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Sociopolitical and psychological correlates of COVID-19 vaccine hesitancy in the United States during summer 2021

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ABSTRACT

Vaccine hesitancy and refusal continue to hamper COVID-19 control efforts. Throughout the pandemic, scientists and journalists have attributed lagging COVID-19 vaccination rates to a shifting set of factors including demography, experiences during the height of the pandemic, political views, and beliefs in conspiracy theories and misinformation, among others. However, these factors have rarely been tested comprehensively, in tandem, or alongside other potentially underlying psychological factors, thus limiting our understanding of COVID-19 vaccine hesitancy. This cross-sectional study assesses a diverse set of correlates of COVID-19 vaccine hesitancy identified in previous studies using US survey data (N = 2055) collected in July–August 2021. The survey contained modules designed to assess various sociopolitical domains and anti- and pro-social personality characteristics hypothesized to shape vaccine hesitancy. Using logistic and multinomial regression, we found that the strongest correlate of vaccine hesitancy was belief in misinformation about the COVID-19 vaccines, though we surmise that this common explanation may be endogenous to vaccine hesitancy. Political beliefs explained more variation in vaccine hesitancy—and in particular, vaccine refusal—after belief in COVID-19 vaccine misinformation was excluded from the analysis. Our findings help reconcile numerous disparate findings across the literature with implications for health education and future research.

1. Introduction

Vaccine hesitancy continued to obstruct COVID-19 control efforts well after the release of free, safe, and effective COVID-19 vaccines. The public health transition from a pandemic that led to a global lockdown—and subsequent economic, social, and political externalities—to a manageable endemic disease (Phillips, 2021) more akin to influenza remains highly contingent on vaccination rates. Vaccine hesitancy has always been a global phenomenon and historical barrier to immunization campaigns ranging from measles, mumps, and rubella to human papillomavirus (MacDonald, 2015; Nayar et al., 2019). But the scope of the COVID-19 pandemic, combined with its politicization and the easy availability of conspiracy theories and misinformation on social media, have spawned widespread interest in the individual factors that shape COVID-19 vaccine hesitancy (Dubé and MacDonald, 2020; Sallam, 2021). There are many emerging explanations for COVID-19 vaccine hesitancy; for reviews of this growing literature, see Aw et al., 2021; Bierwiaczonek et al., 2021; Biswas et al., 2021; Puri et al., 2020; Salomoni et al., 2021; Solís Arce et al., 2021.

Early in the pandemic, many explanations were advanced by researchers and gained widespread acceptance, only to be supplanted by newer research pointing to other explanatory factors (Skelley, 2021). Thus, there remain numerous competing explanations for lagging vaccination rates in the United States (Mejia, 2021). For example, higher levels of vaccine hesitancy (e.g., Fisher et al., 2020; Willis et al., 2021) were observed in the Black American community, with similar patterns observed among American Hispanics (e.g., Jacobi and Vaidyanathan, 2021). These racial and ethnic disparities have complex causes but have been framed around structural racism and the resultant lack of trust in the medical community (e.g., Stoler et al., 2021; Webb Hooper et al., 2021). Others have identified religious views as a potential cause (Corcoran et al., 2021; Garcia and Yap, 2021). For example, in a 2020 survey of twelve religious congregations of various faiths, the frequency of prayer/meditation was negatively related to vaccine acceptance

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(Jacobi and Vaidyanathan, 2021). Vaccination gaps between predominantly Republican and predominantly Democratic states (Kates et al., 2021) have also led to the conclusion that right-wing political orientations (El-Mohandes et al., 2021; Latkin et al., 2021), fueled by anti-mitigation rhetoric employed by right-wing media and opinion leaders (Germani and Biller-Andorno, 2021; Romer and Jamieson, 2021; Stecula and Pickup, 2021), suppressed vaccination rates. In this same vein, deficits in education, trust in the scientific community, and science literacy have also received attention (Austin et al., 2021; Liu and Li, 2021). Researchers have also found that psychological factors, such as dark triad personality traits, were associated with vaccine hesitancy (Hughes and Machan, 2021); such findings suggested the need for further research about the link between hesitancy and psychological factors. Moreover, the perceived superiority of natural immunity through infection was also cited as a cause of vaccine hesitancy, one that has been amplified by media celebrities such as Joe Rogan (Lee, 2021).

Beliefs in conspiracy theories and misinformation about the COVID-19 pandemic and vaccines have also been associated with hesitancy (Enders et al., 2020; Romer and Jamieson, 2020), often with claims that these narratives gain greater traction, and reach a wider audience, through social media (Burki, 2020; Neff et al., 2021; Puri et al., 2020; Romer and Jamieson, 2020). Outgoing NIH Director Francis Collins echoed these sentiments, arguing that 100,000 unnecessary deaths in 2021 were "because of misinformation campaigns that discouraged people from taking advantage of lifesaving vaccines" (AAMC, 2021). The propensity for believing in conspiracy theories or misinformation about the pandemic remains a common scapegoat for vaccine hesitancy and the eschewing of other disease prevention behaviors (Bierwiaczonek et al., 2021). But it also remains unclear whether beliefs in COVID-19 conspiracy theories and misinformation *cause* vaccine hesitancy or are merely just another visible manifestation of it. For example, many of the people intentionally seeking out anti-vaccine misinformation and conspiracy theories online already hold vaccine hesitant views (Guess et al., 2020).

Questions remains as to which individual characteristics, seemingly changing in prominence with each successive study and news cycle, are best able to explain COVID-19 vaccine hesitancy, and how these relationships can be translated into policies and interventions to end the pandemic. We address this using survey data collected from a large national sample of Americans in the summer of 2021. The survey contained an extensive battery of questions designed to assess the overlapping narratives about correlates of COVID-19 vaccine hesitancy, as well as questions measuring psychological factors, to allow us to further explore the role of personality characteristics in vaccine hesitancy. The survey also contained a detailed measure that assessed respondents' short-term willingness to receive a COVID-19 vaccine (if at all).

This study therefore allows us to test the relationships between factors which dominate media discourse (Wood and Brumfiel, 2021) and are commonly theorized to shape COVID-19 vaccine hesitancy—political ideology and belief in COVID-19 conspiracy theories and misinformation (Bierwiaczonek et al., 2021; Latkin et al., 2021; van Mulukom et al., 2022)—while controlling for a wide range of individual sociodemographic, ideological, and psychological characteristics. Specifically, we hypothesize that political ideology and belief in COVID-19 misinformation, after adjusting for six blocks of covariates representing individual-level demographics, pandemic experiences, pandemic information and beliefs, views on science, political orientations, and psychological predispositions, will remain significant and substantively meaningful correlates of vaccine hesitancy. This study also expands our understanding of these relationships by conceptualizing vaccine hesitancy both in absolute terms—whether one is vaccinated or not—and in relative terms by modeling four different types of hesitancy. We close by discussing how the results can inform health communication interventions, and the prospects for mitigating pandemic and vaccine-related misinformation.

2. Materials and method

2.1. Participants and procedures

Qualtrics (qualtrics.com) administered a cross-sectional survey from July 17 – August 5, 2021, to 2055 American adults. Qualtrics partnered with Lucid (luc.id) to recruit a sample that matched 2019 US Census American Community Survey records on sex, age, race, education, and income. Based on this quota-based recruitment procedure there is no response or completion rate to report. Survey question wording and additional details about variable coding are included in Appendix A, Supplementary Materials, and participant demographics of our sample relative to 2019 census data are in Table S1, Appendix B, Supplementary Materials. The data file and code for replicating this analysis are publicly available on the Harvard Dataverse (Klofstad, 2022).

In line with emerging best practices for self-administered online questionnaires (Berinsky et al., 2021), four attention check questions were included in the questionnaire. Participants who failed to complete all four correctly were not included in the data set. A soft-launch test of the questionnaire ($N = 127$) yielded a median time to complete of 11.6 min. Participants who finished the questionnaire in less than one-half of the median completion time were not included in the dataset. Survey demographic quotas were filled after the exclusion of participants who failed the attention and speed checks, i.e., excluded participants were replaced to ensure we achieved our quotas, so there were no negative impacts in the sample. Online convenience samples, and those provided by Lucid in particular, have been shown to produce results suitable for social science research (Coppock and McClellan, 2019).

2.2. Dependent variables: vaccine hesitancy

Here we measure vaccine hesitancy as a function of respondents' self-reported COVID-19 vaccination status. Respondents were asked: "Have you personally received at least one dose of a COVID-19 vaccine?" Consistent with wording used by the Kaiser Family Foundation (kff.org) COVID-19 Vaccine Monitor project, those responding that they had *not* received at least one dose were asked, "Which of the following best describes how you feel about the COVID-19 vaccine?" with possible responses of, "I plan to get the vaccine as soon as possible" (henceforth referred to as *plans to ASAP*); "I am open to it, but will keep waiting and see what happens" (*wait and see*); "I will only get the vaccine if required by my job or places I need to go" (*only if required*); and "I definitely will not get the vaccine" (*definitely not*). We conceptualize these four responses as types of vaccine hesitancy given that all US adults had, in theory, 2.5–7 months to seek out a first shot by the time our survey was fielded. Our survey was fielded seven months after the Food and Drug Administration (FDA) issued Emergency Use Authorizations for adult use of the Pfizer-BioNTech and Moderna COVID-19 vaccines (December 11 and 18, 2020, respectively). Although older and immunocompromised adults were prioritized, President Biden instructed states to make vaccines available to all adults 18 years and older by May 1 (Miller and Lemire, 2021). The *plans to ASAP* hesitancy type, in particular, accounts for people who may have intended to vaccinate, but were struggling to overcome various social and structural barriers to utilizing health resources such as vaccines.

2.3. Independent measures

The analysis includes six blocks of individual-level independent variables that characterized respondent demographics, health- and employment-related COVID-19 experiences, pandemic-related beliefs and information sources (social media use), views on science, political orientations, and psychological predispositions. Detailed item phrasing and scoring is included in the Supplemental Materials.

2.3.1. Demographics

The first block begins with gender, age, education, and income. Based upon previous findings, we expect that women, younger respondents, and those with less education and lower levels of income will show higher levels of vaccine hesitancy (Stroope et al., 2021; Troiano and Nardi, 2021). This block also goes beyond these measures and includes *Perceived Social Status* as measured using the MacArthur Scale of Subjective Social Status (Adler et al., 2007). We include these demographic measures as standard covariates, but also because lower levels of status have been associated with higher levels of vaccine hesitancy (Freeman et al., 2020).

We also include indicators of affiliation with various religious denominations, an indicator of whether the respondent considers themselves born-again or Evangelical Christian, and religiosity. *Religiosity* is measured as an additive scale of responses to a question about the importance of religion in one's life, agreement with the statement that "People who are right with God are unlikely to be injured by the coronavirus," agreement with the statement that "Prayer can protect me from the coronavirus," frequency of religious service attendance, and frequency of prayer ($\alpha = 0.81$). Religious denominations were aggregated into: (a) Protestant; (b) Catholic; (c) other Christian (Mormon, Eastern Orthodox, and Greek Orthodox); (d) Jewish, Muslim, Buddhist, Hindu; (e) other; and (f) atheist, agnostic, and nothing in particular (used as the reference category). Previous findings have shown that Christians and those who are more religious will demonstrate higher levels of hesitancy (Jacobi and Vaidyanathan, 2021). We also include a standard measure of race/ethnicity given that Black Americans exhibited higher levels of hesitancy prior to the release of the COVID-19 vaccine (Stoler et al., 2021).

2.3.2. Pandemic experiences

The second block captures the respondent's personal experiences during the pandemic. First, we include a dichotomous indicator of whether the respondent was ever ill from COVID-19. Previous literature leads us to expect that those who previously caught COVID-19 will be more hesitant to vaccinate (Lee, 2021). Second, we include whether the respondent worked outside the home during lockdown, and whether they lost income due to the pandemic (i.e., laid off, hours cut, loss of business/clients, furloughed, and/or cut salary/wages), as unstable job status has been associated with COVID-19 vaccine hesitancy (S. E. Hwang et al., 2021).

2.3.3. Pandemic information and beliefs

The third block measures the information respondents have been exposed to during the pandemic. Belief in *COVID Vaccine Misinformation* is measured as an additive scale of beliefs in five pieces of misinformation that were prominent during the survey field period (e.g., vaccines causing infertility or altering one's DNA; $\alpha = 0.93$). *COVID Conspiracy Beliefs* is measured as an additive scale of beliefs in seven prominent conspiracy theories about the virus (e.g., the threat of having been exaggerated by political groups to damage former President Trump, 5G cell phone technology being responsible for the spread; $\alpha = 0.93$). *Social Media Use* is an additive scale of responses to questions about how frequently respondents use Facebook, Twitter, Instagram, and YouTube ($\alpha = 0.70$). A growing body of literature has demonstrated that social media use and beliefs in COVID-19 conspiracy theories and misinformation have been associated with vaccine hesitancy (Enders et al., 2020; Romer and Jamieson, 2020, 2021).

2.3.4. Views on science

The fourth block captures views on science. *Science Literacy* is an additive index of correct (coded 1) or incorrect (coded 0) responses to 11 questions about scientific facts (Durant et al., 1989; Okamoto et al., 2001). *Trust in Scientists*, excerpted from a larger battery of questions measuring anti-intellectualism (Merkley, 2020), is measured with an additive index of questions about one's trust in scientists, doctors, and pharmaceutical companies ($\alpha = 0.84$). *Confidence in Science*, as in the General Social Survey (gss.norc.org), is measured as level of agreement with the statement: "I have confidence in the scientific community". Previous findings suggest that these variables should have a negative relationship with vaccine hesitancy (Austin et al., 2021).

2.3.5. Political orientation

The fifth block measures political orientation. The standard American National Election Studies (electionstudies.org) questions were used to measure *Partisanship* and *Ideology*. We expect, given previous studies, that Republican and conservative identities will be associated with vaccine hesitancy (El-Mohandes et al., 2021; Latkin et al., 2021). *Anti-Establishment* orientations (Uscinski et al., 2021) is measured using a combination of conspiratorial (Uscinski et al., 2016), Manichean (Uscinski et al., 2020), and populist (Uscinski et al., 2020) sentiments ($\alpha = 0.85$). We expect, given that this predisposition is associated with a distrust of established institutions and mainstream information sources (Enders and Uscinski, 2021), a positive association with vaccine hesitancy. *Trump Approval* is measured on a 0-to-100-point "feeling thermometer" scale (electionstudies.org) of warmth towards the former president. Given both the politicization of the pandemic in the US and previous findings, support for the former president has been positively associated with vaccine hesitancy (Hornsey et al., 2020). *Interest in Politics* measures how often respondents follow government and current events on a scale ranging from "never" to "most of the time."

2.3.6. Psychological predisposition

The sixth block includes a variety of psychological traits. *Machiavellianism*, *Narcissism*, and *Psychopathy*—the "dark triad" (Jonason and Webster, 2010)—are each four-item scales with Cronbach's alpha reliability estimates ranging from 0.83 to 0.87. *Perceived Victimhood* (Armaly and Enders, 2021) is an additive scale based on agreement with five statement such as "I rarely get what I deserve in life" and "I usually have to settle for less" ($\alpha = 0.87$). *Stress* is the short-form Perceived Stress Scale (PSS-4) (Cohen et al., 1983), a scale based on how frequently, in the past month, respondents felt "unable to control the important things" in life, "confident about your ability to handle your personal problems," "that things were going your way," and "difficulties were piling up so high that you could not overcome them" ($\alpha = 0.72$). Higher levels of these characteristics have been associated with higher levels of vaccine hesitancy (Hughes and Machan, 2021; Yang et al., 2021).

EQ-8 *Empathy* (Loewen et al., 2009; Wakabayashi et al., 2006) is a scale based on agreement with eight statements such as "I find it easy to put myself in somebody else's shoes" ($\alpha = 0.65$). The Santa Clara Brief *Compassion* Scale (J. Y. Hwang et al., 2008) is based on agreement with five statements such as "I tend to feel compassion for people, even though I do not know them" ($\alpha = 0.89$). Given that vaccination is a pro-social act that protects others as much as the self, we control for the possibility that higher levels of empathy and compassion would lead to less hesitancy (Fraser, 2019; Pfattheicher et al., 2022), in contrast with anti-social characteristics such as Machiavellianism, narcissism, and psychopathy.

Predisposition toward *Physical Conflict*—based on the Crime and Violence Scale (Conrad et al., 2010)—is an additive scale of ten different types of conflict, ranging from insulting someone verbally to harming someone with a knife or gun ($\alpha = 0.81$). Previously identified relationships between aggression and vaccine hesitancy suggest that this predisposition will be positively associated with vaccine hesitancy (O'Connell et al., 2021). *Perceived Physical Strength* is based on a question that asks respondents how physically strong they are compared to other people from their gender on a ten-point scale ranging from 0% to 100% (Sell et al., 2009). Previous research suggests that individuals who view themselves as stronger will be more likely to be vaccine hesitant because those individuals will view vaccination as unnecessary (Khankeh et al., 2021).

2.4. Method of analysis

The survey respondent was the unit of analysis. We used logistic regression to assess the odds of reporting being unvaccinated relative to those who reported being vaccinated. We used multinomial logistic regression to assess the odds of being in each category of vaccine hesitancy (*planning to vaccinate*, *willing but waiting*, *only if required at work*, and *definitely not*), relative to those reporting being vaccinated. We first fitted partial models using each of the six blocks of independent variables separately, and then fit a full model containing all six blocks together. The six block of covariates yielded complete data for 2010 of 2055 respondents (97.8%). We proceeded with a complete case analysis because our missing data rate of 2.2% was well below the recommended threshold of 5% for implementing multiple imputation (Jakobsen et al., 2017). All analyses were conducted in Stata/MP v. 15.1 (College Station, TX). We used Stata's *margins* command to interpret maximum likelihood coefficients with all other model covariates held at their means.

2.5. Ethics statement

Qualtrics and Lucid comply fully with European Society for Opinion and Marketing Research (ESOMAR) standards for protecting research subjects' privacy and information. Lucid maintains panels of subjects that are used only for research. Individuals voluntarily join these panels (e.g., through the company's website, or by responding to a banner advertisement). Respondents received reward points redeemable from Lucid in exchange for voluntary participation in the study. They were invited to participate by email and consented voluntarily to particulate by reading an informed consent statement and clicking a button to proceed to the next screen in the survey. Respondents were free to end participation at any time by closing their Internet browser. The University of Miami Human Subject Research Office provided ethical oversight and approved this study on July 14, 2021 (protocol #20210618).

3. Results

3.1. Vaccination status

Table S2 (Appendix B, Supplementary Materials) summarizes respondents' vaccination status in binary form (at least one vaccine dose vs. unvaccinated) and across the four types of vaccine hesitancy, as well as descriptive statistics for all measures used in the multivariable analysis. Although some large national surveys overestimated US vaccine uptake in 2021 (Bradley et al., 2021), in our study 68.4% of 2055 respondents (1406) reported at least one dose of a COVID-19 vaccine, approximating the Centers for Disease Control and Prevention (CDC) July 18–24, 2021 estimate of 69.4%—and within the 95% confidence interval of 67.1–71.0 (CDC, 2021a)—corresponding to the mid-point of our survey period. In Table 1, the partial model columns present multivariable associations between unvaccinated status and each of the six blocks of independent variables (i.e., partial models), and the full model columns present associations from a model which included all six blocks simultaneously.

The partial model for the demographics block yielded associations with gender, age, education, and religious affiliations of *Catholic* or *Jewish, Muslim, Buddhist, or Hindu* that disappeared, i.e., were explained by other factors, in the full model. In the partial model, age was positively associated—and Age^2 was negatively associated—with being unvaccinated; this was the result of a non-linear effect between age and vaccination where people in their 20s and 30s were increasingly less likely to be vaccinated, but then became more likely to vaccinate as age increased beyond 50. In the full model, this effect disappeared with older adults more likely to be vaccinated (, and with the likelihood increasing from age 50 to 80 (Fig. 1A). In the full adjusted model, participants reporting higher *income* (odds ratio [OR] = 0.78, 95%

Table 1
Summary of logistic regression analysis of reporting being *unvaccinated* for COVID-19 (reference category = *vaccinated*). Partial models include only items within the same item category, whereas the full model includes all items from all categories.

Item Category	Partial Model		Full Model (n = 2011)	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Demographics	*n* = 2046			
Female gender	1.29 (1.02–1.62)	0.032	1.33 (0.99–1.77)	0.054
Age (years)	1.08 (1.03–1.12)	<0.001	1.04 (0.99–1.09)	0.108
Age^2	0.99 (0.99–0.99)	<0.001	0.99 (0.99–0.99)	0.004
Education level	0.86 (0.79–0.95)	0.001	0.95 (0.85–1.07)	0.412
Income level	0.78 (0.72–0.84)	<0.001	0.78 (0.71–0.86)	<0.001
Perceived social status	0.96 (0.91–1.01)	0.122	0.96 (0.90–1.03)	0.275
Religiosity	1.20 (1.07–1.34)	0.002	0.84 (0.72–0.98)	0.026
Religious affiliation (ref = Atheist, Agnostic, or nothing in particular)				
Protestant	0.72 (0.47–1.09)	0.123	0.99 (0.59–1.66)	0.977
Catholic	0.49 (0.34–0.71)	<0.001	0.71 (0.46–1.09)	0.114
Other Christian	0.45 (0.16–1.22)	0.115	0.88 (0.27–2.85)	0.836
Jewish, Muslim, Buddhist, Hindu	0.42 (0.25–0.70)	0.001	0.74 (0.41–1.34)	0.322
Other	1.20 (0.85–1.70)	0.309	1.50 (0.98–2.31)	0.063
Evangelical/born again	1.22 (0.78–1.89)	0.383	0.93 (0.55–1.57)	0.773
Race/Ethnicity (ref = White)				
Black	0.79 (0.58–1.06)	0.119	0.93 (0.63–1.37)	0.709
Asian	0.30 (0.18–0.51)	<0.001	0.28 (0.15–0.53)	<0.001
Native American	1.03 (0.57–1.85)	0.928	1.18 (0.57–2.45)	0.649
Other	1.01 (0.59–1.76)	0.961	0.77 (0.39–1.50)	0.441
Hispanic or Latino	0.54 (0.40–0.74)	<0.001	0.68 (0.47–0.98)	0.040
Model fit	LL = −1052.2; pseudo-R^2 = 0.17			
COVID-19 Experiences	*n* = 2044			
Had COVID-19	1.05 (0.81–1.35)	0.721	0.80 (0.57–1.12)	0.195
Worked outside home	1.19 (0.98–1.45)	0.083	0.94 (0.72–1.23)	0.657
Lost income	0.94 (0.76–1.17)	0.598	0.81 (0.60–1.09)	0.171
Model fit	LL = −1271.2; pseudo-R^2 = 0.00			
Information	*n* = 2046			
COVID-19 vaccine misinformation	3.03 (2.56–3.58)	<0.001	3.35 (2.70–4.16)	<0.001
COVID-19 conspiracy beliefs	1.05 (0.89–1.23)	0.579	1.08 (0.87–1.35)	0.477
Social media use	0.85 (.077–0.93)	0.001	0.97 (0.84–1.12)	0.666
Model fit	LL = −1025.1; pseudo-R^2 = 0.20			
Views on Science	*n* = 2045			
Science literacy	0.91 (0.86–0.96)	0.001	1.08 (1.00–1.17)	0.056
Trust in scientists	0.61 (0.55–0.68)	<0.001	0.83 (0.72–0.96)	0.012
Confidence in science	0.59 (0.52–0.68)	<0.001	0.70 (0.58–0.83)	<0.001
Model fit				

(*continued on next page*)

Table 1 (*continued*)

Item Category	Partial Model		Full Model (n = 2011)	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
	LL = −1068.7; pseudo-R^2 = 0.16			
Political Orientations	*n* = 2018			
Partisanship (Democrat to Republican)	1.04 (0.98–1.10)	0.208	1.01 (0.93–1.09)	0.877
Ideology (Liberal to Conservative)	1.08 (1.01–1.16)	0.031	1.06 (0.97–1.17)	0.193
Anti-establishment	1.73 (1.49–2.00)	<0.001	0.89 (0.72–1.11)	0.292
Trump approval (percentage points)	1.01 (1.00–1.01)	<0.001	1.00 (1.00–1.01)	0.235
Interest in politics	0.66 (0.60–0.73)	<0.001	1.01 (0.88–1.15)	0.894
Model fit	LL = −1130.6; pseudo-R^2 = 0.10			
Psychological Predispositions	*n* = 2042			
Machiavellianism	0.94 (0.82–1.07)	0.327	0.89 (0.75–1.06)	0.195
Narcissism	0.77 (0.69–0.87)	<0.001	0.86 (0.73–1.03)	0.100
Psychopathy	1.04 (0.89–1.20)	0.638	0.77 (0.63–0.94)	0.011
Perceived victimhood	1.08 (0.95–1.22)	0.248	0.83 (0.69–0.99)	0.034
Perceived stress	1.48 (1.29–1.70)	<0.001	1.04 (0.85–1.26)	0.715
Empathy	1.14 (0.90–1.44)	0.271	1.11 (0.81–1.53)	0.509
Compassion	0.96 (0.88–1.04)	0.304	1.00 (0.89–1.13)	0.966
Conflict tactic (less to more severe)	1.08 (1.02–1.15)	0.010	0.98 (0.90–1.06)	0.613
Perceived physical strength	1.03 (0.99–1.07)	0.141	1.02 (0.97–1.08)	0.339
Model fit	LL = −1230.4; pseudo-R^2 = 0.03			
Model fit			LL = −777.8; pseudo-R^2 = 0.38	

Note: OR = odds ratio; CI = confidence interval; LL = log likelihood.

confidence interval [CI] = 0.71–0.86, $P < 0.001$; Fig. 1B) or *religiosity* (OR = 0.84 [0.72–0.98], $P = 0.026$), and self-identifying as *Asian* (OR = 0.28 [0.15–0.53], $P < 0.001$) or *Hispanic/Latino* (relative to *White*) (OR = 0.68 [0.47–0.98], $P = 0.040$; see Fig. 1C) were all less likely to be unvaccinated. Religiosity is largely explained by other variables in the full model, with a residual signal that may be an artifact of Catholics' lower likelihood of being unvaccinated in the partial, unadjusted model.

We found no relationship between respondents' COVID-19 experiences—which included contracting COVID-19, working outside the home during lockdown, and losing income during the lockdown—and vaccination status. In contrast, the information environment did matter: individuals who believed more strongly in misinformation about the COVID-19 vaccine were more than three times as likely to be unvaccinated (OR = 3.35 [2.70–4.16], $P < 0.001$). As shown in Fig. 1D, those most skeptical of false COVID-19 narratives were more likely to be vaccinated (predicted probability [PP] = 0.94 [0.92–0.95], while those most accepting of them were least likely to be vaccinated (PP = 0.10 [0.05–0.16]. Belief in conspiracy theories about the nature and origin of SARS-CoV-2 was not related to vaccination status. While social media use was positively associated with being vaccinated in the partial model, this relationship was accounted for by other factors in the full model.

Views on science were also related to COVID-19 vaccination. Participants reporting higher levels of basic science literacy, trust in scientists (Fig. 1E), and trust in science (Fig. 1F) were less likely to be unvaccinated in the partial model, with the relationships for *trust in scientists* (OR = 0.83 [0.72–0.96], $P = 0.012$) and *confidence in science* (OR = 0.70 [0.58–0.83], $P < 0.001$) persisting in the full model. Put another way, each interval on our Likert scales denoting higher *trust in scientists* and *confidence in science* was associated with participants being 20% and 43% (respectively) more likely to be vaccinated.

In the partial model of the political orientation block, ideological conservatism, anti-establishment views, and positive feelings toward Donald Trump were all positively associated with being unvaccinated, while higher levels of interest in politics were positively associated with vaccination. None of these associations persisted in the full model, suggesting that these relationships were accounted for by other factors.

Finally, the partial model of psychological predispositions revealed that narcissism was negatively associated with being unvaccinated, while perceived stress and severe conflict tactics were positively associated with being unvaccinated, though none of these relationships were significant in the full model. However, participants with higher psychopathy (OR = 0.77 [0.63–0.94], $P = 0.011$) and perceived victimhood (OR = 0.83 [0.69–0.99], $P = 0.034$) scores were less likely to report being unvaccinated in the full model.

3.2. Vaccine hesitancy

Table S3 (Appendix B, Supplementary Materials) summarizes the factors associated with four types of vaccine hesitancy from our multinomial logistic regression analysis—*plans to ASAP*, *wait and see*, *only if required*, and *definitely not*—relative to those who reported being vaccinated with at least one dose. The first four columns of Table S3 present the results of entering the six blocks of independent variables separately (i.e., partial models), and the middle four columns present results from the full model where all six blocks were included in the analysis simultaneously. Here we report significant associations for each type of vaccine hesitancy from the full model as a relative risk ratio (RRR) with corresponding 95% confidence interval and *P*-value.

Respondents were 15% more likely to report planning to get the vaccine as soon as possible (*plans to ASAP*) for each addition year of age (RRR = 1.15 [1.02–1.29], $P = 0.022$) compared to those who reported being vaccinated, though a negative association for age^2 (RRR = 0.998 [0.997–0.999], $P = 0.008$) indicates that this relationship attenuates with age. This suggests that older Americans who were not already vaccinated—primarily those in middle age (see Fig. 1A)—were more likely to report their hesitancy as *plans to ASAP* than those already vaccinated. In addition to age, income was negatively associated (RRR = 0.73 [0.60–0.89], $P = 0.002$), and social media use was positively associated (RRR = 1.52 [1.14–2.02], $P = 0.004$), with *plans to ASAP*. The income association is striking: respondents were 37% more likely to report *plans to ASAP*, relative to being vaccinated, for each lower income category on our scale. *Plans to ASAP* was the mildest type of hesitancy we measured—and potentially not a form of hesitancy at all; this relationship highlights the many structural barriers related to transportation, child care responsibilities, disabilities, or work schedules that were more likely to limit access to the COVID-19 vaccine for lower-income residents. Together, these results suggest that respondents of middle age, with lower incomes, and who spend more time on social media were more likely to report the *plans to ASAP* type of COVID-19 vaccine hesitancy compared to those who reported being already vaccinated.

Respondents were more likely to report the *wait and see* type of hesitancy if they had lower income (RRR = 0.77 [0.67–0.90], $P = 0.001$) and educational attainment (RRR = 0.82 [0.69–0.98], $P = 0.025$), did not work outside the home during lockdown (RRR = 0.65 [0.42–0.98], $P = 0.041$), had lower confidence in science (RRR = 0.68 [0.52–0.88], $P = 0.004$), a lower narcissism score (RRR = 0.72 [0.56–0.93], $P = 0.013$), and believed in COVID-19 vaccine misinformation (RRR = 3.67 [2.65–5.07], $P < 0.001$). Belief in COVID-19 vaccine misinformation had the strongest effect on the *wait and see* type of hesitancy; for every one unit increase in the factor score for COVID-19 vaccine misinformation, respondents were 267% more likely to report *wait and see* compared to being vaccinated.

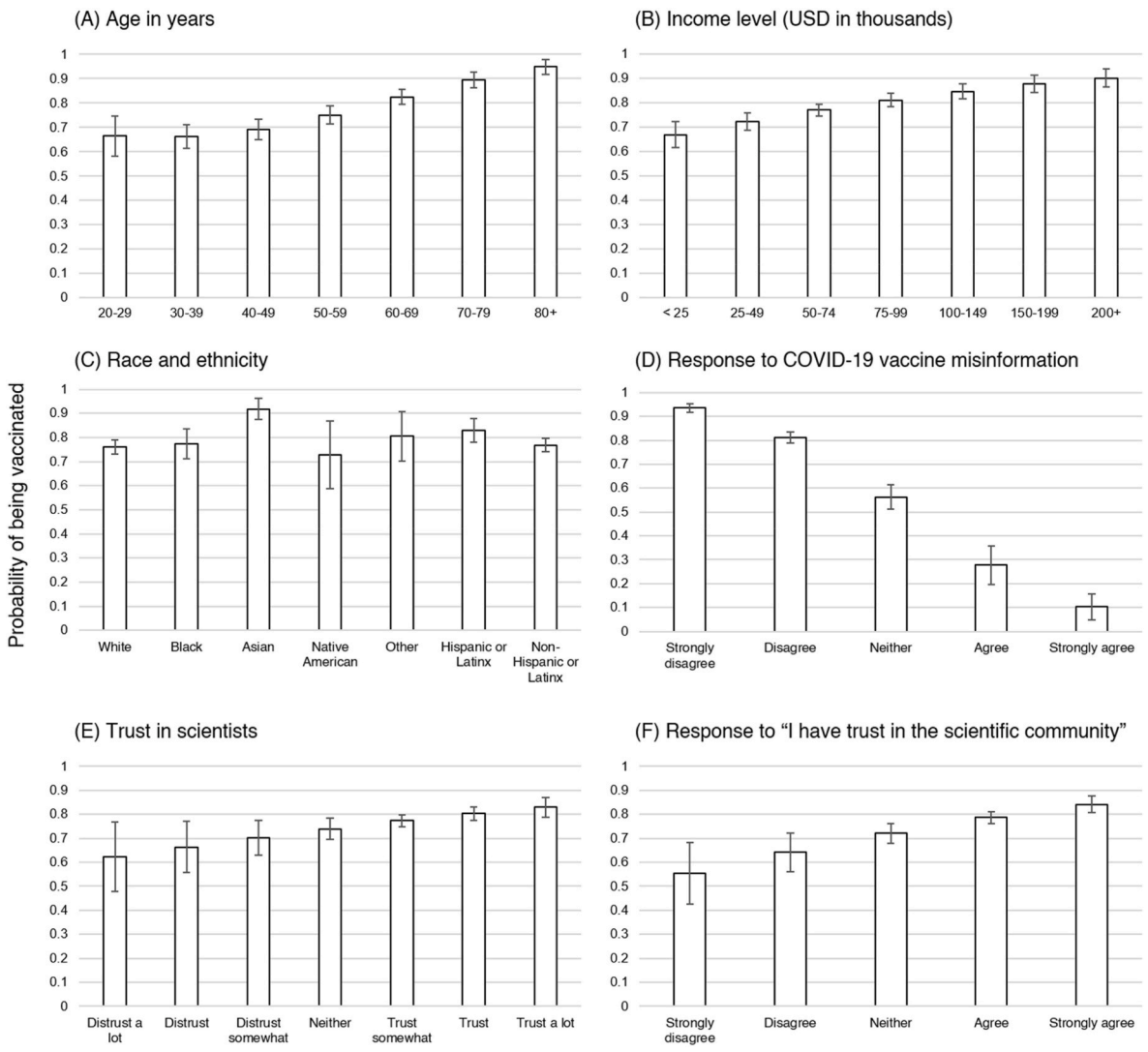

Fig. 1. Full regression model estimated probability of being vaccinated by: (A) age (based on effects of *Age* and *Age*^{2}), (B) income, (C) race and ethnicity, (D) agreement with COVID-19 misinformation statements, (E) trust in scientists, and (F) trust in the scientific community. Error bars represent 95% confidence intervals.

Respondents were more likely to report the *only if required* type of hesitancy if their religious affiliation was Protestant (RRR = 2.76 [1.03–7.36], $P = 0.043$) or other (RRR = 3.05 [1.31–7.07], $P = 0.010$), had a more conservative political ideology (RRR = 1.22 [1.01–1.47], $P = 0.037$), and believed in COVID-19 vaccine misinformation (RRR = 3.60 [2.37–5.45], $P < 0.001$). Respondents were also less likely to report *only if required* if they identified as Asian American (RRR = 0.16 [0.04–0.76], $P = 0.020$) or Hispanic/Latino (RRR = 0.32 [0.13–0.78], $P = 0.012$), or expressed higher confidence in science (RRR = 0.58 [0.41–0.81], $P = 0.002$). Again, belief in COVID-19 vaccine misinformation had the strongest association—260% more likely to report the *only if required* type of hesitancy compared to those who were vaccinated—a similar effect size as with *wait and see*.

Our analysis revealed the most differences between respondents who reported that they would *definitely not* get the COVID-19 vaccine and those reporting being already vaccinated. Respondents were more likely to report *definitely not* if they were women (RRR = 1.90 [1.25–2.87], $P = 0.002$), had lower incomes (RRR = 0.74 [0.65–0.86], $P < 0.001$), believed in COVID-19 vaccine misinformation (RRR = 5.68 [4.16–7.75], $P < 0.001$), had higher science literacy (RRR = 1.16 [1.04–1.30], $P = 0.010$), lower trust in science (RRR = 0.69 [0.57–0.83], $P < 0.001$), lower confidence in science (RRR = 0.68 [0.54–0.86], $P = 0.001$), more ideologically conservative (RRR = 1.15 [1.01–1.31], $P = 0.038$), higher approval rating of Donald Trump (RRR = 1.01 [1.00–1.01], $P = 0.041$), lower psychopathy score (RRR = 0.67 [0.51–0.89], $P = 0.005$), lower perceived victimhood score (RRR = 0.73 [0.57–0.93], $P = 0.010$), and higher perceived physical strength (RRR = 1.08 [1.01–1.16], $P = 0.029$). Respondents were also less likely to report *definitely not* if they were more religious (RRR = 0.78 [0.63–0.96], $P = 0.020$), identified as Catholic (RRR = 0.42 [0.22–0.79], $P = 0.007$) or Asian American (RRR = 0.11 [0.03–0.37], $P < 0.001$), or had contracted COVID-19 (RRR = 0.57 [0.35–0.93], $P = 0.024$). To summarize the strongest associations, members of this most strongly vaccine-hesitant group were more likely to be female, lower-income, neither Catholic nor Asian, believe in COVID-19 vaccine misinformation, have lower trust in scientists and less confidence in science, and have lower psychopathy.

3.3. Post-hoc analysis: exogeneity of misinformation and conspiracy beliefs

Given our finding that belief in false narratives about COVID-19 was associated with vaccine hesitancy, we reconsidered whether these beliefs are truly exogenous to vaccination status. More specifically, is belief in false COVID-19 vaccine narratives conceptually distinct from COVID-19 vaccine hesitancy, or are we tautologically modeling attitudes with similar attitudes? To test this empirically, we replicated our full model

excluding *COVID-19 vaccine misinformation* and *COVID-19 conspiracy beliefs*, with results summarized in the last four columns of Table S3.

While most of the results described above were robust to this *post-hoc* analysis, there were two key differences. First, the *post-hoc* models have fewer significant terms: many of the items demonstrating modest associations in the original full model—including all items from the COVID-19 experiences and psychological predispositions blocks—were no longer associated with any type of vaccine hesitancy in the *post-hoc* model. Second, more variation in the most extreme expressions of vaccine hesitancy, *only if required* and *definitely not*, was captured by items from the views on science and political beliefs blocks. With the *COVID-19 vaccine misinformation* and *COVID-19 conspiracy beliefs* items excluded, we observed stronger evidence that *low trust in scientists* (RRR = 0.54 [0.45–0.64], $P < 0.001$) and *low confidence in science* (RRR = 0.66 [0.54–0.81], $P < 0.001$), having *anti-establishment attitudes* (RRR = 1.73 [1.33–2.26], $P < 0.001$), and warmer feelings toward *Donald Trump* (RRR = 1.01 [1.01–1.02], $P < 0.001$) were positively associated with the *definitely not* type of hesitancy. *Anti-establishment attitudes* and age^2 were the only two significant items in the *definitely not* model that were not already significant in the corresponding full model, and there was no evidence of collinearity between any of these items and *COVID-19 vaccine misinformation* or *COVID-19 conspiracy beliefs*. In addition, the Akaike information criterion (AIC) of the full model (3,032) was lower than that of the post hoc model (3,270) which had two fewer items (AIC penalizes models with more parameters). This suggests that the full model was a better fit, and that the variation lost by the removal of *COVID-19 vaccine misinformation* and *COVID-19 conspiracy beliefs* is not captured by other measures. It is possible that these two items present an endogeneity problem, but it is also possible that the specific examples of misinformation and conspiracies used in these items just happened to be strongly correlated with the *only if required* and *definitely not* types of vaccine hesitancy.

4. Discussion and conclusion

Vaccine hesitancy, a chronic threat to public health that is as old as vaccines themselves, has taken center stage during the COVID-19 pandemic and inhibited control efforts. Many scholars explored the root causes of vaccine hesitancy as the pandemic progressed, with explanations including race and ethnicity, religiosity, belief in false narratives, perceived superiority of natural immunity, and political orientations, among others. Our study assessed these factors in tandem, accounted for a wider set of psychological characteristics, and used a more nuanced measure of hesitancy that elucidated correlates of four common forms of vaccine hesitancy. We found that the strongest correlates of the most extreme form of COVID-19 vaccine hesitancy—those who said they would *definitely not* take this vaccine—were having lower income, higher belief in COVID-19 vaccine misinformation, and lower trust in scientists. When we excluded belief in COVID-19 vaccine misinformation from the model due to being theoretically endogenous to COVID-19 vaccine hesitancy, we found that the strongest correlates were having lower income, lower trust in scientists, lower confidence in science, higher antiestablishment views, and higher approval of Donald Trump.

Our results contrast with prominent theories and empirical results—particularly from studies conducted prior to vaccine approval in December 2020—that attributed COVID-19 vaccine hesitancy to race (e.g., Callaghan et al., 2020; Stoler et al., 2021; Willis et al., 2021), religion (e.g., Corcoran et al., 2021; Garcia and Yap, 2021), and social media use (e.g., Jennings et al., 2021; Puri et al., 2020; Wilson and Wiysonge, 2020). Aside from strong pro-vaccination signals for Catholics and Asian Americans, none of these factors played much of a role in shaping COVID-19 vaccine hesitancy in our fully adjusted models. This does not mean that factors such as race and social media use do not matter, but rather that after accounting for a wide array of respondent characteristics, these effects were accounted for by personal politics and views of science. We emphasize that even non-significant relationships between a given characteristic and vaccine hesitancy does not mean that the characteristic is unrelated to hesitancy, but rather that, given our large set of covariates, its relationship is accounted for by other measures. We therefore do not position these results as necessarily contradicting other findings, but rather as providing greater clarity around which characteristics emerge as capturing the most shared variance among many characteristics associated with vaccine hesitancy.

The rest of our results generally support recent findings. Consistent with the literature on health disparities and social class (e.g., Krieger and Fee, 1994), we observed a significant and substantively meaningful 23-percentage-point difference in vaccination rates between individuals in the lowest and highest income groups. Our finding that individuals with lower trust and confidence in science were more likely to be vaccine hesitant is consistent with the discourse on COVID-19 and trust (Goldenberg, 2021; Rosenbaum, 2021). The associations between political orientations and vaccine hesitancy are also consistent with recent findings (e.g., Fridman et al., 2021; Gerretsen et al., 2021).

The influence of belief in COVID-19 misinformation was the most statistically robust and substantively meaningful. We estimated that 94% of those most skeptical of vaccine misinformation were vaccinated; this number falls to 10% among those who believe most strongly in these false narratives. Likewise, belief in misinformation about the vaccines was the most robust predictor of the stronger forms of hesitancy. This dramatic difference underscores the merit of our post hoc analysis: what if one's propensity for believing COVID-19 misinformation and COVID-19 vaccine hesitancy are part of the same construct? Our post hoc analysis found that measures related to political identity are more strongly associated with hesitancy after excluding belief in COVID-19 misinformation and conspiracy theories from the analysis.

Our findings support three conclusions. First, policy focused on mitigating misinformation and conspiracy theories may be useful in the fight against COVID-19. Some have already followed this suggestion by designing interventions to debunk (Vraga and Bode, 2021) or "pre--bunk" false narratives (Basol et al., 2021), though these strategies can also backfire and lead people to cling even more tightly to their beliefs (Rosenbaum, 2021). Second, this policy prescription is not a straightforward one; as shown in our post-hoc analysis of the potential endogeneity of belief in false narratives, the effect of COVID misinformation on vaccine hesitancy appears to be tied to deeper, less malleable, belief structures like political ideology and anti-establishment views. Third, as such, future research should assess more systematically whether other exogenous underlying variables are predictive of both belief in COVID-19 misinformation and conspiracy theories, and vaccine hesitancy. Our analysis tested several candidate measures in our psychological predisposition block, including measures of both anti- and pro-social personality traits, but none of these were significant in our full adjusted model. Despite our wide range of measures, our models only explained about a third of the variation in vaccine hesitancy; the substantial amount of unexplained variance in vaccine hesitancy highlights the complexity of this phenomenon. Identifying these deeper root-cause factors will allow for the creation of more effective public health policy by addressing belief in false narratives at the source rather than bandaging its expressed wounds. This suggests implications not only for targeted public health messaging to address the different forms of vaccine hesitancy, but also for how insights from psychiatry can address the range of manifestations of vaccine hesitancy by focusing on people's past experiences with disenfranchisement and structural racism (Goldberg, 2021).

The strength of this study lies in the clarity that emerges from the breadth of measures modeled concurrently. But these findings have several limitations typical of cross-sectional studies. While the study timing—late-July to early-August 2021—is crucial for comparing our findings to similar surveys, our results may not speak directly to the current state of COVID-19 vaccine hesitancy, particularly given federal mandates issued after the study period, recent authorization for use in

young children, and increased vaccination rates over time (76% of the US population had received at least one dose as of January 23, 2022 (USA Facts, 2022)). COVID-19 cases were on the rise during our study period, with tens of thousands of new infections and hundreds of deaths occurring daily in the US. On July 27, 2021 alone—the mid-point of our study—the US reported over 87,000 new cases and 539 deaths (CDC, 2021b), an vaccine hesitancy may have varied among certain sub-populations at different stages of the pandemic. Additionally, just weeks before our study was fielded, 15 million adults were estimated to have missed their second scheduled vaccine dose (Anders, 2021). It is still not clear what proportion were truly vaccine hesitant—some may have had adverse reactions to the injection or simply received their second shot late—but this may have constituted an additional, under-recognized type of vaccine hesitancy that our survey did not capture. Finally, this study also only focused on individual-level characteristics and did not account for how local or state political leadership, the enforcement of mask mandates and school closures, and other contextual factors related to social group identity may contribute to vaccine hesitancy.

Our results spotlight several of the most widespread sources of vaccine hesitancy among millions of Americans at a crucial point in the pandemic—a willingness to believe in false narratives, mistrust of science, and deeply-held political convictions. These factors are unlikely to change as the COVID-19 pandemic persists and will likely threaten public health during the next pandemic. The faster we understand and address the root cause of these drivers, the more lives may be saved.

Credit author statement

Justin Stoler: Conceptualization, Methodology, Writing- Original Draft Preparation, Writing- Reviewing and Editing, Funding Acquisition; **Casey Klofstad**: Data Curation, Visualization, Investigation, Supervision, Writing- Original Draft Preparation, Writing- Reviewing and Editing, Funding Acquisition; **Adam M. Enders**: Methodology, Investigation, Data Curation, Validation, Writing- Reviewing and Editing; **Joseph E. Uscinski:** Conceptualization, Writing- Reviewing and Editing, Funding Acquisition.

Data and replication

All data and code are available at the Harvard Dataverse: https://doi.org/10.7910/DVN/XKSKBX.

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Declaration of competing interest

All authors declare no competing interests.

Appendix A and B. Supplementary data

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