Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Vaccine 40 (2022) 2191–2201

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Understanding the influence of political orientation, social network, and economic recovery on COVID-19 vaccine uptake among Americans

Feng Hao [a,*], Wanyun Shao [b]

[a] Department of Sociology, University of South Florida, United States
[b] Department of Geography, University of Alabama, United States

ARTICLE INFO

Article history:
Received 20 October 2021
Received in revised form 24 January 2022
Accepted 17 February 2022
Available online 22 February 2022

ABSTRACT

The COVID-19 pandemic poses unprecedented risks to the well-being of Americans. To control the pandemic, a sufficient proportion of the population needs to be vaccinated promptly. Despite the proven efficacy and widespread availability, vaccine distribution and administration rates remain low. Thus, it is important to understand the public behavior of COVID-19 vaccination. This study aims to identify determinants at multiple levels that promote or inhibit one's vaccine uptake. We combine individual-level data from a national survey conducted in the summer of 2021 with corresponding state-level indicators. Findings of multilevel logistic regression show that political orientation, social network, and economic recovery altogether have significant influence. We articulate that individual decision to take the vaccine are a function of their personal characteristics and are also rooted in their home state's political, public health, and economic contexts. These findings contribute to the literature and have policy implications. Knowledge of the profiles among people who take/refuse the vaccine provides essential information to leverage certain factors and maximize vaccine uptake to mitigate the pandemic's devastating impact.

© 2022 Elsevier Ltd. All rights reserved.

1. Introduction

The COVID-19 pandemic has unprecedented and widespread impacts on the population across the United States. The most recent data from Johns Hopkins University dashboard shows more than 70 million people have been infected and over 866 thousand people lost their lives by January 2022. According to the Centers for Disease Control and Prevention [1], the COVID-19 vaccines are critical to mitigate the pandemic's devastating damage. Vaccination programs can foster individual immunity and establish herd immunity without requiring a large proportion of the population to be infected [2–3]. A Department of Health and Human Services report indicates that COVID-19 vaccinations from January until May 2021 were associated with an estimated reduction of more than a quarter million cases and nearly 39,000 deaths among Medicare beneficiaries [4]. Currently, 114 vaccines are tested in trials, and nine vaccines including the Pfizer-BioNTech and Moderna are approved for full use [5].

Despite the vaccines' effects to protect public health and reduce the transmission of the virus, skepticism, hesitancy, and resistance remain [6–9]. Misinformation has further increased public anxieties and compromised acceptance [10]. The data shows low vaccine distribution and administration rates, which pose a major threat to controlling the pandemic and delaying the track of attaining herd immunity. The latest data shows that fully vaccinated people only account for approximately 63% of the population [11]. Against this backdrop, there is an urgent need to understand the public behavior of vaccination and identify factors leading to vaccine uptake.

Existing studies of Americans have documented stark variation in public intentions to be vaccinated against COVID-19, which is attributed to different sociodemographic characteristics including political view, age, race, and education [12–20]. Psychological traits also influence the attitudes towards the vaccine. For example, adults higher on a sense of purpose reported a greater willingness to get the vaccine [21]. The lack of trust in the vaccine approval and development processes explained most variations in vaccination likelihood [22]. The design of behavioral nudges can also help overcome vaccine hesitancy and promote the uptake of vaccines [23]. Moreover, several studies reveal the impact of vaccine attributes (e.g., efficacy rates, side effects, and protection duration) on subjects' willingness to inoculate [24–26]. Other studies show the influence of message framing and information channel on vaccine acceptance [27–29].

Although previous research contributed to understanding public attitudes toward vaccines, several gaps remain. First, most studies used data before the vaccines were available and thus analyzed

* Corresponding author.
E-mail address: fenghao@usf.edu (F. Hao).

https://doi.org/10.1016/j.vaccine.2022.02.066
0264-410X/© 2022 Elsevier Ltd. All rights reserved.

the intention rather than the actual behavior, i.e., whether people had taken the vaccine. Second, while political orientation has been investigated using individual-level data, there is a lack of scrutiny of its effect at the collective level. Third, in addition to those factors included for inquiry, other predictors such as social network and economic recovery received less attention, and there has not been a study that analyzed these factors using measures at multiple levels. The features of a network can decide the contents of (mis) information about the vaccine. The public expects to recover from economic disruptions caused by the pandemic and to be re-employed, which at the same time might affect their perception of the virus. To complement the literature and respond to the evolving pandemic, we analyze survey data collected in the summer of 2021 and aim to understand the joint influence of political orientation, social network, and economic recovery on one's vaccine uptake. We include measures at both the individual level and state level.

In what follows, we first explain theoretical reasons why these factors influence one's decision to take the COVID-19 vaccine and use the rationale to develop hypotheses. Next, we introduce data from multiple sources to build measurements. We then estimate multilevel logistic regression models to test these factors' effects empirically. The findings shed light on the underlying factors regarding why some people decide to take the vaccine (and others do not) and provide public health officials with insights to promote the vaccine targeting different populations.

2. Literature review

In this study, we analyze the influence of political orientation, social network, and economic recovery on one's decision to take the COVID-19 vaccines. These factors have been included when investigating public risk perception of the pandemic and preventive behaviors such as mask wearing and social distancing. Building on the existing arguments, we elaborate on how these factors might also affect one's vaccine uptake.

2.1. Political orientation

In a political climate where polarization has become the norm, trust in political leaders is connected to one's partisan identity, and people rely on separate information sources related to their identity [30]. Regarding the pandemic, many aspects of the new virus are largely unknown, especially at the initial stages. The public has to turn to political elites (e.g., party leaders) they trust for guidance. The public reliance upon these elites to conceptualize a complicated and new issue such as a quickly evolving public health crisis grants the party leaders the power to frame the issue as they deem necessary [31]. Framing is the exercise of emphasizing certain aspects of an issue while neglecting other aspects by both the speaker (e.g., a politician) and individual members of the audience [31–32]. In a polarized political environment, the political elites frame on a wide variety of issues are far apart on both sides. On the receiving end, individual members of the audience tend to favor the frame advocated by the political elites they trust. To further complicate matters, polarization drives the public trend to have greater confidence in opinions of the party leaders rather than substantive information [33].

From the outset, Democratic and Republican leaders have framed COVID-19 differently by sending contrasting messages about its severity. For example, President Biden highlighted the risk, recommended mitigation measures, and promoted the vaccine. At the same time, former President Trump downplayed the risk, rejected strategies to control the pandemic, and disseminated misinformation about the vaccine [34–35]. Meanwhile, the partisan media outlets can relay and reinforce messages from political elites in a way that influences public attitudes and behaviors regarding the pandemic, as individuals are likely to encounter politicians' messages through the consumption of increasingly-polarized media sources [36–37].

The politically-driven rhetoric from leaders led to polarization of how the public responds to COVID-19. The confidence and favorability in political leaders can slant public response to the pandemic among people with different political orientations [38]. Americans who had more confidence in Trump's handling of COVID-19 perceived fewer threats posed by the virus [39]. In contrast, Americans who were in favor of Biden were more likely to support COVID-19 mitigation measures such as encouraging work from home and restricting non-essential travels [40]. Recent studies of the COVID-19 vaccine find that Republicans [41], people with conservative political ideology [42–43], and those exposed to conservative media outlets [44] have greater skepticism than their counterparts.

In addition, the immediate social setting's political context also exerts an unignorable influence on individual perceptions and behaviors [45]. Consequently, the political climate of a region where Americans reside is expected to affect their response to COVID-19. For instance, counties with high proportions of Trump voters had higher per capita cases [46]. Another study finds that people from states with unified Democratic Party controlled governments were more likely to wear a mask [47]. In comparison, people in areas with more Republicans engaged in less social distancing [48] and were less likely to comply with the stay-at-home orders [49–51].

While individual political preferences and state political institutions are different, the partisan control of the state can reflect collective public opinion to some extent. Regarding the pandemic, the state-level legislation and policies on vaccine and mask mandate are outcomes of both the party leadership and collective public opinion. Unified Democratic Party controlled states are more likely to propose COVID measures and the people are also more likely to follow the recommendations compared to Republican states. Moreover, unified Democratic control or lack of could determine whether messages and actions with regards to COVID-19 from the state government are consistent. Inconsistency can certainly lead to confusion among the public. In addition to unified Democratic party control, we include the proportion of Biden votes in the 2020 presidential election to further gauge state-level political context, as we will elaborate in the Methods section. The opinion-based Biden vote variable can complement the institutional party control variable.

2.2. Social network

The extent to which people are embedded in a social network influences their information sharing. Information that most members of the network value are more likely to be shared and upon which people base their attitudes and behaviors. Meanwhile, people who strongly identify as members of a social network are more likely to take action to protect and serve network members' collective interests [52]. One underlying mechanism of the network effect might be the social identity that defines one's sense of self with respect to a broader group [53]. Group membership provides self-esteem and a sense of belonging for individuals [54]. Accordingly, there is a distinct social identity between people who have taken the vaccine and those who resist the vaccine [55]. Individuals align their attitudes and behaviors with others within each group. On the one side, the people with a tendency to be vaccinated derive social benefits from the group receptive view on vaccination that in turn leads to vaccine uptake to conform to group expectation. On the other side, to maintain consensus and group

identity, the unvaccinated attach their identity to the anti-vaccine group, reinforcing the anti-vaccine sentiment such as negative views toward vaccine safety.

While one's social network has several properties, we focus on the vaccination behavior of people in the network. Such property is directly related to individual decisions of whether to get vaccinated. A close network that exposes people to timely information on the efficacy of the COVID-19 vaccine would promote uptake. In comparison, if people are surrounded by anti-vaxxers and misinformation, they might become skeptical and resist taking the vaccine. Previous studies highlight the impact of the social network by showing that communities with close ties have fewer cases and deaths as information on the pandemic spreads and people engage more in health-protective actions [56–58]. Individual behaviors are influenced by others and the features of the network [59]. For example, one study shows that networking with neighbors, friends, and family was positively associated with the odds of wearing a mask [47]. People living in counties with extensive social networks reduced mobility faster, especially those directed at retail and recreational activities with higher COVID-19 risk [60].

2.3. Economic recovery

The economy that was damaged considerably due to the pandemic began to recover at the beginning of 2021. We have witnessed reducing unemployment rates for consecutive months. However, the connection between economic recovery and public understanding of the pandemic is in question. A previous study finds that people from states whose economies recovered closer to the pre-pandemic level in the summer of 2020 became less likely to perceive threats, take precautionary measures, and support mitigation policies than people from states whose economies were far from full recovery [61]. The authors used the back-to-normal index to measure economic recovery that captures a wide range of indicators including the labor market, housing value, investments, consumer behavior, and travel and leisure activity. They contend that the underlying reason for the finding is that a better and recovering economymight send a misleading message that the return to normalcy is on track and the COVID-19 outbreak is under control. As a result, the public could perceive it is unnecessary to continue taking those actions (e.g., wearing a mask and keeping social distance) in response to the pandemic. Following the logic, we argue that people from states whose economy has recovered (e.g., score high on the back-to-normal index) will neglect the growing cases, disregard the risk, and resist the vaccine because they misjudge the pandemic due to better economic conditions.

2.4. Hypotheses

The existing literature suggests that political orientation, social network, and economic recovery likely affect public response to the pandemic. Considering the scholarship and applying these theoretical perspectives to explain one's vaccine uptake, we propose the following hypotheses and test the effect of these factors at both individual and state levels:

H1a: People who trust President Biden are more likely to take the vaccine.
H1b: People from Democratic Party controlled states or states with more Biden votes in the 2020 presidential election are more likely to take the vaccine.
H2a: People with a higher proportion of people in their social network who already took the vaccine are more likely to take the vaccine.
H2b: People from states with higher vaccination rates are more likely to take the vaccine.
H3: People from states with better economic recovery are less likely to take the vaccine.

3. Methods

We utilize data from several sources. All individual-level data, including one's decision to take the COVID-19 vaccine, political orientation, social network, and other sociodemographic control variables, are drawn from Understanding America Study (UAS). The UAS is a longitudinal study of nationally representative samples for adults aged $\geq$ 18 years and managed by the Center for Economic and Social Research at the University of Southern California. The UAS, which began in 2014, recruited panel members through address-based sampling from the U.S. Postal Service Computerized Delivery Sequence file. Participants complete surveys online, and those without Internet access are provided with a tablet and broadband Internet. Surveys were administered in English and Spanish, and respondents were compensated with about $20 for each half-hour of their survey time [62].

Starting on March 10th, 2020, UAS panelists were invited to participate in an ongoing survey related to the COVID-19 pandemic. A total of 29 waves of surveys were conducted on a range of issues related to the pandemic such as risk perception, protective behaviors, perceived symptoms, and mental health [63]. For this study, we use the last wave of the survey carried out between June 9th and July 21st, 2021. The data includes approximately 6,000 respondents from all 50 states and Washington D.C.

We include state-level variables and merge those measures with individual-level data drawn from the UAS survey. The state-level indicators measure the political context (party control of the government and Biden votes in the election), the full vaccination rate of the adult population, and the level of economic recovery. We describe these variables below, and the summary statistics are reported in Table 1.

3.1. Dependent variable

One question of the survey asks respondents whether they have gotten vaccinated for the coronavirus. Answers to this question are coded in a binary way as yes (1) and no (0). On average, around 72% of respondents said yes to this question.

3.2. State-level independent variables

We adopt the party control of state government to gauge the political climate of each state and obtain the 2021 data from the National Conference of State Legislatures. The variable is measured binary, with states coded as 1 if the Democratic Party controls both chambers of Congress and the governor's office. States are coded as 0 if the Democratic Party does not have unified control. We also use MIT's Election Lab data to calculate the proportion of Biden votes in the 2020 presidential election. A higher proportion suggests the state has more Biden supporters and is more pro-Democratic. The variable has been transformed into the logarithmic form to correct skewness when included for regression analysis. In addition, we get the adult population's full vaccination rates from the CDC. The rates varied during the period when the survey was conducted. We computed the mean of these daily rates and used them for analyses. Economic recovery is measured using a back-to-normal index constructed by Moody's Analytics and CNN Business. The index represents the percentage of the economy returning to its pre-pandemic level. The index has daily indicators and we also calculated the mean based on the data when the

Table 1
Descriptive Statistics.

Variable	Mean	S.D.	Min	Max
Dependent Variable				
Vaccinated for the Coronavirus	72%*		0	1
State-Level Independent Variables				
Political Party Control of Government (Democrats = 1)	30%		0	1
Biden Votes in the 2020 Presidential Election (%)	49	12	26	92
People $\geq$ 18 who are Fully Vaccinated (%)	56	9	39	75
Back-to-Normal Index	94	6	81	109
Individual-Level Independent Variables				
Trust Biden	2.037	1.009	1	4
Trust Trump	1.523	0.831	1	4
Proportion of Family or Close Friends Vaccinated (%)	63	32	0	100
Positive View of COVID-19 Vaccine	3.268	0.767	1	4
Negative View of COVID-19 Vaccine	2.227	0.839	1	4
Sex (Male = 1)	41%		0	1
Age	53	16	18	111
Race (White = 1)	78%		0	1
Marital Status (Married = 1)	56%		0	1
Income	2.573	1.116	1	4
Employment status (Employed = 1)	51%		0	1
Education	2.425	1.009	1	4

* We report percentages for variables that are binary coded.

survey was administered. The political party control variable does not have data for Washington D.C., and the other variables are available for all 50 states and Washington D.C.

3.3. Individual-level independent variables

There are three variables to measure the key concepts of this study. Political orientation is gauged by the level of trust to Biden and Trump, respectively. The responses include: do not trust at all (1), trust somewhat (2), trust mostly (3), and trust completely (4). The survey does not provide information about one's political party and ideology. We acknowledge this is a limitation. Meanwhile, we contend that trust in either political leader can represent one's political identity as party loyalty exceeds substantive political views in a highly polarized environment. The social network is measured by the proportion of respondents' family or close friends who received the COVID-19 vaccine, ranging from 0% to 100%. We get the information by computing the ratio of vaccinated people out of one's total number of family and close friends. We use the logarithmic form of this variable in regression analysis.

Next, we include nine sociodemographic variables. Two questions ask whether respondents consider the COVID-19 vaccines provide important benefits to society and are useful and effective. Responses include strongly disagree (1), disagree (2), agree (3), and strongly agree (4). We compute the average to represent a positive view of the vaccine. Two other questions ask whether respondents perceive the vaccines have many known harmful side effects and may lead to illness and death. Responses also range from strongly disagree (1) to strongly agree (4), and we use the mean to represent a negative view of the vaccine. We also control for respondents' sex (male = 1), age, race (white = 1), marital status (married = 1), household income (measured in four deciles that group annual household income from the lowest to the highest), employment status (employed = 1), and education (ranges from 1 being high school or less to 4 being a graduate degree or higher).

3.4. Multilevel logistic regression

We employ multilevel logistic regression with random intercepts to assess the influence of individual-level and state-level variables on one's decision of vaccine uptake. Multilevel modeling is used because the data is hierarchical with two levels; the individual units of analysis at a lower level are nested within the state units at a higher level. We use the logistic model because the dependent variable (whether respondents take the COVID-19 vaccine) is coded in a binary way [64].

We run an unconditional multilevel model (or intercept-only model) with no predictors in the preliminary analysis. In this model, one's decision to take the vaccine is estimated to test whether multilevel modeling is needed. We obtain the intraclass correlation (ICC), which estimates the percentage of the total variance of whether taking COVID-19 vaccine between states and is calculated by dividing the between-states variance by the total variance. The ICC statistic is 0.093, indicating that approximately 9% of the variance in the dependent variable occurs between states. The result suggests that a multilevel specification is reasonable for data analysis [65].

The regression models include several individual-level and state-level variables. We conduct regression in different models step-by-step. Model 1 includes the 12 individual-level variables and we add one state-level variable in Models 2–5 subsequently. We weight the data when performing regression analysis using the wave-specific weight variable (final_weight). The relative final post-stratification weights ensure the representativeness of the survey sample with respect to the U.S. population 18 years of age or older along several demographic dimensions. These dimensions include gender, race/ethnicity, age, education, household size, and household income as well as Census region and urban/rural characteristics of the area of residence. The models are estimated using Stata 17 and we report the odds ratio findings in Table 2.

4. Results

Model 1 shows that one's political orientation and social network significantly affect their behavior of vaccination. Notably, the odds of taking the COVID-19 vaccine increase by 32.7% for a one-unit increase in the trust of President Biden. The findings support Hypothesis 1a about a positive association between vaccine uptake and the trust in Biden. In addition, People are also more likely to take the vaccine if a higher proportion of their family or close friends have already received it (odds ratio = 3.458), which supports H2a about the positive effect of the social network. For other variables, people who have a positive view of the COVID-19 vaccine are more likely to take it (odds ratio = 5.151), while

Table 2
Multilevel Logistic Regression Results on Vaccine Uptake.

	Model 1	Model 2	Model 3	Model 4	Model 5
	Odds Ratio				
Individual-Level Independent Variables					
Trust Biden	1.327**	1.330**	1.324**	1.328**	1.324**
Trust Trump	0.888	0.890	0.892	0.892	0.89
Family/Friends (%) Vaccinated (ln)	3.458***	3.438***	3.430***	3.429***	3.428***
Positive View of Vaccine	5.151***	5.133***	5.173***	5.125***	5.175***
Negative View of Vaccine	0.372***	0.373***	0.373***	0.375***	0.373***
Male	0.791	0.796	0.788	0.788	0.791
Age	1.037***	1.037***	1.037***	1.037***	1.037***
White	0.644**	0.645**	0.644**	0.633**	0.651**
Married	1.523***	1.533***	1.543***	1.537***	1.537***
Income	1.122	1.118	1.114	1.110	1.118
Employed	1.267	1.271	1.267	1.259	1.271
Education	1.095	1.089	1.093	1.096	1.092
State-Level Independent Variables					
Democratic Party Control	–	1.441*	–	–	–
Biden Votes (ln)	–	–	2.533*	–	–
Vaccination Rate	–	–	–	1.026*	–
Back-to-Normal Index	–	–	–	–	0.964*
Model Statistics					
Constant	0.041	0.037	0.082	0.010	1.275

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

those with a negative view are less likely to do so (odds ratio = 0.372). Also, the odds of taking the vaccine increase by 3.7% for each year increase in age. The white is 35.6% less likely to take the vaccine than black, Asian, and others. Married people are 52.3% more likely to take the vaccine than people with other marital statuses such as separated or divorced. The impacts of gender, income, employment status, and education are statistically insignificant. The statistical significance of these individual-level variables remains in subsequent models after adding state-level variables. We display the effects of these variables in Fig. 1.

Next, we add the political party control variable in Model 2. The significant coefficient suggests that respondents from states that have unified Democratic Party controlled governments are 44.1% more likely to take the vaccine. Similarly, we include the Biden votes variable in Model 3 and we find that respondents from states with more Biden votes in the 2020 presidential election are more likely to take the vaccine (odds ratio = 2.533). Both findings support Hypothesis 1b. To further examine the effect of this variable, we use the "margins" suite of commands in Stata to visualize the association. We compute the adjusted means of the odds of taking the vaccine given different values of state government political party control and the share of Biden votes after controlling for other variables in the models. Fig. 2 provides the estimated odds with 95% confidence intervals. The odds of taking the COVID-19 vaccine are higher in states with unified Democratic Party control and states with more Biden votes.

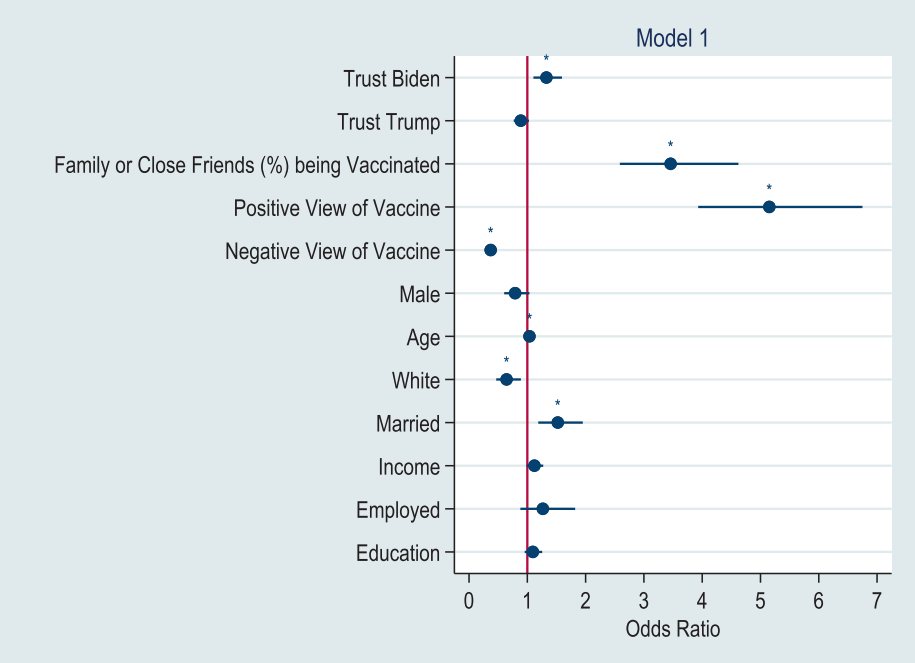
Finally, we include two other state-level variables in Model 4 and 5. The finding supports Hypothesis 2b by showing that the odds of people taking the COVID-19 vaccine increase by 2.6% for each percent increase in the adult population that is fully vaccinated. In comparison, the odds decrease by 3.6% for each percent increase in the back-to-normal index, which supports Hypothesis 3 about a negative association between economic recovery and vaccine uptake. We visualize the associations between the two state-level predictors and the dependent variable in Fig. 3. The odds of taking the vaccine increase concomitantly with vaccination rates and decrease with the back-to-normal index.

In sum, our analyses that control for a series of individual-level and state-level variables reveal the influence of different factors on one's decision to take the COVID-19 vaccine. Politically, people who trust Biden or reside in states with unified Democratic Party controlled governments and more Biden votes are more likely to take the vaccine (H1a and H1b). From a social network perspective, people with a higher proportion of family and friends who received the vaccine or from states with higher vaccination rates are more likely to take the vaccine (H2a and H2b). Moreover, better economic recovery at the state level inhibits vaccine uptake (H3). The decision to take the vaccine is also influenced by other factors, including views of the vaccine, age, race, and marital status. The R-square values suggest that the state-level variables account for around 70% of the variance in personal decision to take the vaccine and individual-level variables explain nearly 50% of the variance in the dependent variable.[1]

5. Discussion and conclusion

The COVID-19 pandemic imposes enormous morbidity and mortality burdens and disrupts societies and economies. The number of cases increased exponentially and the Summer/Fall of 2021 witnessed another surge due to the Delta variant. The emerging Omicron variant continues to speed up the transmission in the Winter and we have seen more than one million cases per day in January 2022. Meanwhile, different types of vaccines authorized for use in the U.S. have been proven safe and effective in helping prevent severe disease or death. While science informs the public that the vaccine can reshape the course of the pandemic, there are still a significant amount of Americans who are hesitant to get the vaccine. Thus, it is critical to know how to persuade a sufficient proportion of the U.S. population to take the vaccine especially now there is the newest Omicron variant threatening

[1] We have run multiple diagnostics to test the model fit, and the results show that we specify the models reasonably well. The AIC value is used to evaluate models in terms of their parsimony/complexity and statistical fit. The scores decrease as we include state-level measures for analyses, which suggest better fitting models. The tests for multicollinearity find no substantial problem. The details of each model including the coefficients, p-value, and 95% confidence intervals are presented in appendices.



*Refers to the statistically significant coefficient.

Fig. 1. Estimated Odds of taking COVID-19 Vaccine predicted by Individual-Level Factors *Refers to the statistically significant coefficient.

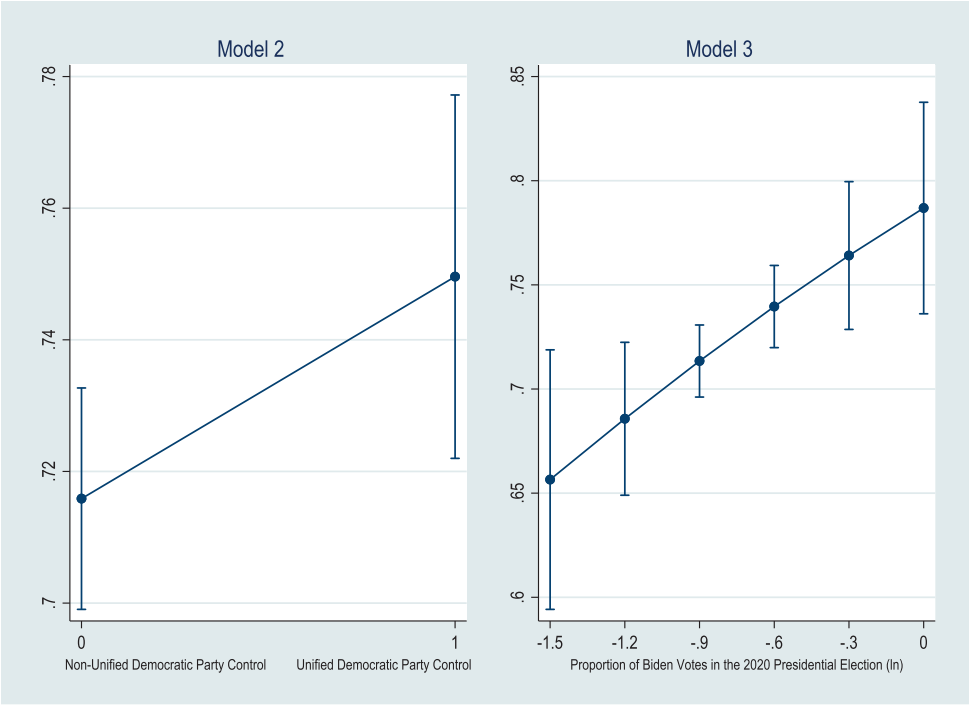


Fig. 2. Estimated Odds of taking COVID-19 Vaccine predicted by State-Level Political Party Control of Government and the Proportion of Biden Votes in the 2020 Presidential Election.

progress made already with vaccine rollout. This study responds to the need and identifies factors that affect one's vaccine uptake.

The regression analyses reveal the influence of factors at multiple levels. First, one's political orientation and the political context of their home state significantly contribute to the polarization of this issue. The Biden supporters and residents of blue states have higher odds to take the vaccine than Trump supporters and residents of red states. Second, the extensive connections people possess with vaccine takers can increase their information about the vaccine's efficacy. Together with high vaccination rates at the state

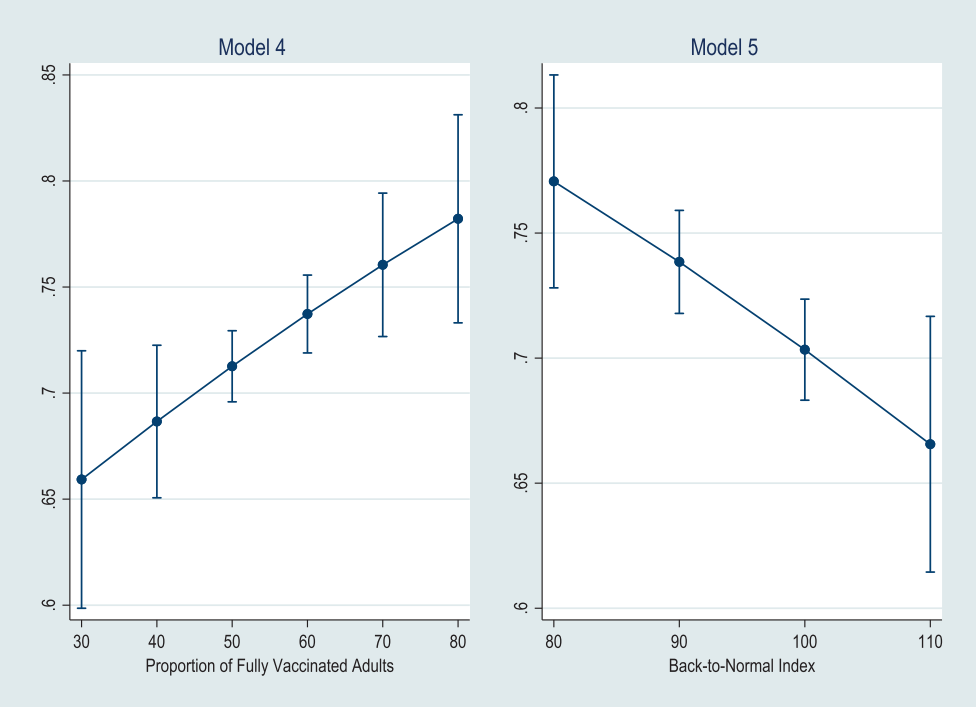


Fig. 3. Estimated Odds of taking COVID-19 Vaccine predicted by State-Level Proportion of Fully Vaccinated Adults and Back-to-Normal Index.

level, they all promote vaccine uptake. While we focus on testing the effect of vaccination behavior among one's family and friends, other social network characteristics might also shape one's decision. For example, the political partisan homophily of a network can reinforce the pattern of effects outlined when discussing the influence of political orientation. Thus, future research needs to examine different network properties' effects when relevant measures are available. Third, economic recovery, which is the public's common expectation, has a side effect of reducing the odds of vaccine uptake. The transition toward normalcy might create a false image that the pandemic is almost over and the vaccine has become less indispensable. Meanwhile, we acknowledge that the objective performance of the macro-economy at the state level is different from the subjective economic experience at the individual level. The economic performance indicators sometimes differ from public perceptions of how well the economy is doing. Subsequent studies can explore the association with other additional measures such as one's judgment of the macro-economy. Furthermore, people who have a positive view of the vaccine and are older, married, and non-white are more likely to take the vaccine than their counterparts.

Most previous studies have analyzed factors shaping one's intention or acceptance of the vaccine (e.g., [12,17,25,29]). We contribute to the literature by systematically investigating multilevel determinants that promote or inhibit vaccine uptake. We articulate that individual decisions to take the vaccine are a function of their personal characteristics and are also rooted in their home state's political, public health, and economic contexts. From a methodological perspective, our research demonstrates the value of analyzing one's vaccine uptake compared to evaluating the willingness to take the vaccine, which might not accurately gauge one's authentic attitude towards the vaccine. In addition, it is critical to include measures of the same predictor at multiple levels as people's vaccine uptake is importantly related to a multitude of variables that exist at personal, local and overarching, state levels. Similar findings regarding multilevel measures of the same concept can reinforce the hypothesized relationship than counting on conclusions of the one-level analysis.

The successful control of this unprecedented public health crisis relies on the extent to which people are vaccinated promptly. Knowledge of the profiles among people who have taken/refused the vaccine provides essential information to leverage the relevant factors and maximize vaccine uptake. According to our findings, the public health officials and locally trusted leaders need to work collaboratively to de-politicize the arguments surrounding the vaccine. They need to highlight a common identity that all Americans share when facing the same virus and bipartisan support is necessary for locating effective solutions. Their endorsement of the vaccine may be helpful. This concerted endeavor is multifactorial that must be addressed simultaneously at national, state, and county levels. In addition, encouraging vaccine takers to recommend vaccines to their family, friends, colleagues, and neighbors is also effective. A social network that delivers accurate information about the vaccine's benefits, especially targeting the younger, less-educated, and those who have a skeptical view about the vaccine, can be critical to securing this group's commitment to vaccination and establishing a national inoculation program. Meanwhile, it is imperative to alert residents from states with a better economic recovery that the pandemic remains severe and deadly, which will disrupt the trajectory if we cannot achieve a sufficient vaccination rate.

Overall, this study provides evidence regarding the public behavior in taking the COVID-19 vaccine. There are limitations and research on vaccine uptake call for more studies. First, we analyze the latest wave of the UAS survey conducted in the past summer. With the ups and downs of confirmed cases, emerging variants, and more information around different kinds of vaccines, public behavior will likely be affected. Thus, future studies should continue monitoring the trend using more recent data or panel data if available. Additional studies might also focus on the booster uptake since vaccine efficacy wanes over time and the booster has become increasingly necessary [66]. Second, in addition to the

three factors included in the present study, scholars might consider other factors (e.g., personal experience with the virus and government mandate) that might also shape one's decision to take the vaccine and change the mindsets of anti-vaxxers. Third, our individual-level political orientation measure is trust in Biden or Trump. Constrained by the data availability, we did not use formal measures of partisanship (Democrat, Independent, and Republican) and political ideology (liberal, moderate, and conservative). While we contend that trust in either political leader overlaps with one's partisan identity in a highly polarized environment, it would be ideal to include both formal measures in future studies.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Authors' Note

F.H. conceptualized the study and performed statistical analyses. F.H. and W.S. wrote the manuscript. All authors approve of the final version of the manuscript.

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.

Acknowledgement

Xxxx

Appendix

Appendix 1. Multilevel Logistic Regression Results for Model 1

	OddsRatio	p-value	95% Confidence Intervals	
Trust Biden	1.327	0.002	1.105	1.595
Trust Trump	0.888	0.113	0.767	1.029
Proportion of Family or Close Friends Vaccinated (ln)	3.458	0.000	2.588	4.622
Positive View of COVID-19 Vaccine	5.151	0.000	3.931	6.750
Negative View of COVID-19 Vaccine	0.372	0.000	0.302	0.458
Male	0.791	0.089	0.603	1.037
Age	1.037	0.000	1.029	1.045
White	0.644	0.008	0.467	0.889
Married	1.523	0.001	1.188	1.952
Income	1.122	0.075	0.988	1.273
Employed	1.267	0.202	0.881	1.820
Education	1.095	0.192	0.955	1.255

Appendix 2. Multilevel Logistic Regression Results for Model 2

	OddsRatio	p-value	95% Confidence Intervals	
Trust Biden	1.330	0.002	1.107	1.599
Trust Trump	0.890	0.121	0.769	1.031
Proportion of Family or Close Friends Vaccinated (ln)	3.438	0.000	2.574	4.594
Positive View of COVID-19 Vaccine	5.133	0.000	3.911	6.738
Negative View of COVID-19 Vaccine	0.373	0.000	0.302	0.460
Male	0.796	0.098	0.607	1.043
Age	1.037	0.000	1.029	1.045
White	0.645	0.008	0.467	0.891
Married	1.533	0.001	1.197	1.961
Income	1.118	0.087	0.984	1.270
Employed	1.271	0.197	0.883	1.829
Education	1.089	0.217	0.951	1.247
Democratic Party Control of Government	1.441	0.047	1.005	2.065

Appendix 3. Multilevel Logistic Regression Results for Model 3

	OddsRatio	p-value	95% Confidence Intervals	
Trust Biden	1.324	0.003	1.101	1.592
Trust Trump	0.892	0.127	0.770	1.033
Proportion of Family or Close Friends Vaccinated (ln)	3.430	0.000	2.568	4.582
Positive View of COVID-19 Vaccine	5.173	0.000	3.937	6.796
Negative View of COVID-19 Vaccine	0.373	0.000	0.303	0.460
Male	0.788	0.086	0.600	1.034
Age	1.037	0.000	1.029	1.045
White	0.644	0.007	0.467	0.889
Married	1.543	0.001	1.205	1.975
Income	1.114	0.098	0.981	1.265
Employed	1.267	0.200	0.882	1.820
Education	1.093	0.203	0.953	1.253
Biden Votes in the 2020 Presidential Election (ln)	2.533	0.020	1.157	5.544

Appendix 4. Multilevel Logistic Regression Results for Model 4

	OddsRatio	p-value	95% Confidence Intervals	
Trust Biden	1.328	0.003	1.105	1.597
Trust Trump	0.892	0.126	0.770	1.033
Proportion of Family or Close Friends Vaccinated (ln)	3.429	0.000	2.569	4.576
Positive View of COVID-19 Vaccine	5.125	0.000	3.905	6.726
Negative View of COVID-19 Vaccine	0.375	0.000	0.304	0.462
Male	0.788	0.084	0.601	1.032
Age	1.037	0.000	1.029	1.045
White	0.633	0.005	0.459	0.874
Married	1.537	0.001	1.200	1.969
Income	1.110	0.109	0.977	1.261
Employed	1.259	0.211	0.877	1.808
Education	1.096	0.186	0.957	1.257
People 18 + who are Fully Vaccinated	1.026	0.024	1.003	1.050

Appendix 5. Multilevel Logistic Regression Results for Model 5

	OddsRatio	p-value	95% Confidence Intervals	
Trust Biden	1.324	0.003	1.101	1.592
Trust Trump	0.890	0.119	0.769	1.030
Proportion of Family or Close Friends Vaccinated (ln)	3.428	0.000	2.565	4.581
Positive View of COVID-19 Vaccine	5.175	0.000	3.947	6.784
Negative View of COVID-19 Vaccine	0.373	0.000	0.303	0.459
Male	0.791	0.088	0.604	1.035
Age	1.037	0.000	1.029	1.045
White	0.651	0.009	0.471	0.899
Married	1.537	0.001	1.198	1.971
Income	1.118	0.082	0.986	1.268
Employed	1.271	0.197	0.883	1.829
Education	1.092	0.206	0.953	1.252
Back-to-Normal Index	0.964	0.022	0.934	0.995

References

[1] Centers for Disease Control and Prevention (CDC). COVID-19 Vaccine Effectiveness; 2021. https://www.cdc.gov/coronavirus/2019-ncov/vaccines/effectiveness/how-they-work.html.

[2] Anderson RM, Vegvari C, Truscott J, Collyer BS. Challenges in creating herd immunity to SARS-CoV-2 infection by mass vaccination. 2020. Lancet 2020;396(10263):1614–6.

[3] Omer SaB, Yildirim I, Forman HP. Herd immunity and implications for SARS-CoV-2 control. JAMA 2020;324(20):2095–6. https://doi.org/10.1001/jama.2020.20892.

[4] Samson LW, Tarazi W, Orav EJ, Sheingold S, De Lew N, Sommers BD. *Associations Between County-level Vaccination Rates and COVID-19 Outcomes Among Medicare Beneficiaries. (Research Report No. HP-2021-23)*. Washington, DC: Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services; 2021.

[5] The New York Times. Coronavirus vaccine tracker; 2021. https://www.nytimes.com/interactive/2020/science/coronavirus-vaccine-tracker.html

[6] Larson Heidi J, Broniatowski David A. Volatility of vaccine confidence. Science 2021;371(6536):1289. https://doi.org/10.1126/science.abi6488.

[7] Machingaidze S, Wiysonge CS. Understanding COVID-19 vaccine hesitancy. Nat Med 2021;27(8):1338–9. https://doi.org/10.1038/s41591-021-01459-7.

[8] Schneider KE, Dayton L, Rouhani S, Latkin CA. Implications of attitudes and beliefs about COVID-19 vaccines for vaccination campaigns in the United States: A latent class analysis. Prevent Med Rep 2021;24:101584. https://doi.org/10.1016/j.pmedr.2021.101584.

[9] Troiano G, Nardi A. Vaccine hesitancy in the era of COVID-19. Public Health 2021;194:245–51. https://doi.org/10.1016/j.puhe.2021.02.025.

[10] Bonnevie E, Gallegos-Jeffrey A, Goldbarg J, Byrd B, Smyser J. Quantifying the rise of vaccine opposition on Twitter during the COVID-19 pandemic. J Commun Healthcare 2021;14(1):12–9. https://doi.org/10.1080/17538068.2020.1858222.

[11] Centers for Disease Control and Prevention (CDC). COVID Data Tracker; 2022. https://covid.cdc.gov/covid-data-tracker/#datatracker-home.

[12] Callaghan T, Moghtaderi A, Lueck JA, Hotez P, Strych U, Dor A, et al. Correlates and disparities of intention to vaccinate against COVID-19. Soc Sci Med 2021;272:113638. https://doi.org/10.1016/j.socscimed.2020.113638.

[13] Chu H, Liu S. Integrating health behavior theories to predict American's intention to receive a COVID-19 vaccine. Patient Educ Couns 2021;104(8):1878–86. https://doi.org/10.1016/j.pec.2021.02.031.

[14] Daly M, Robinson E. Willingness to Vaccinate Against COVID-19 in the U.S.: Representative Longitudinal Evidence From April to October 2020. Am J Prev Med 2021;60(6):766–73. https://doi.org/10.1016/j.amepre.2021.01.008.

[15] Head KJ, Kasting ML, Sturm LA, Hartsock JA, Zimet GD. A National Survey Assessing SARS-CoV-2 Vaccination Intentions: Implications for Future Public Health Communication Efforts. Sci Commun 2020;42(5):698–723. https://doi.org/10.1177/1075547020960463.

[16] Khubchandani J, Sharma S, Price JH, Wiblishauser MJ, Sharma M, Webb FJ. COVID-19 Vaccination Hesitancy in the United States: A Rapid National Assessment. J Community Health 2021;46(2):270–7. https://doi.org/10.1007/s10900-020-00958-x.

[17] Latkin C, Dayton LA, Yi G, Konstantopoulos A, Park Ju, Maulsby C, et al. COVID-19 vaccine intentions in the United States, a social-ecological Framework. Vaccine 2021;39(16):2288–94. https://doi.org/10.1016/j.vaccine.2021.02.058.

[18] Niño MD, Hearne BN, Cai T. Trajectories of COVID-19 vaccine intentions among U.S. adults: The role of race and ethnicity. SSM – Popul Health 2021;15:100824. https://doi.org/10.1016/j.ssmph.2021.100824.

[19] Reiter PL, Pennell ML, Katz ML. Acceptability of a COVID-19 vaccine among adults in the United States: How many people would get vaccinated? Vaccine 2020;38(42):6500–7.

[20] Salmon DA, Dudley MZ, Brewer J, Kan L, Gerber JE, Budigan H, et al. Vaccine 2021;39(19):2698–711. https://doi.org/10.1016/j.vaccine.2021.03.034.

[21] Hill PL, Burrow AL, Strecher VJ. Sense of purpose in life predicts greater willingness for COVID-19 vaccination. Soc Sci Med 2021;284:114193. https://doi.org/10.1016/j.socscimed.2021.114193.

[22] Szilagyi PG, Thomas K, Shah MD, Vizueta N, Cui Y, Vangala S, et al. The role of trust in the likelihood of receiving a COVID-19 vaccine: Results from a national survey. Prev Med 2021;153:106727. https://doi.org/10.1016/j.ypmed.2021.106727.

[23] Dai H, Saccardo H, Han MA, Roh L, Raja N, Vangala S, et al. Behavioral Nudges Increase COVID-19 Vaccinations. Nature 2021;597:404–9. https://doi.org/10.1038/s41586-021-03843-2.

[24] Kreps S, Kriner DL. Factors influencing Covid-19 vaccine acceptance across subgroups in the United States: Evidence from a conjoint experiment. Vaccine 2021;39(24):3250–8. https://doi.org/10.1016/j.vaccine.2021.04.044.

[25] Kreps S, Dasgupta N, Brownstein JS, Hswen Y, Kriner DL. Public attitudes toward COVID-19 vaccination: The role of vaccine attributes, incentives, and misinformation. NPJ Vaccines 2021;6:73. https://doi.org/10.1038/s41541-021-00335-2.

[26] Motta M. Can a COVID-19 vaccine live up to Americans' expectations? A conjoint analysis of how vaccine characteristics influence vaccination intentions. Soc Sci Med 2021;272:113642. https://doi.org/10.1016/j.socscimed.2020.113642.

[27] Borah P, Hwang J, (Louise) Hsu YC. COVID-19 Vaccination Attitudes and Intention: Message Framing and the Moderating Role of Perceived Vaccine Benefits. J Health Commun 2021;26(8):523–33. https://doi.org/10.1080/10810730.2021.1966687.

[28] Diament SM, Kaya A, Magenheim EB. Frames that matter: Increasing the willingness to get the Covid-19 vaccines. Soc Sci Med 2022;292:114562. https://doi.org/10.1016/j.socscimed.2021.114562.

[29] Piltch-Loeb R, Savoia E, Goldberg B, Hughes B, Verhey T, Kayyem J, et al. Examining the effect of information channel on COVID-19 vaccine acceptance. PLoS ONE 2021;16(5):e0251095. https://doi.org/10.1371/journal.pone.0251095.

[30] Bartels LM. Beyond the running tally: partisan bias in political perceptions. Polit Behav 2002;24(2):117–50. https://doi.org/10.1023/A:1021226224601.

[31] Chong D, Druckman JN. Framing theory. Ann Rev Polit Sci 2007;10(1):103–26. https://doi.org/10.1146/annurev.polisci.10.072805.103054.

[32] Chong D, Druckman JN. A theory of framing and opinion formation in competitive elite environment. J Commun 2007;57(1):99–118. https://doi.org/10.1111/j.1460-2466.2006.00331_3.x.

[33] Druckman J, Peterson E, Slothuus R. How Elite Partisan Polarization Affects Public Opinion Formation. Am Polit Sci Rev 2013;107(1):57–79. https://doi.org/10.1017/S0003055412000500.

[34] Beauchamp Z. The Stunning Contrast between Biden and Trump on Coronavirus. Vox.com 2020. , https://www.vox.com/policy-and-politics/2020/3/12/21177135/coronavirus-covid-19-pandemic-trump-biden-speeches.

[35] Coppins M. Trump's Dangerously Effective Coronavirus Propaganda. TheAtlantic.com 2020. , https://www.theatlantic.com/politics/archive/2020/03/trump-coronavirus-threat/607825/.

[36] Jamieson KH, Albarracin D. The Relation between Media Consumption and Misinformation at the Outset of the SARS-CoV-2 Pandemic in the US. *The Harvard Kennedy School (HKS)*. Misinformat Rev 2020;1(2). https://doi.org/10.37016/mr-2020-012.

[37] Motta M, Stecula D, Farhart C. How Right-Leaning Media Coverage of COVID-19 Facilitated the Spread of Misinformation in the Early Stages of the Pandemic in the U.S. Can J Polit Sci 2020;53(2):335–42. https://doi.org/10.1017/S0008423920000396.

[38] Graham A, Cullen FT, Pickett JT, Jonson CL, Haner M, Sloan MM. Faith in trump, moral foundations, and social distancing defiance during the coronavirus pandemic. Socius 2020;6:1–23. https://doi.org/10.1177/2378023120956815.

[39] Shao W, Hao F. Confidence in political leaders can slant risk perceptions of COVID–19 in a highly polarized environment. Soc Sci Med 2020;261:113235. https://doi.org/10.1016/j.socscimed.2020.113235.

[40] Shao W, Hao F. Understanding American Public Support for COVID-19 Risk Mitigation: The Role of Political Orientation, Socio-Demographic characteristics, Personal Concern, and Experience, the United States, 2020. Int J Public Health 2021;66:1604037. https://doi.org/10.3389/ijph.2021.1604037.

[41] Fridman A, Gershon R, Gneezy A, Capraro V. COVID-19 and vaccine hesitancy: A longitudinal study. PLoS ONE 2021;16(4):e0250123. https://doi.org/10.1371/journal.pone.0250123.

[42] Scheitle CP, Corcoran KE. COVID-19 Skepticism in Relation to Other Forms of Science Skepticism. Socius 2021;7:1–12. https://doi.org/10.1177/23780231211049841.

[43] Stroope S, Kroeger RA, Williams CE, Baker JO. Sociodemographic correlates of vaccine hesitancy in the United States and the mediating role of beliefs about governmental conspiracies. Soc Sci Quart 2021;102(6):2472–81. https://doi.org/10.1111/ssqu.13081.

[44] Romer D, Jamieson KH. Conspiratorial thinking, selective exposure to conservative media, and response to COVID-19 in the US. Soc Sci Med 2021;291:114480. https://doi.org/10.1016/j.socscimed.2021.114480.

[45] MacKuen M, Brown C. Political context and attitude change. Am Polit Sci Rev 1987;81(2):471–90. https://doi.org/10.2307/1961962.

[46] Albrecht DE. COVID-19 in Rural America: Impacts of Politics and Disadvantage. Rural Sociol 2021. https://doi.org/10.1111/ruso.12404.

[47] Hao F, Shao W, Huang W. Understanding the Influence of Contextual Factors and Individual Social Capital on American Public Mask Wearing in Response to COVID–19. Health Place 2021;68:102537.

[48] Allcott H, Boxell L, Conway J, Gentzkow M, Thaler M, Yang D. Polarization and public health: Partisan differences in social distancing during the coronavirus pandemic. J Public Econ 2020;191:104254. https://doi.org/10.1016/j.jpubeco.2020.104254.

[49] Goldstein DAN, Wiedemann J. Who Do You Trust? The Consequences of Partisanship and Trust for Public Responsiveness to COVID-19 Orders. Perspect Politics 2021. https://doi.org/10.1017/S1537592721000049.

[50] Painter M, Qiu T. Political beliefs affect compliance with COVID-19 social distancing orders. J Econ Behav Organ 2020;185:688–701. https://doi.org/10.1016/j.jebo.2021.03.019.

[51] Roberts DC, Utych SM. Polarized social distancing: Residents of Republican-majority counties spend more time away from home during the COVID-19 crisis. Soc Sci Quart 2021;102(6):2516–27. https://doi.org/10.1111/ssqu.13101.

[52] Lin Nan. A network theory of social Capital Edited by Dario Castiglione. In: van Deth Jan W, Wolleb Guglielmo, editors. The Handbook of Social Capital. Oxford, England: Oxford University Press; 2008. p. 50–69.

[53] Turner JC, Oakes PJ, Alexander Haslam S, McGarty C. Self and Collective: Cognition and Social Context. Pers Soc Psychol Bull 1994;20(5):454–63. https://doi.org/10.1177/0146167294205002.

[54] Abrams D, Hogg MA. Comments on the Motivational Status of Self-esteem in Social Identity and Intergroup Discrimination. Eur J Social Psychol 1988;18 (4):317–34. https://doi.org/10.1002/ejsp.2420180403.
[55] Motta M, Callaghan T, Sylvester S, Lunz-Trujillo K. Identifying the prevalence, correlates, and policy consequences of anti-vaccine social identity. Politics, Groups, Identities 2021. https://doi.org/10.1080/21565503.2021.1932528.
[56] Fraser T, Aldrich DP, Page-Tan C. Bowling alone or distancing together? The role of social capital in excess death rates from COVID19. Soc Sci Med 2021;284:114241. https://doi.org/10.1016/j.socscimed.2021.114241.
[57] Makridis CA, Wu C, Freeman J. How social capital helps communities weather the COVID-19 pandemic. PLoS ONE 2021;16(1):e0245135. https://doi.org/10.1371/journal.pone.0245135.
[58] Pitas N, Ehmer C. Social capital in the response to COVID-19. Am J Health Promot 2020;34(8):942–4. https://doi.org/10.1177/0890117120924531.
[59] Michaels JL, Hao F, Ritenour N, Aguilar N. Belongingness is a Mediating Factor Between Religious Service Attendance and Reduced Psychological Distress During the COVID-19 Pandemic. J Relig Health 2022. https://doi.org/10.1007/s10943-021-01482-5.
[60] Borgonovi F, Andrieu E. Bowling together by bowling alone: social capital and COVID-19. Soc Sci Med 2020;265:113501. https://doi.org/10.1016/j.socscimed.2020.113501.
[61] Hao F, Shao W. Understanding the Effects of Individual and State-level Factors on American Public Response to COVID–19. Am J Health Promot 2021;35 (8):1078–83. https://doi.org/10.1177/08901171211017286.
[62] Alattar L, Messel M, Rogofsky D. An introduction to the Understanding America Study internet panel. Soc Secur Bull 2018;78(2):13–28.
[63] Kapteyn A, Angrisani M, Bennett D, Bruine de Bruin W, Darling J, Gutsche T, et al. Tracking the Effect of the COVID-19 Pandemic on the Lives of American Households. Survey Res Methods 2020;14(2):179–86. https://doi.org/10.18148/srm/2020.v14i2.7737.
[64] Robson K, Pevalin D. Multilevel modeling in plain language. London: Sage; 2016.
[65] Hox JJ. Multilevel analysis: Techniques and applications. Mahwah, NJ: Lawrence Erlbaum; 2002.
[66] Gupta RK, Topol EJ. COVID-19 vaccine breakthrough infections. Science 2021;374(6575):1561–2. https://doi.org/10.1126/science.abl8487.