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Association between Covid-19 sources of information, beliefs, and vaccination rates: an EU-wide survey

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Background: Misinformation hampers vaccine uptake. The European Union (EU) employed a coordinated effort to curb misinformation during the Covid-19 pandemic. In this context, we investigated relationships between sources of information, vaccine safety/effectiveness, satisfaction with government vaccination strategy, and vaccination intent. **Methods:** We used cross-sectional survey data (May 2021) from Flash Eurobarometer 494, a population-adjusted dataset comprised of a representative sample of those ≥15 years from 27 EU nations. We employed a latent class analysis to create clusters of information sources as the independent variable and beliefs in vaccine safety/efficacy, satisfaction with government vaccination strategy, and vaccine intent as four outcome variables. We first estimated the association between source clusters and each of the first three outcomes separately. Then, using these three as intermediate variables, we employed structural equation modeling to estimate the relationship between sources and vaccine intent. We adjusted for individual and country-level variables. **Results:** Among 23 012 respondents, four clusters of information sources emerged: (1) national authorities/health professionals ($n = 9602$; 42%), (2) mostly health professionals (6184; 27%), (3) mixed ($n = 1705$; 17%) and (4) social media/family/friends ($n = 5524$; 24%). Using cluster (3) as the referent, we found decreasing odds of beliefs in vaccine safety/effectiveness, satisfaction and vaccine intent across clusters (1), (2) and (4), respectively. Demographics played a role. **Conclusion:** In the context of the Covid pandemic, these results provide the first EU-wide estimates of the association between sources of information about vaccine safety/effectiveness, satisfaction and vaccine intent. The coordinated approach promulgated by the EU to minimize misinformation provides a model for managing future pandemics.

Introduction

The European Union (EU) acted swiftly and in a coordinated fashion to standardize its response to all aspects of the Covid-19 pandemic to bring relief to its citizens.[1] Early on, country-specific vaccine policy stringency contributed to varying pandemic management strategies,[2] and misinformation caused confusion.[3] In May 2020, EU leaders agreed to launch an ambitious recovery plan, Next Generation EU, intended as a support package for jobs, workers, businesses and member states.[4] In a statement made on 5 May 2023, EU President Ursula von der Leyen formally declared the pandemic over,[5] and the most recent data from the European Centre for Disease Prevention and Control (16 June 2023) indicates that there are decreasing or stable trends across all countries and all age groups.[6] Despite this welcome news, Next Generation EU encourages continued vigilance to mitigate future pandemics as they emerge. The countering of associated disinformation will require ongoing efforts.[4]

Literature published prior to January 2020 has shown that vaccine hesitancy influences intent to be vaccinated which, in turn, is associated with rates of infection.[7] In 2019, the World Health Organization (WHO) named vaccine hesitancy as one of the top 10 threats to global health.[8,9] In the context of Covid-19, the literature is replete with global evidence that indicates that vaccine hesitancy is driven by beliefs in the safety/effectiveness of vaccinations,[7,9,10] which in turn are driven by beliefs in the credibility of sources of information.[11–13]

Misinformation and conspiracy theories abound, particularly in social media.[9,14,15] Collectively called the 'infodemic',[16] these impacted Covid-19 vaccine acceptance.[9,17,18] Complicating beliefs are citizen-specific characteristics of socioeconomic background, life experiences, family living situations and comorbidities.[7,9] Countries with lower gross domestic product per capita show a higher prevalence of misinformation.[13] Satisfaction with government vaccination strategy also plays a role.[7,9,17] Although studies represent numerous countries on most continents,[11–13] no study summarizes these elements specifically for the EU region.

Using publicly available online survey data from 27 EU countries, our first aim was to estimate the association between sources of information and three outcomes: vaccine safety, effectiveness and satisfaction with the national vaccination strategy (hereafter called 'satisfaction'). Using the first three outcomes as intermediate variables, our second aim was to estimate the association between sources of information and vaccine intent.

We hypothesized that respondents who obtained their information from professional sources would consider vaccines safer and more effective and would be more likely to be vaccinated than

respondents who obtained their information from online social networks or family/friends.

Methods

Data sources and respondents

To conduct these analyses, we used data from Flash Eurobarometer 494 (Survey ZA7771).[19] Eurobarometer is a set of *ad hoc* cross-sectional, public opinion surveys conducted periodically by the European Commission.[20] Flash Eurobarometer forms a subgroup of surveys conducted on special topics. Representative general population samples of between 500 and 1000 individuals per country are drawn by interviewing, in the native language, those aged ≥15 years, living in the EU.[19] Between 21–26 May 2021, Ipsos European Public Affairs, Brussels, completed the 26 106 computer-assisted web interviews using their online panel and partner network. The sampling procedure of the survey was a non-probability (quota) method. In this type of sampling, the target population is subdivided into separate and mutually exclusive segments according to predefined quotation criteria of the population distribution of sociodemographic characteristics such as age, gender, ethnicity, or income to reflect the real structure of the target population. The survey data were weighted to known population proportions. The survey posed questions about favored sources of reliable information about Covid-19, attitudes about risks and benefits of vaccination, satisfaction, intent to be vaccinated, and whether each respondent had received other vaccinations as a child or adult. The survey was comprised of 11 questions; response options varied. Questions soliciting demographic information completed the survey (Supplementary table S1-Survey).

Participant- and country-level variables

In both aims, we used survey question 6 as the independent variable: 'Among the following sources which ones would you trust more to give you reliable information on Covid-19 vaccines?' Nine answer options were available (EU, national government, national health authorities, local public authorities, health professionals, media (television, radio, newspapers), websites, online social networks, people around); respondents could select more than one option. In the first aim, we explored three outcome variables. We used the two-part survey question SD2: 'To what extent do you agree or disagree with the following statements about vaccines in general?' Respondents indicated their agreement with vaccine safety and effectiveness, separately. We also used survey question 8_1: 'Thinking about the way [your national government] has handled the vaccination strategy, would you say that you are. . ..' To answer each question, five mutually exclusive answer options were available. In the second aim, we used survey question 1 as the outcome variable: 'When would you like to get vaccinated against Covid-19?' Seven mutually exclusive answer options were available. As mediator variables, we included the responses to survey question SD2 and survey question 8_1, described above.

In both analyses, we considered adjustment variables. At the participant-level, we included age, age group, gender, household size, education, employment, resident place and whether vaccinated as a child/adult. At the country-level, we adjusted for three characteristics: percent of national government expenditures on healthcare using data from the WHO Global Expenditure Database,[21] a government policy Stringency Index using data from the Oxford Covid-19 Government Response Tracker (OxCGRT) Project,[2,22] and number of confirmed Covid-19 cases and deaths, also from OxCGRT.[2,22]

Statistical analysis

To address the first aim, we dichotomized the answer options for the vaccine safety/effectiveness questions into 'agree or disagree' and the satisfaction question into 'satisfied or dissatisfied'. To address the second aim, we trichotomized the answer options for the intent to be vaccinated question into: 'already vaccinated or to be vaccinated as soon as possible, plan to be vaccinated later and some time in 2021, and never plan to be vaccinated'. We did not collapse answer options for the independent variable (sources of information), but rather, used all nine in our analyses. Throughout, those who answered any question with 'don't know' or 'prefer not to answer' were excluded. We characterized national healthcare spending as tertiles, and the rates of confirmed Covid-19 cases and deaths per 100 000 population. The OxCGRT Stringency Index was calculated using the mean of nine variables (school closures, workplace closures, cancellation of public events, restrictions on gatherings, public transportation closures, stay-at-home requirements, restrictions on domestic travel, restrictions on international travel and public information campaigns measuring the response level of a national government against the COVID-19 pandemic; range 1–100). Since the collection period comprised 21–26 May 2021, we computed means of that period for the Stringency Index, and rates of confirmed Covid-19 cases and deaths.

We conducted our analyses in two steps. In step 1, we conducted a latent class analysis (LCA) to characterize patterns among sources of information.[23] Determining the optimal number of clusters is based on both model fit statistics and diagnostic statistics, the latter to measure classification certainty. In step 2, the identified clusters of sources of information served as the independent variable. We employed binomial logistic regression to estimate the odds of cluster membership on safety/effectiveness/satisfaction, each separately. (Aim 1) We performed multinomial logistic regression to estimate the odds of cluster membership on intent to be vaccinated. (Aim 2) We then employed structural equation modeling (SEM) methods to estimate the effect of cluster membership on intent to be vaccinated, using vaccine safety/effectiveness/satisfaction with the vaccine strategy of the national government as mediation variables. All regression models adjusted for demographic characteristics using covariate balanced propensity scores (CBPS), a method that accounts for treatment assignment while, at the same time, optimizing covariate balance.[24] We estimated significance using bootstrapped 95% confidence intervals, and provide estimates of total effects, direct effects and indirect effects in table format, and using a Sankey diagram to illustrate the relationship between the results of both aims. Finally, by country, we mapped the percentage of respondents who provided each answer option for vaccine safety/effectiveness/satisfaction, intent to be vaccinated, vaccinated as a child/adult, and the OxCGRT Stringency Index.

To determine if the post-stratification survey weights suggested by the Eurobarometer and/or covariate adjustment influence the results compared with the CPBS weights, we evaluated four weighting schemas when estimating the binomial and multinomial logistic regression models (details in our protocol, available from the authors). As they did not, we adopted the CPBS approach for all regression analyses.

As all three datasets are publicly available, permission from an Institutional Review Board was not required. Data analysis and management were conducted in R Version 3.6.1 (https://www.r-project.org/). The study is reported in accordance with the STROBE Guidelines.[25]

Results

The four-cluster model provides the best fit, using a relatively parsimonious number of parameters and balancing absolute and relative entropy. It also provides the lowest minimum percent of a cluster that contains more than 5% of the observations in each cluster. (Supplementary table S2) The distribution of the proportion of respondents who used the combination of the nine sources of information varies (Supplementary figure S1).

i. Cluster 1: predominantly national health authorities and health professionals (abbreviated 'auth/healthprof').

ii. Cluster 2: predominantly health professionals ('healthprof').
iii. Cluster 3: mixed ('mixed').
iv. Cluster 4: predominantly people around ('people').

Supplementary figure S2 presents the absolute standardized mean differences (SMDs) in β coefficients when comparing before to after application of the CBPS exercise. Before applying the CBPS method, the absolute SMDs ranged from 0 to almost 0.6, afterward the range was reduced to less than 0.1, suggesting that in using this approach we were successful in adjusting for inter-participant characteristics.

After removing those who responded to the sources of information variable with 'don't know' or 'prefer not to answer', 23 012 respondents comprised the analytic dataset. Approximately 42% ($n = 9602$) were assigned membership in auth/healthprof cluster, less than 8% (1705) to mixed, and the remaining respondents almost equally split between healthprof (6814) and people (5524).

Overall, 86% of respondents believed vaccines are safe and 91% believe they are effective, although these proportions were slightly lower in the people cluster, at 72.1% and 79.2%, respectively (table 1). The proportions of those who had already been vaccinated or planned to be, were higher in the auth/healthprof and mixed clusters and slightly lower in the healthprof and people clusters. The pattern was similar for satisfaction with vaccination strategy of the national government. Almost 50% of the participants were between the ages of 35 and 64; mean age decreases across clusters. The ratio of males to females was almost equal. Household size was similar across clusters. Most individuals completed their education when they were over 16 years of age. The proportion of those who were employed and not working was similar; far fewer were self-employed or were manual laborers. Approximately 75% were urban or suburban residents. A greater proportion were vaccinated as a child than as an adult. Across clusters, no remarkable patterns were seen for government spending on healthcare, Stringency Index, case rate or death rate.

Figure 1 illustrates the results of the vaccine safety/effectiveness/satisfaction analysis. When compared to respondents in the mixed cluster (referent), the adjusted odds of considering vaccines safe for respondents in each of the other clusters were significantly lower. The width of the confidence intervals narrowed when comparing auth/healthprof to healthprof, to people. The results of the vaccine effectiveness analysis followed the same pattern. The pattern for government management of the national vaccine strategy differed slightly, with the adjusted odds of those in the healthprof cluster being satisfied with the management being the lowest among the clusters. In figure 2, when compared with respondents who obtained their information from mixed sources, and who never intended to be vaccinated (referent), the adjusted odds of being vaccinated later are significantly lower in each of the other clusters, with the adjusted odds of already having been vaccinated or intent to be vaccinated as soon as possible lower still. The greatest amount of uncertainty is for those in the auth/healthprof cluster, followed by the healthprof, then people cluster.

Table 2 provides respondent-level characteristics for each of the three mediation variables in the SEM. As in table 1, a large proportion considered vaccines to be safe/effective. However, the proportions are slightly lower in those who had never been in full-time education, manual workers, those who had not been vaccinated as a child/adult, and those who plan to be vaccinated later or who never plan to be vaccinated. A slightly greater proportion of those who were $\geq$65 years and had already been vaccinated considered vaccines to be safe/effective and were slightly more satisfied with the way the national government was managing the vaccination strategy.

Results of the adjusted mediation analysis (Supplementary table S3) suggest there was significantly lower belief in vaccine safety for those in the healthprof cluster (SMD -0.235, $P < 0.001$) or those in the people cluster (SMD -0.350, $P < 0.001$), when compared to the mixed cluster; similarly for effectiveness and satisfaction, although the latter is also significant when comparing the auth/healthprof cluster (SMD -0.202, $P < 0.001$). The impact of each of the three mediation variables on vaccination intent was also significant. The total effect, that is, if not mediated by any of the three potential mediators, indicates that those in each cluster (compared to mixed) had a significantly lower intent to be vaccinated. The direct effect of each mediator indicates that those in the health professional cluster and the people cluster (each compared to mixed) also had a significantly lower intent to be vaccinated. Finally, the indirect effect (the proportion mediated by each potential mediator) indicates similar proportions when comparing each cluster for vaccine safety/effectiveness. Satisfaction was a stronger mediator between auth/healthprof vs. mixed (115%) and a lesser proportion between people vs. mixed. Supplementary figure S3 illustrates the mediated relationships between each of the clusters and intent to be vaccinated.

In Supplementary figure S4 and Supplementary table S5, we see that the highest percentage of respondents who report they had already been vaccinated resided in Malta, Germany, Spain, Luxembourg, Belgium, Ireland and Sweden. The highest percentage of those who wished to be vaccinated later or who did not wish to be vaccinated ever resided in Bulgaria. The highest percentage of respondents who believed vaccines are safe resided in Spain and Portugal, followed by Malta, Sweden, Netherlands and Germany. The percentages are slightly higher for beliefs in vaccine effectiveness. A high percentage of respondents from many countries reported that they were vaccinated as a child, while these percentages decline somewhat for adults. Malta, Luxembourg and Portugal led with the highest proportion of respondents who were satisfied that their national government was correctly managing the vaccine strategy, while the Stringency Index was the highest for Germany.

Discussion

The results of our analysis suggest that sources of information do play a role in vaccination intent across the EU region and that this relationship is mediated by vaccine safety/effectiveness and satisfaction with government strategy. It is noteworthy that those who received their information from mixed sources believed more strongly in vaccine safety/effectiveness and were more willing to be vaccinated than those in the other clusters. This is an ordered trend, with those whose sources of information were national government and health professionals more likely to believe in and uptake when compared to those who received their information solely from health professionals or from people around them. Moreover, socioeconomic status played an important role, with those relying on social media and friends/family being younger, less likely to have had a formal education, to have been vaccinated as children, and to believe that vaccines are safe/effective. They were more likely to be manual laborers, and never planned to be vaccinated. It is also interesting that those who relied on health professionals as their source of information ranked third. One hypothesis would be that health professionals, due to time constraints, are not always aware of the most recent information and therefore might be more skeptical of vaccines, while research scientists who serve in government positions, setting policy, are required to remain current. We conclude that the EU's initiatives to counter misinformation are important and encourage health professionals and citizens alike to seek out information from reliable government sources.

Our results are consistent with others who have found that beliefs in vaccine safety/effectiveness influence vaccination intent,[7] and that those who believe that government will provide them with an effective vaccine are more likely to uptake it. Moreover, decisions to be vaccinated are also shaped by interactions with peers. Those exposed to warnings against the vaccine from family and friends on social media are less willing to uptake and are more likely to share negative information with peers.[10,12] Using several online sources (e.g. Google) gathered from 52 countries, Islam found that of 637 Covid-19 vaccine-related items, 91% were rumors and 9% were

Table 1 Respondent-level characteristics, by cluster

		Sources of information[a]			
	Total[a]	Cluster 1: auth/healthprof	Cluster 2: healthprof	Cluster 3: mixed	Cluster 4: people
Total (*n*, %)	23 015 (100)	9602 (100) (41.7)[b]	6184 (100) (26.9)[b]	1705 (100)[a] (7.4)[b]	5524 (100)[a] (24.0)[b]
Vaccines are safe (*n*, %)	21 923	9252	5773	1672	5226
Agree	18862 (86.0)	8630 (93.3)	4872 (84.4)	1592 (95.2)	3768 (72.1)
Disagree	3061 (14.0)	622 (6.7)	901 (15.6)	80 (4.8)	1458 (27.9)
Vaccines are effective (*n*, %)	22 201	9379	5924	1690	5208
Agree	20 248 (91.2)	9043 (96.4)	5428 (91.6)	1650 (97.6)	4127 (79.2)
Disagree	1953 (8.8)	336 (3.6)	496 (8.4)	40 (2.4)	1081 (20.8)
Intent to be vaccinated (*n*, %)	21 751	9275	5756	1648	5072
Already vaccinated/As soon as possible	15 579 (71.6)	7527 (81.2)	3892 (67.6)	1381 (83.8)	2779 (54.8)
Plan to be vaccinated later	4388 (20.2)	1480 (16.0)	1284 (22.3)	240 (14.6)	1384 (27.3)
Never plan to be vaccinated	1784 (8.2)	268 (2.9)	580 (10.1)	27 (1.6)	909 (17.9)
Age (mean, SD)	47.6 (17.6)	50.2 (17.5)	48.6 (16.7)	46.7 (18.4)	42.3 (17.2)
Age group (*n*, %)	23 016	9602	6184	1705	5525
15–34	6471 (28.1)	2236 (23.3)	1538 (24.9)	526 (30.9)	2171 (39.3)
35–64	10 987 (47.7)	4603 (47.9)	3166 (51.2)	749 (43.9)	2469 (44.7)
≥65	5558 (24.1)	2763 (28.8)	1480 (23.9)	430 (25.2)	885 (16.0)
Gender (*n*, %)	22 992	9595	6179	1700	5518
Men	11 340 (49.3)	4604 (48.0)	2700 (43.7)	953 (56.1)	3083 (55.9)
Women	11 577 (50.4)	4968 (51.8)	3455 (55.9)	745 (43.8)	2409 (43.7)
In another way	75 (0.3)	23 (0.2)	24 (0.4)	2 (0.1)	26 (0.5)
Size of household (mean ± SD)	2.7 (1.5)	2.5 (1.4)	2.7 (1.4)	2.6 (1.5)	2.9 (1.9)
Education (*n*, %)	21 748	9128	5922	1618	5080
Up to 15 years	737 (3.4)	302 (3.3)	214 (3.6)	57 (3.5)	164 (3.2)
16 to 19 years	7086 (32.6)	2898 (31.7)	2169 (36.6)	420 (26.0)	1599 (31.5)
20 years and older	10 604 (48.8)	4635 (50.8)	2838 (47.9)	838 (51.8)	2293 (45.1)
Still in full-time education	2766 (12.7)	1081 (11.8)	616 (10.4)	276 (17.1)	793 (15.6)
Never been in full-time education	555 (2.6)	212 (2.3)	85 (1.4)	27 (1.7)	231 (4.5)
Employment (*n*, %)	21 985	9169	5922	1625	5269
Self-employed	2043 (9.3)	696 (7.6)	537 (9.1)	137 (8.4)	673 (12.8)
Employees	8901 (40.5)	3693 (40.3)	2389 (40.3)	612 (37.7)	2207 (41.9)
Manual workers	1004 (4.6)	346 (3.8)	221 (3.7)	52 (3.2)	385 (7.3)
Not working	10 037 (45.7)	4434 (48.4)	2775 (46.9)	824 (50.7)	2004 (38.0)
Resident place (*n*, %)	23 015	9602	6184	1705	5524
Urban	8077 (35.1)	3385 (35.3)	2059 (33.3)	616 (36.1)	2017 (36.5)
Suburban	9193 (39.9)	3820 (39.8)	2495 (40.3)	713 (41.8)	2165 (39.2)
Rural	5745 (25.0)	2397 (25.0)	1630 (26.4)	376 (22.1)	1342 (24.3)
Vaccinated as a child (*n*, %)	22 421	9441	6083	1674	5223
Yes	21 061 (93.9)	9077 (96.1)	5843 (96.1)	1600 (95.6)	4541 (86.9)
No	1360 (6.1)	364 (3.9)	240 (3.9)	74 (4.4)	682 (13.1)
Vaccinated as an adult (*n*, %)	21 708	9133	5894	1624	5057
Yes	16 214 (74.7)	7191 (78.7)	4320 (73.3)	1314 (80.9)	3389 (67.0)
No	5494 (25.3)	1942 (21.3)	1574 (26.7)	310 (19.11)	1668 (33.0)
Vaccination strategy of the national government (*n*, %)	22 009	9236	5924	1657	5263
Satisfied	12 036 (54.7)	6016 (65.1)	2332 (39.8)	1287 (77.7)	2401 (45.6)
Not satisfied	9973 (45.3)	3220 (34.9)	3521 (60.2)	370 (22.3)	2862 (54.4)
Government health spending % Health spending (Terciles)	23 014	9602	6184	1704	5524
Low tercile (48.1%–69.7%)	7305 (31.7)	2877 (30.0)	2054 (33.2)	495 (29.0)	1879 (34.0)
Medium tercile (69.7%–77.1%)	8095 (35.2)	3363 (35.9)	2262 (36.6)	562 (33.0)	1908 (34.5)
High tercile (77.1%–85.9%)	7614 (33.1)	3362 (35.0)	1868 (30.2)	647 (8.0)	1737 (31.4)
Stringency index (mean, SD)	56.87 (8.4)	57.46 (8.3)	56.30 (8.4)	57.51 (8.79)	56.28 (8.54)
Number of confirmed COVID-19 cases per 100 000 (mean, SD)	7862.8 (3033.3)	7779.0 (3107.8)	8232.4 (2988.6)	7466.3 (2993.6)	7716.9 (2924.3)
Number of confirmed COVID-19 deaths per 100 000 (mean, SD)	154.3 (69.4)	146.5 (68.3)	168.7 (16.7)	136.8 (64.1)	157.2 (71.53)

auth/healthprof, national health authorities/health professionals; healthprof, health professionals; mixed, mixed; people, people around.
a: Column total.
b: Row total.

conspiracy theories. Five percent of these items were true, 83% were false, 10% were misleading and 2% were exaggerated. This group concluded that engaging with social media to ensure dissemination of correct information would safeguard the public.[14] Using artificial intelligence methods, Jun analyzed Covid-19 tweets from 192 countries and found that of over 21.3 million tweets posted between November 2020 and August 2021, mentions of fear, sadness and anger appeared as significant predictors of vaccination rates, as did the human development index. They concluded that global efforts are needed to combat misinformation and promote vaccine uptake.[26]

Van De Pas concluded that leadership and governance at the level of the national health system are critical.[27] Not only for this pandemic but moving forward, materials must be developed that meet population needs.[9] In August 2021, scientists from Stanford University hosted the Stanford Conference on social media, Ethics and Covid-19 misinformation ('Infodemic'). These scientists defined infodemic as the 'excess amount of information on a topic that usually spreads rapidly and

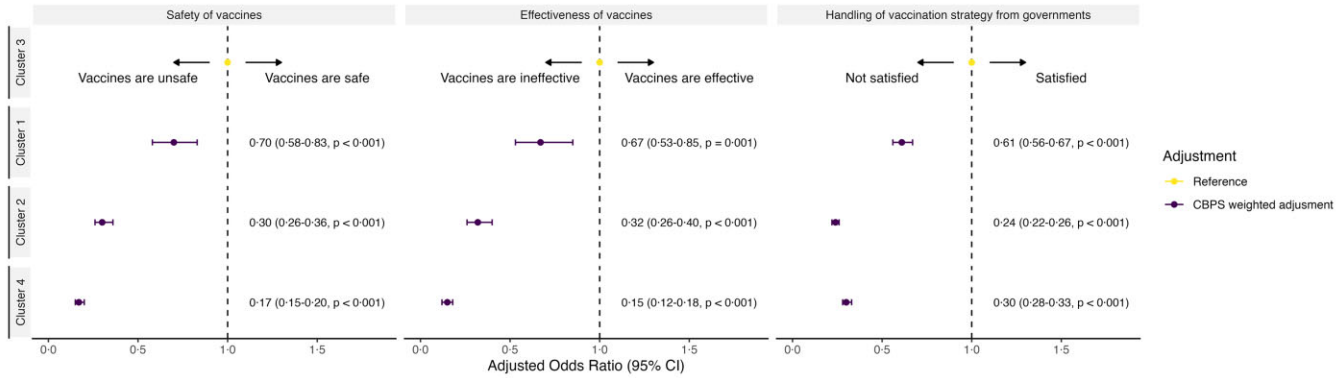

Figure 1 Adjusted odds ratio and 95% confidence intervals of source of information cluster membership on safety, and effectiveness of vaccines and satisfaction with the vaccine strategy of the national government, separately. Binomial logistic regressions were weighted by covariate-balancing propensity-score weights. Reference groups were cluster 3 and unsafe, ineffective vaccines and dissatisfied handling of vaccination strategy from national governments. European Union 27, 21–26 May 2021. CBPS, covariate-balancing propensity-score; Cluster 1: predominantly national health authorities and health professionals (abbreviated 'auth/healthprof'); Cluster 2: predominantly health professionals ('healthprof'); Cluster 3: mixed ('mixed'); Cluster 4: predominantly people around ('people')

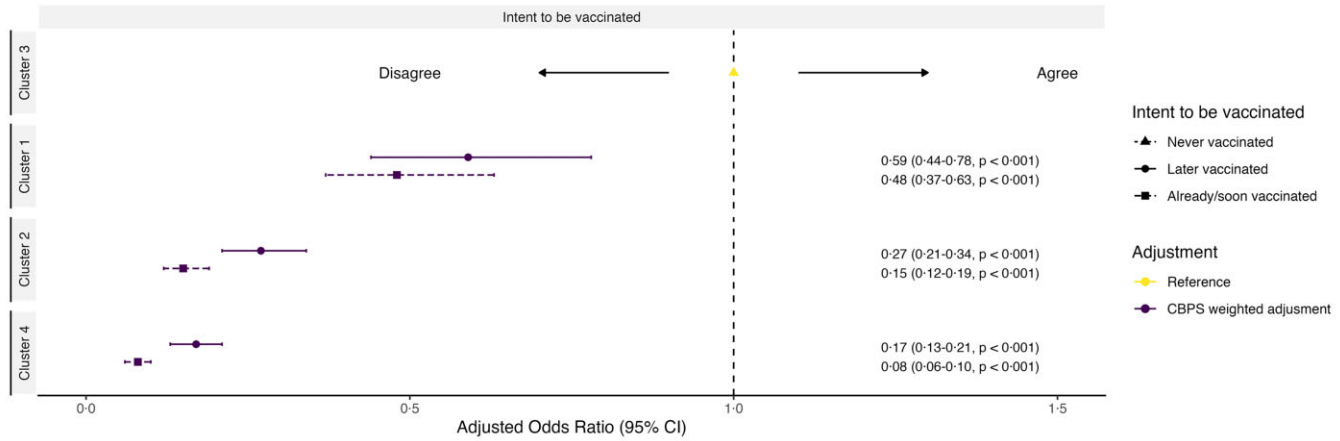

Figure 2 Adjusted odds ratio and 95% confidence intervals of source of information cluster membership on intent to be vaccinated. Multinomial logistic regression was weighted by covariate-balancing propensity-score weights. Reference groups were cluster 3 and never intent to be vaccinated. European Union 27, 21–26 May 2021. CBPS, covariate-balancing propensity-score; Cluster 1: predominantly national health authorities and health professionals (abbreviated 'auth/healthprof'); Cluster 2: predominantly health professionals ('healthprof'); Cluster 3: mixed ('mixed'); Cluster 4: predominantly people around ('people')

is confusing or unreliable'.[16] From the remarks of the 26 participants from numerous countries, 18 response categories were distilled to four themes: trust, equity, social media practices and interorganizational partnerships. Sixteen best practice recommendations were formulated for social media companies, health care organizations and the public. Recommendations included focusing on redesigning social media platforms to reduce the spread of misinformation, rebuilding trust in science and medicine, educating the public, and building public–private partnerships to accomplish these goals.

Our results suggest that the EU's multifaceted and robust efforts to fight disinformation are needed.[23] The efforts include the publication of guidance to follow the recommendations of the European Centre for Disease Prevention and Control and the WHO. The #FactsMatter campaign, promulgated by the European Commission is tackling the spread of online disinformation to protect European values and its democratic systems.[28] On 23 April 2022, the EU parliament and EU member states reached agreement on the Digital Services Act that sets out unprecedented new standards for accountability of online platforms.[29] Recently, the European Commission has adopted the Digital Europe Programme Work Program for 2023–2024, providing €1.3 billion in funding.[30] In June 2022, the EU also published a Strengthened Code of Practice on Disinformation that provides a mechanism for EU-wide fact-checking of online information and requires all actors to abide by the commitments and measures agreed to by all parties.[30] One year later, they are now stepping up their efforts, including deepening efforts on fact-checking.[30] These and other efforts are integrated both to address vaccine hesitancy in the context of the Covid-19 pandemic and to prepare for future regional and global challenges.

Our study has several strengths. We used data from Eurobarometer, which has a well-developed mechanism for conducting surveys representative of the EU population. Data quality is high. In the absence of causal inference, we used robust analytic methods, LCA, to account for the fact that respondents use more than one source of information, CBPS to address respondent heterogeneity, and SEM to account for the fact that several factors can influence intent to be vaccinated. Using external datasets, we adjusted for four country-level variables that may have influenced respondent's responses.[6,21,22] Limitations include that the cross-sectional survey design precludes causal inference and is subject to non-participant bias. Vaccination status was made by self-report. The specific cut

Table 2 Respondent-level characteristics, by variable in the mediation analysis

	Mediation variable					
	Vaccines are safe		Vaccines are effective		Satisfaction with vaccination strategy of the national government	
	Agree	Disagree	Agree	Disagree	Satisfied	Not satisfied
Total (*n*, %)	18 862 (86.0)	3061 (14.0)	20 248 (91.2)	1953 (8.8)	12 035 (54.7)	9973 (45.3)
Intent to be vaccinated (*n*, %)						
Already vaccinated/As soon as possible	14 290 (95.2)	726 (4.8)	14 924 (97.7)	349 (2.3)	9282 (61.7)	5770 (38.3)
Plan to be vaccinated later	3162 (76.6)	967 (23.4)	3566 (85.1)	624 (14.9)	2012 (48.0)	2177 (52.0)
Never plan to be vaccinated	732 (43.4)	955 (56.6)	920 (55.7)	731 (44.3)	332 (20.1)	1316 (79.9)
Age (mean, SD)	48.5 (17.5)	42.3 (16.9)	48.3 (17.5)	41.2 (16.9)	49.0 (17.8)	46.2 (17.2)
Age group (*n*, %)						
15–34	4978 (80.8)	1185 (19.2)	5364 (86.5)	834 (13.5)	3077 (50.4)	3030 (49.6)
35–64	9030 (86.5)	1415 (13.5)	9766 (92.1)	841 (7.9)	5669 (53.8)	4869 (46.2)
≥65	4855 (91.3)	461 (8.7)	5118 (94.8)	278 (5.2)	3289 (61.3)	2074 (38.7)
Gender (*n*, %)						
Men	9474 (86.6)	1471 (13.4)	9991 (90.8)	1011 (9.2)	5982 (54.4)	5006 (45.6)
Women	9314 (85.6)	1572 (14.4)	10 176 (91.6)	933 (8.4)	6014 (55.0)	4918 (45.0)
In another way	58 (81.7)	13 (18.3)	65 (94.2)	4 (5.8)	33 (48.5)	35 (51.5)
Size of household (mean ± SD)	2.6 (1.5)	2.8 (1.7)	2.62 (1.4)	3.0 (2.3)	2.6 (1.5)	2.7 (1.6)
Education (*n*, %)						
Up to 15 years	627 (88.8)	79 (11.2)	657 (91.8)	59 (8.2)	416 (59.1)	288 (40.9)
16 to 19 years	5696 (84.8)	1019 (15.2)	6181 (90.7)	632 (9.3)	3500 (51.9)	3249 (48.1)
20 years and older	8978 (88.3)	1187 (11.7)	9601 (93.2)	703 (6.8)	5710 (55.8)	4522 (44.2)
Still in full-time education	2248 (84.7)	405 (15.3)	2413 (90.2)	262 (9.8)	1425 (54.5)	1190 (45.5)
Never been in full-time education	408 (77.1)	121 (22.9)	414 (77.8)	118 (22.2)	314 (59.2)	216 (40.8)
Employment (*n*, %)						
Self-employed	1646 (84.3)	307 (15.7)	1768 (89.4)	209 (10.6)	1070 (54.5)	892 (45.5)
Employees	7339 (86.5)	1147 (13.5)	7868 (91.5)	729 (8.5)	4599 (53.7)	3967 (46.3)
Manual workers	718 (75.2)	237 (24.8)	766 (80.3)	188 (19.7)	499 (51.4)	471 (48.6)
Not working	8386 (87.50)	1198 (12.5)	9011 (92.8)	697 (7.2)	5342 (55.9)	4219 (44.1)
Resident place (*n*, %)						
Urban	6708 (86.8)	1020 (13.2)	7163 (91.8)	636 (8.2)	4302 (55.6)	3440 (44.4)
Suburban	7504 (86.1)	1207 (13.9)	8091 (91.2)	781 (8.8)	4770 (54.2)	4034 (45.8)
Rural	4651 (84.8)	833 (15.2)	4995 (90.3)	537 (9.7)	2964 (54.2)	2500 (45.8)
Vaccinated as a child (*n*, %)						
Yes	17 695 (88.0)	2403 (12.0)	19 005 (93.2)	1382 (6.8)	11 012 (54.7)	9125 (45.3)
No	870 (67.3)	423 (32.7)	904 (70.3)	382 (29.7)	750 (57.1)	564 (42.9)
Vaccinated as an adult (*n*, %)						
Yes	14 082 (90.1)	1543 (9.9)	15 018 (94.8)	817 (5.2)	8771 (56.4)	6791 (43.6)
No	3932 (76.7)	1193 (23.3)	4316 (83.1)	875 (16.9)	2654 (50.6)	2595 (49.4)
Government health spending % Health spending (Terciles)						
Low tercile (48.1%–69.7%)	5914 (85.5)	1004 (14.5)	6308 (90.0)	704 (10.0)	4126 (58.6)	2918 (41.4)
Medium tercile (69.7%–77.1%)	6559 (85.6)	1107 (14.4)	7231 (92.6)	574 (7.4)	3879 (51.2)	3691 (48.8)
High tercile (77.1%–85.9%)	6390 (87.1)	950 (12.9)	6710 (90.8)	676 (9.2)	4030 (54.5)	3364 (45.5)
Stringency Index (mean, SD)	57.35 (8.4)	54.15 (8.1)	57.11 (8.4)	54.68 (8.1)	57.08 (8.1)	56.38 (8.7)
Number of confirmed COVID-19 cases per 100 000 (mean, SD)	7769.7 (3013.8)	8269.5 (3149.5)	7820.3 (3011.7)	8118.5 (3242.3)	7506.0 (2955.4)	8309.2 (3127.6)
Number of confirmed COVID-19 deaths per 100 000 (mean, SD)	152.3 (69.0)	164.7 (70.5)	153.3 (69.0)	162.5 (72.8)	144.8 (69.8)	165.8 (68.2)

Percentages represent row percentages within each variable.

points we employed for social determinants may have affected the estimates. Finally, the majority of those surveyed indicated they were from urban or suburban settings; work remains to capture information from those living in rural settings.

Future work could include a description of each national government and more definitive information about sources of information, and investigations between these and actual vaccination rates, cases, hospitalizations and deaths from Covid-19. Such a study would serve as an excellent prototype for investigations that will inform strategies for managing future pandemics.

The ongoing Covid-19 pandemic has highlighted the issues surrounding vaccine hesitancy. Our work provides robust evidence that sources of information, individual characteristics, beliefs in vaccine safety/effectiveness/intent to be vaccinated are all linked. Reliable information is necessary to change this paradigm. The EU has taken a forceful approach in providing accurate information to its citizens. These efforts will be helpful for future pandemics.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Author contributions

E.D.l.C.S. conceptualized the study, designed the study, curated the data, verified the underlying data, analyzed the data, interpreted the results, wrote the manuscript and provided supervision. A.M.L. designed the study, curated the data, verified the underlying data, analyzed the data, interpreted the results and edited the manuscript. J.M.O. designed the study, interpreted the results, edited the manuscript and provided supervision. J.G.M. designed the study, analyzed the data, interpreted the results and edited the manuscript. A.T.C. acquired funding, designed the study, interpreted the results and edited the manuscript. E.B.D. acquired funding, conceptualized the study, designed the study, curated the data, verified the underlying data, interpreted the results, wrote the manuscript and provided supervision.

All authors (E.D.l.C.S., A.M.L., J.M.O., J.G.M., A.T.C. and E.B.D.) confirm that they have had full access to all the data in the study and accept responsibility to submit for publication.

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Data availability

All data are publicly available: Flash Eurobarometer 494, dataset ZA7771; WHO Global Expenditure Database; University of Oxford Covid-19 government Response Tracker.

Key points

- The EU has invested in countering the 'infodemic' of misinformation that constrains belief in the safety and effectiveness of Covid-19 vaccines, and the intent to be vaccinated.
- Results of this survey study provide some of the first EU-wide estimates of the association between sources of information about Covid-19 and intent to be vaccinated, using robust methods and adjusting for country-level variables.
- Our findings are consistent with the existing literature in demonstrating that trust in vaccine safety/effectiveness/satisfaction with national vaccination strategies, and intent to be vaccinated are associated with sources of information about Covid-19, with those relying on social media, family/friends declaring lower intents to be vaccinated.
- Those who rely on social media are younger, less likely to self-identify as male or female, to have had a formal education, and to have been vaccinated as children.
- The results of this study provide further support for these investments at the European level and provide a model for managing future pandemics, while reaffirming the characteristics of those to whom these resources are best targeted.

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