination opponents (Mean = 5.66). In light of these characteristics, the class of receptives, in principle, seems to support getting a

[8] We ran models with one to four and partly five underlying classes, but opted for a final model with three classes due to a combination of interpretability, reductions in the goodness of fit improvements, and model convergence problems. In the LCA, where the model's fit can also be assessed for a single model using the likelihood-ratio test of the fitted model versus the saturated model (G2 statistic), we fail to reject the null hypothesis that our model fits just as well as the saturated model.

[9] While we initially measured agreement with the items of the 5C scale on a 7-point Likert scale, we condensed the scale into three categories due to skewed and non-normally distributed data, not allowing the model to converge. The three condensed categories combined the two extreme points of the initial Likert scale as well as the three moderate points (initial values 1 or 2 => condensed value 1; values 3, 4 or 5 => value 2; values 6 or 7 => value 3). The resulting ordinal variables with three categories were then used as categorical indicators for the LCA. The initial 7-point Likert scale and the condensed scale are, on average, across all 15 items highly correlated by a value of approximately 0.95.

Table 2
Respondent characteristics by class membership.

Variable	(1) Opponents (N=1,184)	(2) Sceptics (N=572)	(3) Receptives (N=389)	T-test Difference (1)-(2)	(1)-(3)	(2)-(3)
Willingness to get vaccinated	1.732	3.428	4.495	−1.696***	−2.763***	−1.068***
	(0.036)	(0.061)	(0.102)			
Female	0.658	0.592	0.652	0.066***	0.006	−0.060*
	(0.014)	(0.021)	(0.024)			
18-34 yrs.	0.266	0.404	0.365	−0.138***	−0.099***	0.039
	(0.013)	(0.021)	(0.024)			
35-54 yrs.	0.527	0.484	0.460	0.043*	0.067**	0.024
	(0.015)	(0.021)	(0.025)			
55 yrs. and above	0.207	0.112	0.175	0.095***	0.032	−0.063***
	(0.012)	(0.013)	(0.019)			
Primary education	0.151	0.142	0.132	0.009	0.019	0.010
	(0.010)	(0.015)	(0.017)			
Secondary education	0.375	0.347	0.323	0.027	0.051*	0.024
	(0.014)	(0.020)	(0.024)			
Tertiary education	0.474	0.510	0.545	−0.036	−0.071**	−0.034
	(0.014)	(0.021)	(0.025)			
Residence in new federal states	0.272	0.243	0.198	0.029	0.074***	0.045
	(0.013)	(0.018)	(0.020)			
Intention to vote AFD	0.352	0.219	0.091	0.133***	0.261***	0.128***
	(0.013)	(0.015)	(0.012)			
Trust in scientists	3.716	4.229	5.532	−0.513***	−1.816***	−1.303***
	(0.046)	(0.057)	(0.064)			
Trust in politicians	1.613	2.962	3.653	−1.348***	−2.040***	−0.691***
	(0.029)	(0.061)	(0.085)			
Value/Understanding of anecdotal evidence	3.708	3.458	3.126	0.250***	0.582***	0.332***
	(0.028)	(0.036)	(0.055)			
Value/Understanding of statistical evidence	3.260	3.503	3.972	−0.244***	−0.712***	−0.468***
	(0.033)	(0.035)	(0.047)			
F-test of joint significance (F-stat)				52.297***	97.001***	25.024***
F-test, number of observations				1,756	1,573	961

Notes: Summary statistics contain means and standard deviations for continuous variables and percentages for categorical variables. All summary statistics are calculated based on the full sample.
Notes: Variables are binary indicators, except for Willingness to get vaccinated, Trust in scientists, Trust in politicians and Value/Understanding of anecdotal/statistical evidence, which were measured on a 1-7 point Likert scale, with higher values indicating higher willingness to get vaccinated/trust/self-rated ability, respectively. Willingness to get vaccinated refers to the willingness to get vaccinated with the hypothetical new COVID-19 vaccine introduced in the survey experiment (i.e., it is the outcome variable of interest in the empirical analysis of the survey experiment for evaluating treatments effects of evidence and communicator). See Table A9 in the Appendix for class characteristics regarding the Willingness to get vaccinated with existing vaccines. Class assignment is definite and defined according to each respondents' highest predicted class probability. The resulting class assignment is captured in a categorical variable with three categories. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

COVID-19 vaccination, but their careful weighing of the risks of a newly developed vaccine compared to the consequences of infection may keep them from doing so.

The third class, vaccination sceptics, had a prevalence of approximately one-quarter of our sample (26.63 %). In this class, respondents attributed a similar, moderate relevance to all the investigated reasons against or in favor of a COVID-19 vaccination (Confidence Mean = 3.44; Collective responsibility: Mean = 4.00; Complacency: Mean = 3.87; Constraints: Mean = 3.42). The only exception was calculative considerations of the vaccination decision, which presented the most dominant factor in this class (Mean = 5.20).[10] In light of these characteristics, the class of sceptics seems to have serious doubts towards a COVID-19 vaccination but does not oppose it as strongly as the class of opponents.

In line with the above characterization, we find that the three classes differed linearly in their intentions to get vaccinated with the hypothetical COVID-19 vaccine introduced in the survey experiment (see Table 2 below). Reported willingness was on average lowest among opponents (Mean (SD) = 1.73(1.23)) and highest among the class of vaccination receptives (Mean (SD) = 4.50 (2.00)). Sceptics, coherently, indicated moderate intentions to get vaccinated (Mean (SD) = 3.43(1.46)).[11] Reassuringly, this pattern also holds for respondents' willingness to get vaccinated with the existing developed and widely known COVID-19 vaccines, underlining the credibility of our outcome variable with respect to having chosen a hypothetical vaccine (see Table A9 in Appendix B).

Regarding demographic and socioeconomic characteristics, the class of opponents differed from the other two classes, e.g., with respect to age, gender, educational attainment, and federal state of residence (see Table 2). Specifically, opponents were, on average, (i) older than receptives and sceptics, (ii) more likely to be female compared to sceptics, and (iii) less educated and were more likely to reside in Germany's new Eastern federal states than members of the receptives class. However, the classes differed much more clearly in terms of their intentions and beliefs than in terms of socioeconomic characteristics: Looking at respondents' (i) reported voting intentions in the next national election,[12] (ii) their trust in scientists and (iii) politicians, as well as their perceived value and understanding of (iv) anecdotal and (v) statistical evidence, there seems to be a near-linear pattern across the three classes (see

[10] Due to the condensed indicators employed in the LCA, we additionally conducted a latent profile analysis (LPA) as a robustness check, which employs the initial 7-point Likert scale as continuous indicators of the latent classes. Class prevalences and characteristics (i.e., marginal class probabilities and class means) were very similar to in the LCA and are presented in Tables A6-A8 in Appendix B.

[11] While we argue for a differentiated assessment across the identified subgroups within the unvaccinated population, we also consider average effects within the entire sample of unvaccinated respondents (Mean: 2.69; SD: 1.84).

[12] The next national elections in Germany were held a couple of weeks after the survey was fielded.

Table 2): The more supportive a class' attitude is towards a COVID-vaccination (i.e., receptives > sceptics > opponents), the less often respondents of this class indicated their intention to vote for the AFD party in the next national election (a right-wing party in the German parliament, which opposed pandemic-related restrictions), the higher was their trust in scientists and politicians, the more they valued statistical evidence, and the less they valued anecdotal evidence.

Our findings partly resemble those by Rieger et al. (2022), who surveyed a representative sample of both vaccinated and unvaccinated German respondents and also find that women, right-wing voters and respondents with less trust in the political system were more likely to oppose vaccination. Yet, our results contrast Rieger et al. (2022) in that older and less educated respondents and respondents living in the new federal states are also more likely to oppose vaccination [29].[13]

3.2. Survey experiment: Average effects of communicator and evidence type

We briefly report the average treatment effects of the tested communication strategies in the entire sample and then examine a potential heterogeneity in their effectiveness in terms of communicator and evidence type across the identified classes. In all of the results reported here, the dependent variable is respondents' willingness to get vaccinated with the new hypothetical COVID-19 vaccine.[14,15]

Table 3 below presents the estimation results for average treatment effects: First, the coefficient of scientists as communicators is statistically significant at the 5 % level and positive in both estimations (Columns (1) and (2)), suggesting that scientists were on average more persuasive as communicators than politicians. Employing scientists as the communicator relatively increased the reported willingness to get vaccinated, on average, by approximately 0.184 standard deviations.

Second, the statistically insignificant coefficients of both evidence types in Columns (3) and (4) suggest that neither the provision of statistical nor anecdotal evidence, on average, increased the persuasiveness of information about the efficacy of a COVID-19 vaccine.

Third, Columns (5) and (6) and the t-tests at the bottom of the table report the results for the interaction between types of evidence and each communicator. The t-tests on the point estimates reveal that there are no significant differences between no evidence (reference category), anecdotal evidence, and statistical evidence – neither for politicians nor for scientists as communicators. Therefore, when informing the average unvaccinated public about the efficacy of COVID-19 vaccines, it does not seem to matter what form of evidence communicators use, and whether they use any at all.[16]

[13] Notably, while we focused on the unvaccinated population, Rieger et al. (2022) focused on the general public i.e., vaccinated and unvaccinated individuals. Aside from the different samples, the different outcome variables in terms of vaccination intentions (individual outcome) in our study and attitudes towards mandatory vaccinations (collective outcome) in Rieger et al. (2022) lack comparability and thus prevent strong conclusions [r7].

[14] All models are estimated using OLS regressions. To account for the ordered scale of the dependent variable, we report results of ordered logit estimations in Appendix (see Table A10).

[15] After the respondents received the treatment and were asked about their willingness to get vaccinated, we conducted an attention test in which we asked the participants what profession –the communicating person in the treatment has. 54 % of the respondents answered this question correctly. Table A12 in Appendix B presents the regression results if only the respondents who answered the question correctly are considered.

[16] In the appendix, we also present the main results, when accounting for multiple hypotheses testing via sharpened q-values [30].

3.3. Survey experiment: Heterogeneity by classes of vaccination hesitancy

We now turn to possibly differing effects of the explored treatments due to respondents' differential elaboration likelihood, as reflected in the identified classes of vaccination opponents, sceptics, and receptives. The results of this exercise are presented in Figs. 3 and 4 below, and we discuss them in turn for each class separately.

3.3.1. Opponents

For vaccination opponents, the results in Fig. 3 show that neither the communicator nor the provision and type of evidence seem to be crucial for the persuasiveness of the information about COVID-19 vaccine efficacy. In accordance with this, the results in Fig. 4 suggest no clear communication strategy for politicians and scientists to target vaccination opponents: for both communicators, there are no significant differences between the evidence types.

3.3.2. Sceptics

For sceptics, the results are more unequivocal. First, concerning the communicator, column 2 row 2 of Fig. 3 shows that the coefficient for scientists is 0.2 standard deviations higher than for politicians. This difference is statistically significant at the 5 % level (average p-value[17]: 0.023). This comparatively strong effect suggests that it may be the subgroup of sceptics that drives the effect found for the average population.

Second, we observe that, for sceptics, the provision of evidence about the efficacy of the COVID-19 vaccine does seem to matter. Compared to the no evidence condition, both anecdotal evidence and statistical evidence have a positive and statistically significant effect at the 1 % level (average p-value: 0.006 for anecdotal evidence and 0.019 for statistical evidence). However, sceptics seem not to differentiate between the evidence type since we found no statistically significant difference between anecdotal and statistical evidence.

Third, in terms of the explored interaction between communicator and evidence type, the results in Fig. 4 below reveal that scientists in particular can enhance the persuasiveness of their conveyed information by providing additional evidence (average p-value anecdotal evidence: 0.012; average p-value statistical evidence: 0.043). While the provision of anecdotal evidence seems to be the most promising in this regard, the effects are not significantly different from statistical evidence (average p-value: 0.574).

3.3.3. Receptives

For the group with the highest willingness to get vaccinated, the results reveal no statistically significant differences between communicators and the evidence types. Interestingly, however, the results in Fig. 4 suggest that politicians providing statistical evidence offer the most promising communication strategy (average p-value: 0.010; reference group are politicians without any evidence). This is surprising since, on average, neither politicians nor statistical evidence taken separately had a statistically significant effect on respondents' reported vaccination intentions.

In sum, the above findings reveal notably different patterns across the three identified classes of vaccination hesitancy and point towards potentially promising communication strategies, especially for sceptics and receptives. These insights had not been visible by just exploring average effects. Moreover, the statistically significant subgroup effects are substantially larger in magnitude,

[17] We report average p-values as our estimations are based on 1,000 simulations of Equation 1 with a probabilistic assignment of respondents to the respective classes.

Table 3
Treatment effects of evidence type and communicator on vaccination intentions.

	(1)	(2)	(3)	(4)	(5)	(6)
Politician	Reference category					
Scientist	0.184**	0.185**				
	(2.32)	(2.34)				
No Evidence			Reference category			
Anecdotal Evidence			0.137	0.153		
			(1.41)	(1.57)		
Statistical Evidence			0.0354	0.0477		
			(0.36)	(0.49)		
No Evidence x Politicians					Reference category	
Anecdotal Evidence x Politicians					0.204	0.209
					(1.49)	(1.53)
Statistical Evidence x Politicians					0.143	0.159
					(1.04)	(1.16)
No Evidence x Scientists					0.300**	0.297**
					(2.18)	(2.16)
Anecdotal Evidence x Scientists					0.372***	0.395***
					(2.70)	(2.88)
Statistical Evidence x Scientists					0.228*	0.234*
					(1.66)	(1.70)
Ex post t-tests (t-values):						
No Evidence Scientists vs. Anecdotal Evidence Scientists					0.28	0.50
No Evidence Scientists vs. Statistical Evidence Scientists					0.27	0.21
Anecdotal Evidence Scientists vs. Statistical Evidence Scientists					1.09	1.37
Socioeconomic Controls	No	Yes	No	Yes	No	Yes
Observations	2142	2141	2142	2141	2142	2141

Notes: The table shows standardized regression coefficients. Estimations in Columns (2), (4), and (6) include controls for age, gender, level of education, state of residency, and level of income. *t* statistics in parentheses.
*, **, *** indicate significance at the 1, 5, and 10 percent critical level

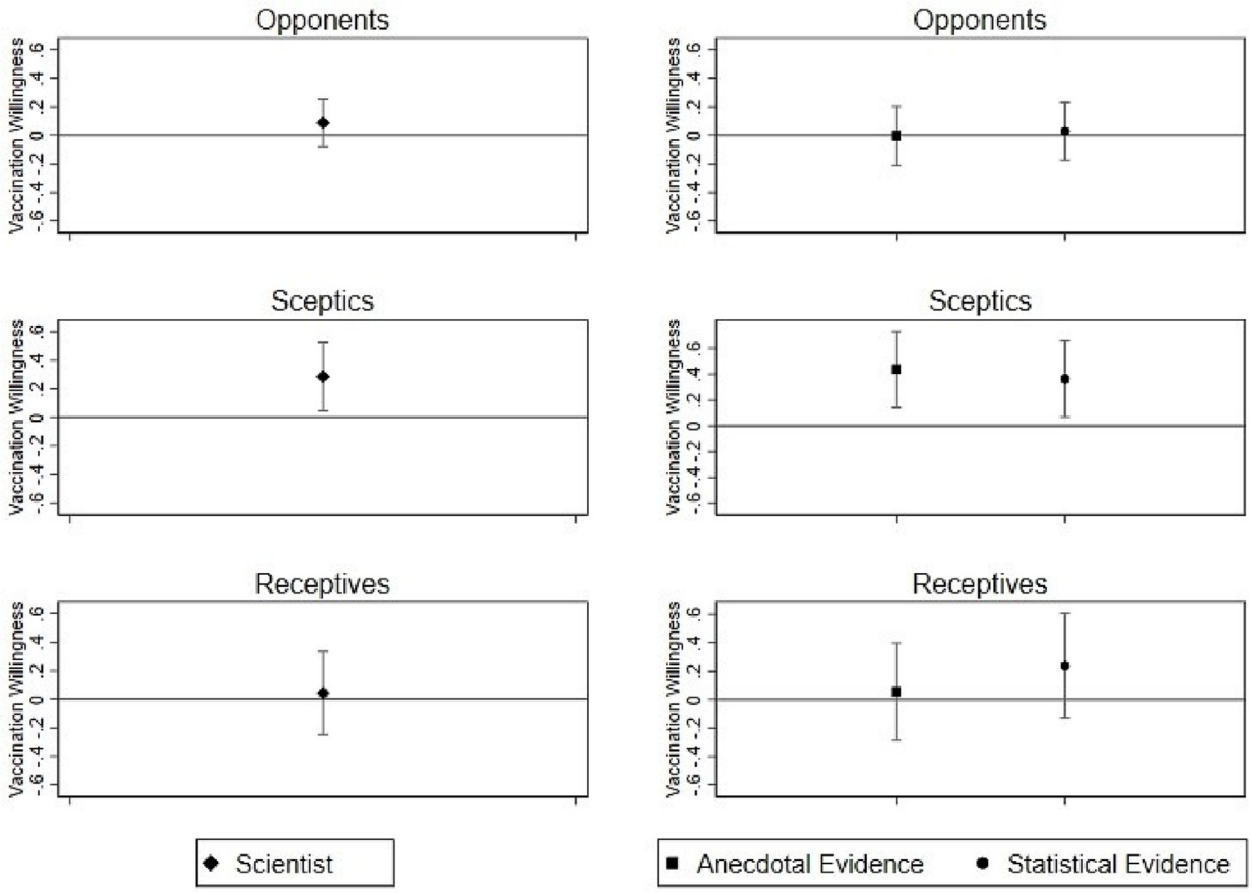

Fig. 3. Heterogeneity by Class: Separate Treatment Effects of Evidence Type and Communicator on Vaccination Intentions. *Notes:* The figure shows the mean estimation coefficient and 95 % confidence intervals of 1,000 simulations for each of the three classes of vaccination hesitancy. Class assignment for each respondent is based on the class membership probability, which is derived from the LCA. The left column shows the treatment effects of the communicator, with the reference category "Politician". The right column shows treatment effects for evidence type with the reference category "no evidence". Estimations include controls for age, gender, education level, state of residency, and income level. Detailed estimation results are available in Table A11, A13, and A14 in Appendix B.

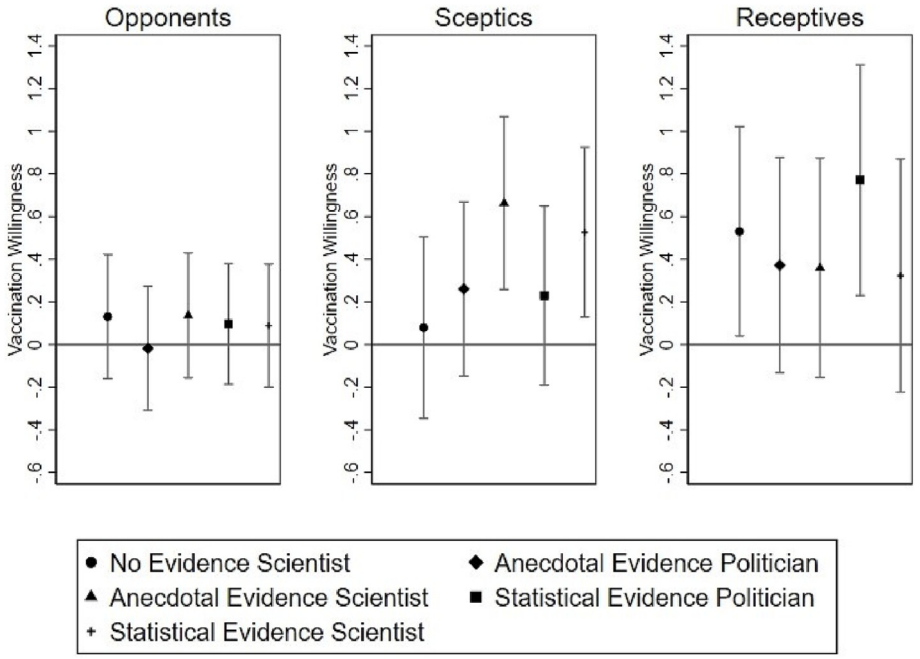

Fig. 4. Heterogeneity by Class: Interacted Treatment Effects of Communicator-Evidence Combinations on Vaccination Intentions. *Notes:* The figure shows mean treatment effects and 95 % confidence intervals of 1,000 simulations for each of the three classes of vaccination hesitancy. The reference category is "No Evidence Politicians". Class assignment for each respondent is based on the class membership probability, which is derived from the LCA. Estimations include controls for age, gender, education level, state of residency, and income level. Detailed estimation results are available in Table A11, A13, and A14 in Appendix B.

ranging from 0.38 (politicians addressing receptives based on statistical evidence) to 0.45 standard deviations (scientists addressing sceptics based on anecdotal evidence). This evidence suggests that the different groups of vaccination hesitant respondents indeed express different elaboration likelihoods depending on the communication strategies explored here.[18]

4. Discussion and conclusion

Despite soaring case numbers and a sufficient supply of vaccine doses at their disposal, policy makers in several countries struggled with convincing their unvaccinated population of the benefits of a COVID-19 vaccination. Previous immunization campaigns have included various strategies to increase vaccination rates, ranging from mandatory vaccination, structured appointment planning and reminders, to carefully designed information campaigns [31,32]. Evidence on the effectiveness of the different immunization campaigns is, therefore, urgently needed to inform political decision making. Given that mandatory vaccinations were highly contested politically [29], we investigated how to persuasively communicate information about the efficacy of a COVID-19 vaccination to the unvaccinated parts of the population.

Previous research suggests that the effectiveness of information campaigns depends crucially on the communicator (e.g., the media, politicians, religious leaders), the content of the message, and the characteristics of the targeted population (e.g., scepticism, social attitudes) [8,33,34]. Our latent class analysis points towards the existence of three distinct subgroups within the sample of unvaccinated respondents, who can be differentiated in terms of their views and motivations regarding a COVID-19 vaccination: opponents, sceptics, receptives.

While vaccination opponents seem rather difficult to target, our findings suggest potentially fruitful combinations of communicators and evidence types for the other two subgroups. Specifically, we found that anecdotal evidence provided by scientists is a promising communication strategy to encourage vaccination intentions in the subgroup of sceptics.

Similarly, statistical evidence presented by politicians fortified intentions within receptives. For the case of sceptics, one potential explanation for the somewhat unexpected result could be that scientists are already perceived as highly credible by this subgroup. While anecdotal evidence may decrease the perceived distance towards the public, the additional credibility gains from statistical evidence are limited. Thus, providing communicator-evidence combinations that are less present in the public debate could prove particularly effective.

These insights suggest that, in the short term, receptives and sceptics are the most promising target groups for German vaccination campaigns. Yet, in the medium term, opponents need not be forgotten. While mandatory vaccinations [35,36] may appear as the only strategy to target strict vaccination opponents, politicians and researchers are advised to focus on ways how to rebuild trust and address beliefs in misinformation within this population group, not only in Germany [37,38,39,40]. The inconsistency in vaccine related communication in Germany has led to a loss of trust in political and scientific decision-makers [41]. It is therefore important to rebuild this trust through evidence-based communication. The way we understand and perceive the credibility of a source significantly impacts our processing of messages and can also significantly affect related behaviours [42,43]. Using evidence to validate relevant and reliable information can therefore also be vital to build trust and credibility in the vaccines themselves and their safety.

We acknowledge the following limitations of our study: First, the choice to employ an outcome variable that measures intentions to get vaccinated with a hypothetical vaccine is likely both a limitation and strength of our study. On the one hand, the hypothetical

[18] Appendix A and Figures A2-A4 contain additional analyses that analyse whether the reported effects are due to class differences in (i) perceptions of the credibility of the information, (ii) the relevance of the information for one's reported intention to get vaccinated, and (iii) the credibility of the information source.

vaccine may be more vague and less informative to respondents. But, on the other hand, using existing vaccines like Astra Zeneca would have come with serious repercussions in terms of predefined opinions about them and would have likely biased the results of the messages tested in the survey experiment. The same logic applies to the hypothetical communicators of the messages being "a scientist" or "a politician", deliberately not mentioning specific individuals already well-known to participants in the German pandemic context. Second, we acknowledge that our outcome variable merely measures intentions to get vaccinated as opposed to actual vaccination decisions (though evidence with respect to the Theory of Planned Behavior suggests that stated intentions and observed behaviour are closely related [23,24]). Third, researchers and policy makers should, naturally, interpret our findings with caution in terms of external validity and the potential discrepancies between the measured effects of employing a message once in an online survey compared to the effects of employing messages repeatedly in real-world situations. External validity concerns also include the sample being recruited from an incentivized online panel population. This population may differ somewhat from the representative German population in respects other than the included quotas, though methodological research on this issue has so far not convincingly confirmed these concerns [44–46].

In terms of avenues for future research, further studies may want to examine the perceived relevance of the provided information more closely - a factor that might increase the persuasiveness of information campaigns. Specifically, in this paper, we examined an information treatment about COVID-19 hospitalization risk, but information and evidence on the infection probability or the risk of long-COVID might have a higher relevance [47].

In sum, our study employed sociopsychological theory to challenge the view of the existence of a single homogeneous group of unvaccinated citizens. By drawing on a large sample of unvaccinated citizens and combining latent class analysis with experimental methods, we encourage decision-makers to carefully consider heterogeneities in the effectiveness of their communication strategies, especially regarding their communicator and employed evidence type.

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Ethical approval

The ethical review board of Göttingen University reviewed the study prior to implementation (Ethikkommission, date 15/07/2021).

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2023.03.026.

References

[1] Kim D, Lee YJ. Vaccination strategies and transmission of COVID-19: Evidence across advanced countries. J Health Econ 2022;82:102589.
[2] Robert-Koch-Institut (RKI). Digitales Impfquotenmonitoring zur COVID-19-Impfung. [Online; accessed 13-February-2022]; 2022. url: https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Daten/Impfquoten-Tab.html.
[3] Anderson RM, Vegvari C, Truscott J, Collyer BS. Challenges in creating Herd immunity to SARS-CoV-2 infection by mass vaccination. Lancet 2020;396(10263):1614–6.
[4] Karlsson LC, Soveri A, Lewandowsky S, Karlsson L, Karlsson H, Nolvi S, et al. Fearing the disease or the vaccine: The case of COVID-19. Pers Individ Differ 2021;172:110590.
[5] Paul E, Steptoe A, Fancourt D. Attitudes towards vaccines and intention to vaccinate against COVID-19: Implications for public health communications. Lancet Regional Health-Europe 2021;1:100012.
[6] Courbage C, Peter R. On the effect of uncertainty on personal vaccination decisions. Health Econ 2021;30(11):2937–42.
[7] Hewgill MA, Miller GR. Source credibility and response to fear•arousing communications; 1965.
[8] Argote P, Barham E, Daly SZ, Gerez JE, Marshall J, Pocasangre O. The shot, the message, and the messenger: COVID-19 vaccine acceptance in Latin America. NPJ Vaccines 2021;6(1):118.
[9] Betsch C, et al. German COVID-19 Snapshot Monitoring (COSMO)-Welle 36: Zweite Fokuserhebung zu Impfungen; 2020.
[10] O'Keefe DJ. Justification explicitness and persuasive effect: A meta-analytic review of the effects of varying support articulation in persuasive messages. Argumentation and Advocacy 1998;35(2):61–75.
[11] Reinard JC. The persuasive effects of testimonial assertion evidence. Persuasion: Advances through meta-analysis; 1998. p. 69–86.
[12] O'Keefe DJ. Persuasion: Theory and research. Sage Publications; 2015.
[13] Chaiken S, Trope Y, editors. Dual-process theories in social psychology. Guilford Press; 1999.
[14] Strack F, Deutsch R. The duality of everyday life: dual-process and dual system models in social psychology. In APA handbook of personality and social psychology, Volume 1: Attitudes and social cognition. American Psychological Association; 2015. pp. 891-927.
[15] Betsch C, Ulshöfer C, Renkewitz F, Betsch T. The influence of narrative v. statistical information on perceiving vaccination risks. Med Decis Making 2011;31(5):742–53.
[16] Haase N, Betsch C, Renkewitz F. Source credibility and the biasing effect of narrative information on the perception of vaccination risks. J Health Commun 2015;20(8):920–9.
[17] Hoeken H. Anecdotal, statistical, and causal evidence: Their perceived and actual persuasiveness. Argumentation 2001;15:425–37.
[18] Betsch C, Schmid P, Heinemeier D, Korn L, Holtmann C, Böhm R. Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. PLoS ONE 2018;13(12):e0208601.
[19] Maurer J. Who has a clue to preventing the flu? Unravelling supply and demand effects on the take-up of influenza vaccinations. J Health Econ 2009;28(3):704–17.
[20] Hagenaars JA, McCutcheon AL, editors. Applied latent class analysis. Cambridge University Press; 2002.
[21] Lanza ST, Rhoades BL. Latent class analysis: an alternative perspective on subgroup analysis in prevention and treatment. Prev Sci 2013;14(2):157–68.
[22] Lancsar E, Ride J, Black N, Burgess L, Peeters A. Social acceptability of standard and behavioral economic inspired policies designed to reduce and prevent obesity. Health Econ 2022;31(1):197–214.
[23] Ajzen I. From intentions to actions: A theory of planned behavior. Berlin Heidelberg: Springer; 1985. p. 11–39.
[24] Wollast R, Schmitz M, Bigot A, Luminet O. The theory of planned behavior during the COVID-19 pandemic: A comparison of health behaviors between Belgian and French residents. PLoS ONE 2021;16(11):e0258320.
[25] Campos-Mercade P, Meier AN, Schneider FH, Meier S, Pope D, Wengström E. Monetary incentives increase COVID-19 vaccinations. Science 2021;374(6569):879–82.
[26] Dai H, Saccardo S, Han MA, Roh L, Raja N, Vangala S, et al. Behavioural nudges increase COVID-19 vaccinations. Nature 2021;597(7876):404–9.
[27] Krawczyk AL, Perez S, Lau E, Holcroft CA, Amsel R, Knäuper B, et al. Human papillomavirus vaccination intentions and uptake in college women. Health Psychol 2012;31(5):685.
[28] Jens Spahn, Interview with "Die Welt". "Die Impfung schützt – aber nicht zu 100 Prozent – vor der Infektion". [Online; accessed 6-June-2021]; 2021. url: https://www.welt.de/politik/deutschland/article230681991/Jens-Spahn-Es-geht-um- Grundrechte-da-gibt-s-nichts-zu-relativieren.html.
[29] Rieger T, Schmidt-Petri C, Schröder C. Attitudes Toward Mandatory COVID-19 Vaccination in Germany: A Representative Analysis of Data From the Socio-Economic Panel for the Year 2021. Deutsches Ärzteblatt International 2022;119(19):335.

[30] Anderson ML. Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects. J Am Stat Assoc 2008;103(484):1481–95.
[31] Trucchi C, Costantino C, Restivo V, Bertoncello C, Fortunato F, Tafuri S et al. Immunization campaigns and strategies against human papillomavirus in Italy: the results of a survey to regional and local health units representatives. BioMed Research International; 2019.
[32] Geoffard PY, Philipson T. Disease eradication: private versus public vaccination. Am Econ Rev 1997;87(1):222–30.
[33] Jin Q, Raza SH, Yousaf M, Zaman U, Siang JMLD. Can communication strategies combat COVID-19 vaccine hesitancy with trade-off between public service messages and public skepticism? Experimental Evidence from Pakistan. Vaccines 2021;9(7):757.
[34] Betsch C, Böhm R, Korn L, Holtmann C. On the benefits of explaining herd immunity in vaccine advocacy. Nat Hum Behav 2017;1(3):0056.
[35] Graeber D, Schmidt-Petri C, Schröder C. Attitudes on voluntary and mandatory vaccination against COVID-19: Evidence from Germany. PLoS ONE 2021;16(5):e0248372.
[36] Hirani JLJ. Inattention or reluctance? Parental responses to vaccination reminder letters. J Health Econ 2021;76:102439.
[37] Lazarus JV, Ratzan SC, Palayew A, Gostin LO, Larson HJ, Rabin K, et al. A global survey of potential acceptance of a COVID-19 vaccine. Nat Med 2021;27(2):225–8.
[38] Schernhammer E, Weitzer J, Laubichler MD, Birmann BM, Bertau M, Zenk L et al. Correlates of COVID-19 vaccine hesitancy in Austria: trust and the government. J Public Health, 2022; 44(1): e106-e116.
[39] Stoler J, Klofstad CA, Enders AM, Uscinski JE. Sociopolitical and psychological correlates of COVID-19 vaccine hesitancy in the United States during summer 2021. Soc Sci Med 2022;306:115112.
[40] Strupat C, Shigute Z, Bedi AS, Rieger M. Willingness to take COVID-19 vaccination in low-income countries: evidence from Ethiopia. PLoS ONE 2022;17(3):e0264633.
[41] Busemeyer MR. The welfare state in really hard times: Political trust and satisfaction with the German healthcare system during the COVID-19 pandemic. J Eur Soc Policy 2022;32(4):393–406.
[42] Pornpitakpan C. The persuasiveness of source credibility: A critical review of five decades' evidence. J Appl Soc Psychol 2004;34(2):243–81.
[43] Stiff, James B, Paul A. Mongeau. Persuasive communication. Guilford Publications; 2016.
[44] Revilla M, Saris W. A comparison of the quality of questions in a face-to-face and a web survey. International J Public Opinion Res 2013;25(2):242–53.
[45] Struminskaya B, Kaczmirek L, Schaurer I, Bandilla W. Assessing representativeness of a probability-based online panel in Germany. Online Panel Research: Data Quality Perspective, A 2014:61–85.
[46] Revilla M, Saris W, Loewe G, Ochoa C. Can a non-probabilistic online Panel achieve question quality similar to that of the European Social Survey? Int J Mark Res 2015;57(3):395–412.
[47] Griffin B, Conner M, Norman P. Applying an extended protection motivation theory to predict Covid-19 vaccination intentions and uptake in 50–64 year olds in the UK. Soc Sci Med 2022;298:114819.