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Can we convince the unvaccinated to vaccinate: lessons from COVID-19 vaccination

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Abstract

Background Vaccine hesitancy affects vaccine uptake. Despite initial reluctance to receive the COVID-19 vaccine in 2020, by 2021, many individuals chose to get vaccinated once vaccines became available, while others who had previously been willing to vaccinate changed their minds. In this study, we focused on people who did not follow-up on their intentions to (or not to) vaccinate and why.

Methods This longitudinal study draws on data from a two-wave nationally representative survey of Americans from July 2020 (T1) and July/August 2021 (T2) to examine the factors that contribute to the COVID-19 vaccination-related intention-behavior gap, using multivariable logistic regression.

Results By T2, 52% of previously COVID-19 vaccine-hesitant individuals were vaccinated and 14% of previously pro-vaccine individuals remained unvaccinated. Among the vaccine-hesitant individuals, factors associated with vaccination included higher risk perception, general vaccine acceptance, being informed about the vaccines, endorsing less COVID-19 misinformation, confidence in scientists, and having health insurance. Among the pro-vaccine individuals, factors associated with being unvaccinated included lower risk perception, lower general vaccine acceptance, being less informed about the vaccines, partisan identification, lower confidence in scientists and not having health insurance.

Conclusion The study highlights the factors that explain intention-behavior gap in vaccination. We identified what explains individuals' intentions to vaccinate and their actual vaccination behavior one year later, as well as the potential to influence vaccine-hesitant individuals to vaccinate and pro-vaccine individuals from actualizing their vaccination intentions. Understanding these factors is essential in developing evidence-based strategic communications, which can help convince individuals to vaccinate and increase the uptake of COVID-19 as well as other adult vaccines.

Keywords Vaccine hesitancy, Health communication, Vaccine acceptance, Adult vaccines, COVID-19, Misinformation

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Introduction

On December 8th, 2020, the United States became one of the first countries in the world to administer the COVID-19 vaccines at no cost to the public [1]. Despite scientific evidence that the COVID-19 vaccines are safe and effective, hesitancy among individuals persists. Vaccine hesitancy is defined as "delay in acceptance or refusal of vaccination services despite their availability" [2]. When individuals choose not to get vaccinated, especially during a pandemic, efforts to reduce the impact of the virus are hindered.

As of May 11th, 2023, the last date when data were updated by the CDC, only 79% of all American adults were considered fully vaccinated, which means they had received two doses of the COVID-19 vaccine in the primary series [3]. However, uptake of the annually updated booster doses remained around 20% in December 2022, November 2023, and November 2024 [4, 5].

Literature from media studies, health behavior and social epidemiology offers a number of factors that potentially influence individuals. For example, the Integrated Behavioral Model (IBM) posits that an individual's behavior, through behavioral intention, is influenced by factors such as beliefs, attitudes, self-efficacy, perceived norms, and cultural influences [6, 7]. Additionally, factors such as skills, abilities, and environmental constraints play a role in translating intention into actual behavior [6, 8]. Other behavioral theories, such as the Health Belief Model, Theory of Planned Behavior, and Social Cognitive Theory, indicate that socio-demographic, psychological, ideological, and media exposure factors can also influence people's intentions [9–11]. Work in social epidemiology and media studies identifies additional set of factors- including some social determinants and information exposure- that influence how external social and media environments shape individual behavior [11–14]. Based on these theories, one pathway for behavior change is by targeting behavioral intentions, with the assumption that changing behavioral intentions would lead to actual behavior changes [11]. To understand COVID-19 vaccine hesitancy, most prior research and interventions have also focused on factors that influence vaccine intentions, as intention is argued to be the most direct determinant of behavior [9, 10, 15, 16].

Intentions, however, despite being a strong predictor of behaviors, don't always translate into behaviors, leading to a gap between intention and behavior, or the *intention-behavior gap*. Nonetheless, studies continue to measure behavioral intentions as a proxy for behaviors for several reasons. One, intention is the more immediate and accessible measure compared to behavior [11]. Surveys, questionnaires and interviews can quickly assess intentions whereas actual behaviors are less practical to observe and measure, especially if they are infrequent or complex. Two, studying behaviors may require more resources and time, adding to the costs of the studies. Three, when dealing with sensitive or risky behaviors, studying intentions may also be more ethically acceptable compared to studying the behaviors directly.

The famous quote by the psychiatrist Carl Jung, "You are what you do, not what you say you'll do," encapsulates the essence of the intention-behavior gap. While the quote signifies that a person's character is defined by their actions and behaviors rather than mere intentions, it also suggests that there can be inconsistencies between an individual's intention to do something and their actual behavior. Literature suggests that the associations between intentions and behaviors could be strengthened by targeting the antecedents of intentions [17, 18]. For instance, sociodemographic factors, attitudes, social norms, and self-efficacy have been shown to influence behavior by moderating the intention-behavior relationship [18, 19]. However, little is known about the factors that specifically contribute to vaccination related intention-behavior gap, especially in the context of COVID-19.

The vaccination-related intention-behavior gap presents an opportunity to persuade unvaccinated individuals to get vaccinated. This paper explores the potential factors that influence the translation of individuals' intentions to (or not to) vaccinate against COVID-19 into actual vaccination behavior, addressing the vaccination-related *intention-behavior gap* [20, 21]. Fewer studies have focused on political party identification and communication factors in addition to usual individual factors in understanding intention-behavior gap [22, 23]. With the aim of expanding upon the existing literature on intention-behavior gap, gaining a more comprehensive understanding of these gaps, and informing policies and practices, we ask an important question: What socio-demographic, psychological, party identification, and communication-related factors are associated with people who did not follow-up on their COVID-19 vaccination intentions? Specifically, we focused on factors measuring perceptions of risk, vaccine acceptance, COVID-19 information exposure, political party identification, confidence in scientists, healthcare access, and demographic and social factors.

Vaccination is also among those topics that is subject to considerable misinformation, warranting examination of role of misinformation on vaccines. Misinformation about science is defined as *"[I]nformation that asserts or implies claims that are inconsistent with the weight of accepted scientific evidence at the time (reflecting both quality and quantity of evidence). Which claims are determined to be misinformation about science can evolve over time as new evidence accumulates and scientific knowledge regarding those claims advances."* [12] An understanding of the factors that contribute to this

intention-behavior gap can also help inform communication strategies to address vaccine-related misinformation and encourage the vaccine hesitant individuals to get vaccinated and the pro-vaccine individuals to realize their intentions, with implications for other adult vaccinations as well.

Methods

Study design

The data come from surveys administered to the Ipsos KnowledgePanel®, an online probability-based panel, at two different time points- July 2020 or *'time one'* (T1) and July-August 2021 or *'time two'* (T2) [24]. In July 2020, COVID-19 vaccines were still in the development and trial stages and had not yet been made available to the public, whereas by August 2021, millions of doses had been administered worldwide, and over 52% of the U.S. population was fully vaccinated [25, 26]. The survey participants were randomly recruited using address-based sampling, which relied on the latest version of the Delivery Sequence File (an address database) from the USPS to select address-based samples that are nationally representative of all households [27]. Stratified random sampling methods ensured that the geodemographic composition was representative of American adults. At T1, the survey was administered to 1,822 participants, of which 1,012 participants completed the survey, including non-institutionalized adults aged 18 and older, and oversamples of African Americans, Hispanics, and adults in low-income households (less than 100% of Federal Poverty Level), residing in the U.S. At T2, due to budget constraints, we intentionally recontacted only a subset of the original T1 participants. The T2 survey was fielded to 808 active panel members from T1, of whom 607 completed the survey. The T1 and T2 samples were designed to ensure a composition that remained representative of the U.S. adult population. For this study, we analyzed data from the 607 participants who completed both T1 and T2 the surveys. This reduction in sample size reflects the study design and not participant attrition. The full surveys are provided in the supplementary files.

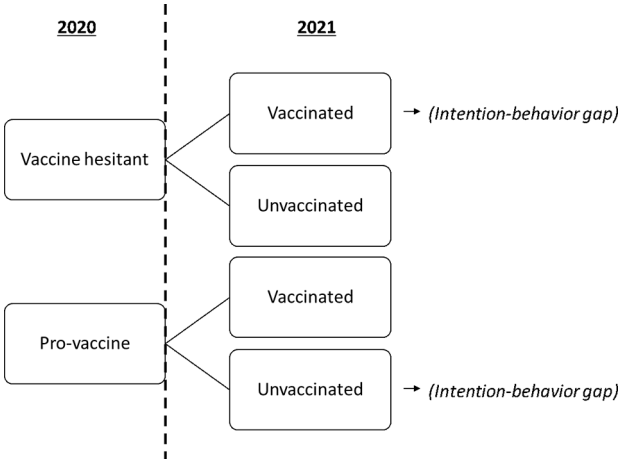

Fig. 1 A schematic representation of the intention-behavior relationship variable construction, highlighting the two types of COVID- 19 vaccination-related intention- behavior gap

Measures

Outcome variables

Vaccination intention was measured at *T1* by asking: "If a vaccine for COVID-19 becomes available during the next 12 months, how likely do you think you would get it for yourself?". For our analysis, we categorized the responses into two groups: "Vaccine hesitant", comprising those who indicated "Not at all likely" or "Unlikely", and "Pro-vaccine", including respondents who indicated "Likely" or "Very likely". Vaccination behavior was measured at *T2* by asking: "Are you fully vaccinated against COVID-19?". Respondents were categorized as "Vaccinated" comprising those who answered "Yes" and "Unvaccinated" comprising those who answered "No". At T2 (July-August 2021), a person was considered fully vaccinated if they had received two doses of the COVID-19 vaccine in the primary series.

Based on the above, an intention-behavior relationship variable was constructed with the following categories: "Vaccine hesitant (2020): Vaccinated (2021)", "Vaccine hesitant (2020): Unvaccinated (2021)", "Pro-vaccine (2020): Vaccinated (2021)", and "Pro-vaccine (2020): Unvaccinated (2021)". For this study, our primary outcome variables were the intention-behavior gap variables: "Vaccine hesitant (2020): Vaccinated (2021)" and "Pro-vaccine (2020): Unvaccinated (2021)" (Fig. 1).

Predictor variables

The following predictors were examined: perceptions of risk, vaccine acceptance, COVID-19 information exposure, political party identification, confidence in scientists, healthcare access (health insurance), and demographic and social factors such as age, gender, income, education, and race and ethnicity (Fig. 2).

Perceptions of risks related to COVID-19 were measured at T1 as perceptions of *susceptibility* and *severity*. Both perceptions were measured using a three-item measure. Using sum scores, we computed likely vs. unlikely susceptibility and serious vs. not very serious severity variables.

Vaccine acceptance was measured at T2 using a nine-item measure to determine acceptance of vaccines in general, such as: "vaccines are safe/effective" and "new vaccines carry more risk than older vaccines". The respondents indicated their agreement on a five-point scale, ranging from "Strongly disagree" to "Strongly

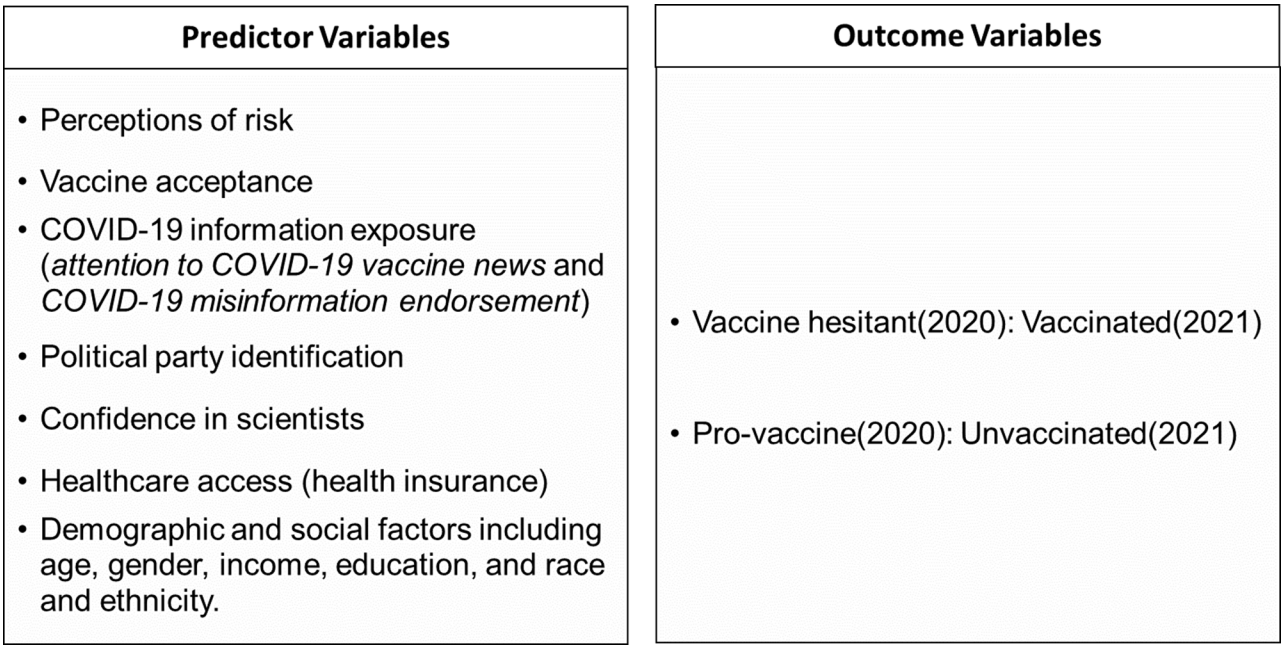

Fig. 2 List of predictor and outcome variables

agree". A vaccine acceptance score was computed as low vs. high score using the median split method [28].

COVID-19 information exposure was measured at T1 as *attention to COVID-19 vaccine news* and *COVID-19 misinformation endorsement*. *Attention to COVID-19 vaccine news* was determined by measuring the degree of attention the respondent's paid to COVID-19 vaccine news, on a four-point scale, ranging from "No attention at all" to "A great deal of attention". The variable was dichotomized into low and high attention using the median split method. *COVID-19 misinformation endorsement* was measured based on the respondent's endorsement of a list of 15 COVID-19 myths, rumors, and facts, such as: "only people with underlying health conditions are at risk for COVID-19", "spraying and introducing bleach into your body can protect you against COVID-19" and "wearing face masks can help prevent COVID-19". The score was categorized as low and high score using the median split method.

Political party identification was measured by identifying the political affiliation of the respondents as Republican, Democrat or Independent.

Confidence in Scientists was measured by enquiring the respondents' level of confidence in scientists ("a great deal of confidence", "only some confidence" or "hardly any confidence at all").

Health insurance is an important determinant of access to healthcare as not having health insurance limits healthcare access [29, 30]. In our study, having health insurance was used as a proxy for having *access to healthcare*.

Demographic and social factors, including age, gender, income, education, and race/ethnicity, were measured using standard questions.

Statistical analysis

Frequency distribution of predictor variables was obtained across the two outcome variables to describe the study sample. Multivariable logistic regression was conducted to determine the associations between the predictor and outcome variables. Each predictor was tested in a separate model while controlling for the demographic and social factors. Additionally, multivariable logistic regression of a combined model including all predictor variables was conducted to estimate their partial associations while accounting for potential confounding among predictors.

Equation 1: individual factors as predictor variables

$$\begin{aligned} &Logit\,(Outcome) = \\ &\beta 0 + \beta 1 \times (PredictorVariable) \\ &+\beta 2 \times Age + \beta 3 \times Gender \\ &+\beta 4 \times Income + \beta 5 \times Education \\ &+\beta 6 \times Race/Ethnicity + \varepsilon \end{aligned}$$

Logit (Outcome) = the log-odds of the outcome variables, which are categorized as "Vaccine hesitant (2020): Vaccinated (2021)" and "Pro-vaccine (2020): Unvaccinated (2021)".

β_0 = the intercept term.

β_1 = the coefficient corresponding to the predictor variables, which represent perceptions of risk (susceptibility and severity), vaccine acceptance, COVID-19 information exposure (attention to COVID-19 vaccine news and COVID-19 misinformation score), political party identification, confidence in scientists and healthcare access (health insurance).

β_2 to β_6 = the coefficients corresponding to the demographic and social factors (age, gender, income, education, and race/ethnicity).

ϵ = the error term.

Equation 2: demographic and social factors as predictor variables

$$\begin{aligned} &Logit\,(Outcome) \\ &= \beta_0 + \beta_1 \times Age + \beta_2 \times Gender \\ &+\beta_3 \times Income + \beta_4 \times Education \\ &+\beta_5 \times Race/Ethnicity + \varepsilon \end{aligned}$$

Logit (Outcome) = the log-odds of the outcome variables, which are categorized as "Vaccine hesitant (2020): Vaccinated (2021)" and "Pro-vaccine (2020): Unvaccinated (2021)".

β_0 = the intercept term.

β_1 to β_5 = the coefficients corresponding to the demographic and social factors (age, gender, income, education, and race/ethnicity).

ϵ = the error term.

Equation 3: all predictor variables combined

$$\begin{aligned} &Logit\,(Outcome) \\ &= \beta 0 + \beta 1 \times Susceptibility + \beta 2 \times Severity \\ &+\beta 3 \times Vaccine\ Acceptance \\ &+\beta 4 \times attention\ to\ COVID-19\ vaccine\ news \\ &+\beta 5 \times COVID-19\ misinformation\ endorsement \\ &+\beta 6 \times political\ party\ identification \\ &+\beta 7 \times confidence\ in\ scientists \\ &+\beta 8 \times health\ insurance \\ &+\beta 9 \times Age + \beta 10 \times Gender \\ &+\beta 11 \times Income + \beta 12 \times Education \\ &+\beta 13 \times Race/Ethnicity + \varepsilon \end{aligned}$$

Logit (Outcome) = the log-odds of the outcome variables, which are categorized as "Vaccine hesitant (2020): Vaccinated (2021)" and "Pro-vaccine (2020): Unvaccinated (2021)".

β_0 = the intercept term.

β_1 *to* β_8 = the coefficients corresponding to the predictor variables, which represent perceptions of risk (susceptibility and severity), vaccine acceptance, COVID-19 information exposure (attention to COVID-19 vaccine news and COVID-19 misinformation endorsement), political party identification, confidence in scientists and healthcare access (health insurance).

β_9 to β_{13} = the coefficients corresponding to the demographic and social factors (age, gender, income, education, and race/ethnicity).

ϵ = the error term.

The data were analyzed and weighted using R version 4.4.3 (2025-02-28) in 2025. R survey package was used for the survey-weighted logistic regression and other analyses.

Results

In our study, an intention-behavior gap to vaccinate (or not vaccinate) was evident. The gap was wider among the vaccine hesitant population compared to the pro-vaccine population. By the summer of 2021 (T2), 52% of individuals who were hesitant about the vaccine in 2020 (T1) had been vaccinated, while only 14% of those who were pro-vaccine at T1 remained unvaccinated (Table 1).

To explore the factors associated with the two types of intention-behavior gaps: vaccinated among the vaccine hesitant population and unvaccinated among the pro-vaccine population, we examined their association with several predictors. These predictors included perceptions of risk, vaccine acceptance, exposure to COVID-19 information, political party identification, confidence in scientists, healthcare access and demographic and social factors. The associations were adjusted for demographic and social factors. Moreover, to better understand the independent effect of each predictor on the intention-behavior gap, we also tested a model that adjusted for all other predictors simultaneously, in addition to demographic and social factors.

Outcome 1: vaccine hesitant (2020): vaccinated (2021)

Perceptions of risk

Vaccine hesitant individuals who perceived serious consequences to COVID-19 had higher odds of being vaccinated compared to those who did not perceive serious consequences to COVID-19 [OR = 2.56, 95% CI = 1.19–5.53] (Fig. 3).

Vaccine acceptance

Vaccine hesitant individuals who had high vaccine acceptance (for vaccines in general) had higher odds of being vaccinated compared to those who had low vaccine acceptance [OR = 29.05, 95% CI = 7.5–112.54] (Fig. 3).

High general vaccine acceptance remained significantly associated with greater odds of vaccination, even after adjusting for other predictors [OR = 73.37, 95% CI = 6.88–782.41] (Figure S1).

Table 1 Demographic characteristics of participants who, in 2020, *were vaccine hesitant or pro-vaccine* and, in 2021, *were vaccinated or unvaccinated*. [CI = Confidence Intervals]

Total, *N* = 607 (%)	**Vaccine hesitant (In 2020) Total, *N* = 204 (%) [95% CI]**			**Pro-vaccine (In 2020) Total, *N* = 381 (%) [95% CI]**		
Intention-behavior relationship	**Unvaccinated (2021)**	**Vaccinated (2021)**	**p-value**	**Vaccinated (2021)**	**Unvaccinated (2021)**	**p-value**
	48.4	51.6		86	14	
Individual Factors						
Risk Perception						
Susceptibility (%)			0.346			0.051
Unlikely (49%)	67.5 [53.5–81.4]	58.5 [46.6–70.4]		39.4 [32.4–46.3]	60.9 [40.7–81.0]	
Likely (51%)	32.5 [18.6–46.4]	41.5 [29.5–53.4]		60.6 [53.7–67.6]	39.1 [18.9–59.2]	
Severity (%)			0.008			0.022
Not very serious (68%)	88.6 [82.8–94.3]	74 [64.5–83.5]		59.8 [52.6–66.9]	78 [66–90]	
Serious (32%)	11.4 [5.7–17.2]	26 [16.5–35.5]		40.2 [33.1–47.4]	22 [10–34]	
Vaccine Acceptance (%)			< 0.001			< 0.001
Low (50.3%)	97 [94–100]	54.4 [42-66.8]		31 [24-37.9]	80.6 [62.2–99.1]	
High (49.7%)	3 [0–6]	45.6 [33.2–58]		69 [62.1–76]	19.4 [0.9–37.8]	
Information						
Attention to COVID-19 Vaccine News (%)			0.004			0.026
Low (45.3%)	80.2 [70.6–89.8]	57.1 [45.3–69]		31.2 [24.3–38.1]	54 [34.3–73.7]	
High (54.7%)	19.8 [10.2–29.4]	42.9 [31-54.7]		68.8 [61.9–75.7]	46 [26.3–65.7]	
COVID-19 Misinformation score (%)			< 0.001			0.135
Low (52.4%)	82.3 [73.4–91.3]	45.8 [33.7–58]		62.5 [55.4–69.6]	46.5 [26.3–66.7]	
High (47.6%)	17.7 [8.7–26.6]	54.2 [42-66.3]		37.5 [30.4–44.6]	53.5 [33.3–73.7]	
Ideology						
Political Party Identification (%)			0.223			0.347
Independent (31.6%)	35.7 [20.7–50.7]	27.9 [16.9–38.8]		31 [24.1–37.8]	28.1 [8.2–48]	
Republican (28.3%)	41 [27-54.9]	33.6 [21.3–46]		22.7 [16.7–28.6]	37 [15.9–58.1]	
Democrat (40.1%)	23.3 [13.2–33.4]	38.5 [27–50]		46.4 [39-53.7]	34.8 [14.4–55.3]	
Confidence In Scientists (%)			0.008			< 0.001
Hardly any (5.4%)	13.9 [5.3–22.5]	4.7 [0.4–9.1]		2 [0.3–3.8]	9.1 [0.9–17.3]	
Only some (36.9%)	63.8 [50.4–77.2]	47 [34.9–59.1]		23.9 [18.3–29.5]	54.8 [34.6–75]	
A great deal (57.8%)	22.3 [9.7–35]	48.2 [36-60.5]		74.1 [68.3–79.9]	36.1 [16.1–56]	
Healthcare Access						
Health Insurance (%)			0.706			< 0.001
No (10.9%)	12.3 [5.3–19.3]	14.6 [4.4–24.8]		5.3 [2.8–7.8]	33.1 [13.7–52.6]	
Yes (89.1%)	87.7 [80.7–94.7]	85.4 [75.2–95.6]		94.7 [92.2–97.2]	66.9 [47.4–86.3]	
Social Factors						
Age (%)			0.114			0.027
18–29 years (19.6%)	22.3 [9.4–35.1]	9 [1.9–16.1]		17.4 [10.4–24.4]	41.8 [20.3–63.3]	
30–44 years (25.5%)	31 [19.2–42.8]	36.1 [24-48.3]		21.7 [15.8–27.6]	14.3 [5-23.7]	
45–59 years (25.1%)	26.8 [15.3–38.3]	21.8 [12.7–30.8]		27.7 [21.3–34.1]	20.9 [8.2–33.6]	
60 + years (29.8%)	20 [9.7–30.3]	33.2 [22.2–44.1]		33.2 [27.2–39.2]	22.9 [7.6–38.2]	
Gender (%)			0.015			0.335
Male (48.8%)	59.5 [46.6–72.4]	37.7 [26.4–49]		50.1 [42.9–57.3]	39.5 [19.6–59.4]	
Female (51.2%)	40.5 [27.6–53.4]	62.3 [51-73.6]		49.9 [42.7–57.1]	60.5 [40.6–80.4]	
Income (%)			0.878			0.004
<$10,000 (3.9%)	5.4 [1.8-9]	3.6 [1-6.1]		3.1 [1.1-5]	6.5 [1.1–11.9]	
$10,000 to <$25,000 (9.9%)	15.7 [5.9–25.5]	13.8 [5.7–22]		7.3 [3.3–11.3]	11.2 [0.1–22.4]	
$25,000 to <$50,000 (17.8%)	14.9 [6.2–23.5]	18.3 [9.6–27]		17.3 [11.6–23]	17.9 [6.3–29.5]	
$50,000 to <$75,000 (17.6%)	16.2 [7-25.5]	23.3 [13.3–33.3]		18.6 [13.1–24]	8.9 [1.4–16.4]	
$75,000 to <$100,000 (13.6%)	14 [4.9–23.1]	15.5 [5.7–25.3]		10.2 [6.3–14.1]	36.1 [15.4–56.8]	
$100,000 to <$150,000 (17.2%)	16.3 [6.9–25.7]	13.3 [5.5–21.2]		18 [12.7–23.3]	15.1 [2.1–28.1]	
>$150,000 (19.9%)	17.5 [4.8–30.2]	12.1 [3.4–20.9]		25.5 [19.1–32]	4.3 [2.6–11.2]	
Education Level (%)			0.019			0.001

Table 1 (continued)

Total, *N* = 607 (%)	Vaccine hesitant (In 2020) Total, *N* = 204 (%) [95% CI]			Pro-vaccine (In 2020) Total, *N* = 381 (%) [95% CI]		
Intention-behavior relationship	**Unvaccinated (2021)**	**Vaccinated (2021)**	**p-value**	**Vaccinated (2021)**	**Unvaccinated (2021)**	**p-value**
Less than high school (10.6%)	8.7 [2.9–14.4]	14.6 [7.1–22.1]		9.2 [5-13.5]	14.1 [2.3–26]	
High school (28.3%)	35 [22.9–47.1]	32.3 [21.3–43.3]		20.2 [15-25.5]	52.3 [32.4–72.1]	
Some college (27.8%)	46.7 [33-60.3]	26.9 [16.8–36.9]		25 [18.7–31.3]	21.1 [5.6–36.6]	
Bachelor's degree or higher (33.3%)	9.7 [2.4–16.9]	26.2 [14.2–38.2]		45.6 [38.4–52.8]	12.5 [0.4–24.6]	
Race/Ethnicity (%)			0.533			0.566
White, Non-Hispanic (62.5%)	55.5 [42.5–68.5]	45.2 [33.2–57.3]		69 [62.8–75.1]	57.5 [38.7–76.2]	
Black, Non-Hispanic (12.0%)	20.7 [12.1–29.3]	20.2 [12.5–27.9]		8.1 [5.9–10.3]	9.3 [2.1–16.5]	
Hispanic (16.7%)	14.5 [6.7–22.4]	24.6 [15.2–33.9]		14.6 [10.8–18.4]	21.2 [8.8–33.7]	
Other, Non-Hispanic (8.7%]	9.2 [0.1–18.3]	10 [0.5–20.5]		8.4 [3.4–13.3]	12 [1.7–22.3]	
Employment Status (%)			0.191			0.717
Working (61.2%)	67.9 [55.2–80.6]	69.2 [59-79.4]		56 [48.7–63.2]	67.7 [49.7–85.7]	
Laid-off/Furloughed (5.4%)	7.5 [2-12.9]	2.5 [0.2–4.8]		5.7 [1.8–9.6]	5.4 [0.7–10.1]	
Retired (23.8%)	12.9 [3.7–22.1]	22.3 [13.2–31.4]		28.3 [22.4–34.2]	18.8 [3.2–34.3]	
Homemaker (7.3%)	10.9 [1.7–20]	4.6 [1.2-8]		7.7 [3.5–11.9]	5.5 [0.4–10.7]	
Full-time student (2.3%)	0.8 [0.1–1.5]	1.4 [0.3–2.5]		2.3 [1-5.6]	2.6 [0.3–4.9]	

Exposure to COVID-19 information

Vaccine hesitant individuals who paid high attention to COVID-19 vaccine news had higher odds of being vaccinated compared to individuals who paid low attention [OR = 2.49, 95% CI = 1.03–6.03]. Furthermore, vaccine hesitant individuals who scored high on COVID-19 misinformation had lower odds of being vaccinated compared to individuals who scored low on COVID-19 misinformation [OR = 0.18, 95% CI = 0.06–0.45] (Fig. 3).

Confidence in scientists

Vaccine hesitant individuals who had a great deal of confidence in scientists had higher odds of being vaccinated compared to individuals who had hardly any confidence in scientists [OR = 11.72, 95% CI = 1.57–87.4] (Fig. 3).

Healthcare access

After adjusting for other predictors, vaccine hesitant individuals with health insurance had higher odds of being vaccinated [OR = 5.57, 95% CI = 1.37–22.62] compared to individuals with no health insurance (Figure S1).

Demographic and social factors

Vaccine hesitant individuals who were 60 years or older had higher odds of being vaccinated compared to 18-29-year-old individuals [OR = 5.4, 95% CI = 1.54–18.96]. Moreover, compared to males, females had higher odds of being vaccinated [OR = 2.25, 95% CI = 1.04–4.84] (Fig. 4).

Outcome 2: Pro-vaccine (2020): unvaccinated (2021)

Perceptions of risk

Pro-vaccine individuals who perceived higher COVID-19 susceptibility [OR = 0.28, 95% CI = 0.12–0.65] and perceived serious consequences to COVID-19 [OR = 0.3, 95% CI = 0.12–0.73], had lower odds of being unvaccinated compared to individuals who had low perceptions of risk. (Fig. 5)

High risk perception remained significantly associated with lower odds of being unvaccinated, even after adjusting for other predictors [susceptibility: OR = 0.32, 95% CI = 0.14–0.77; severity: OR = 0.37, 95% CI = 0.14–0.96] (Figure S2).

Vaccine acceptance

Pro-vaccine individuals with high vaccine acceptance had lower odds of being unvaccinated compared to individuals with low vaccine acceptance [OR = 0.15, 95% CI = 0.05–0.41]. (Fig. 5)

High vaccine acceptance remained significantly associated with lower odds of being unvaccinated, even after adjusting for other predictors [OR = 0.19, 95% CI = 0.06–0.58] (Figure S2).

Exposure to COVID-19 information

Pro-vaccine individuals who paid high attention to COVID-19 vaccine news had lower odds of being unvaccinated compared to individuals who paid low attention [OR = 0.38, 95% CI = 0.16–0.92]. (Fig. 5)

Party identification

Pro-vaccine individuals who identified as Republicans had higher odds of being unvaccinated [OR = 3.74, 95% CI = 1.26–11.06] compared to individuals who identified as Independents (Fig. 5).

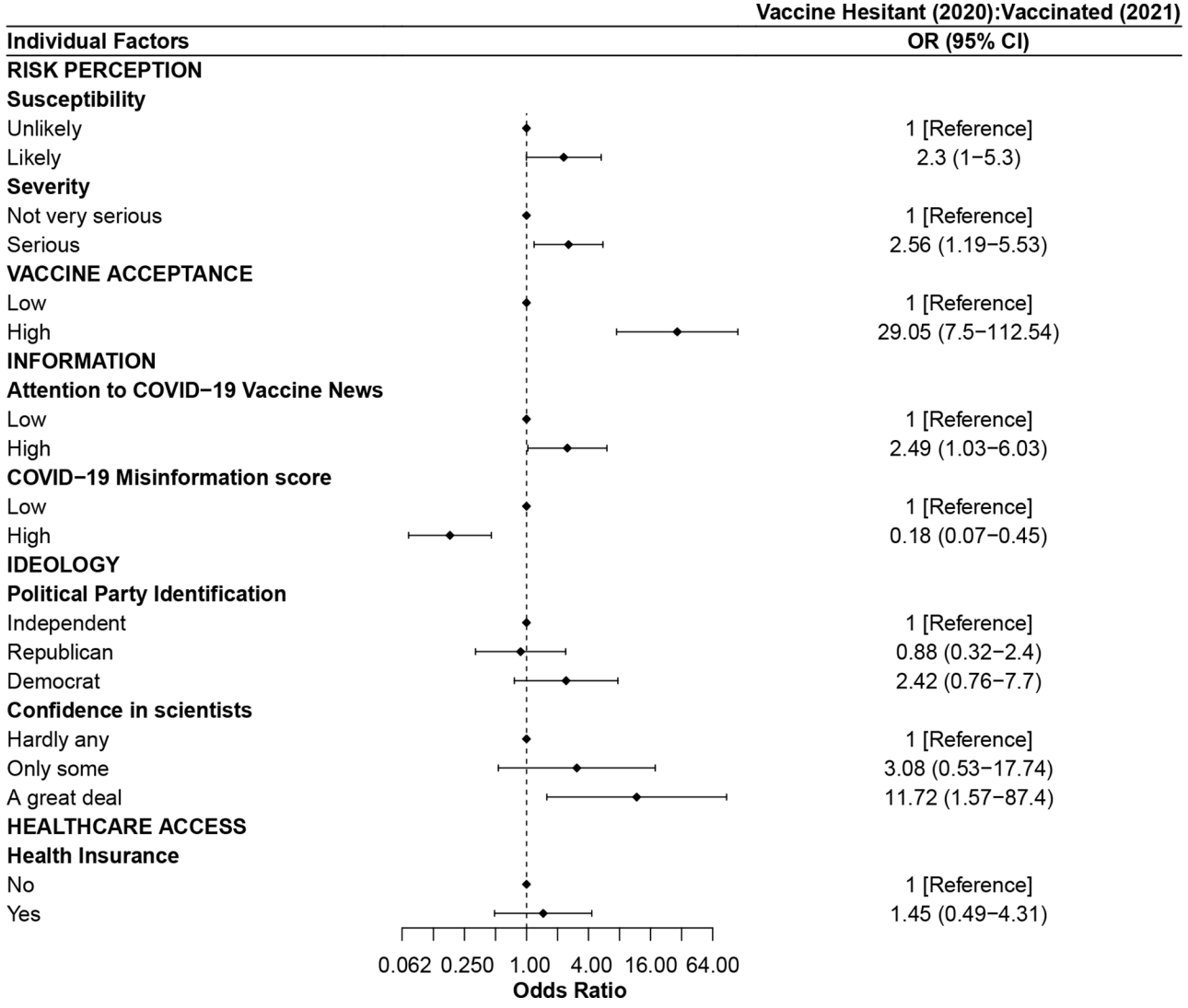

Fig. 3 Odds ratios and 95% Confidence Interval plots for association between predictors of intention-behavior gap and being *vaccinated* (2021) among vaccine hesitant (2020) individuals, after adjusting for gender, age, education, income, and race/ethnicity [OR = Odds Ratio, CI = Confidence Intervals]

Confidence in scientists

Pro-vaccine individuals who had a great deal of confidence in scientists had lower odds of being unvaccinated compared to individuals who had hardly any confidence in scientists [OR = 0.08, 95% CI = 0.02–0.41] (Fig. 5).

Healthcare access

Pro-vaccine individuals with health insurance had lower odds of being unvaccinated [OR = 0.13, 95% CI = 0.05–0.35] compared to individuals with no health insurance. (Fig. 5)

Having health insurance remained significantly associated with lower odds of being unvaccinated, even after adjusting for other predictors [OR = 0.08, 95% CI = 0.02–0.33] (Figure S2).

Demographic and social factors

Pro-vaccine individuals with a bachelor's degree or higher had lower odds of being unvaccinated [OR = 0.16, 95% CI = 0.04–0.68] compared to individuals with less than high school level education (Fig. 6).

Discussion

In the effort to reduce COVID-19 cases, hospitalizations, and deaths, the United States was among the first countries to begin administering vaccines to individuals 16 years and older [31]. The vaccines were made available free of cost to everyone in the country, regardless of their immigration and health insurance status, and were accessible at all major pharmacies, hospitals, doctors offices and community health centers [32]. Furthermore, many businesses such as cinema halls, restaurants, and sports games required proof of vaccination to enter, nudging

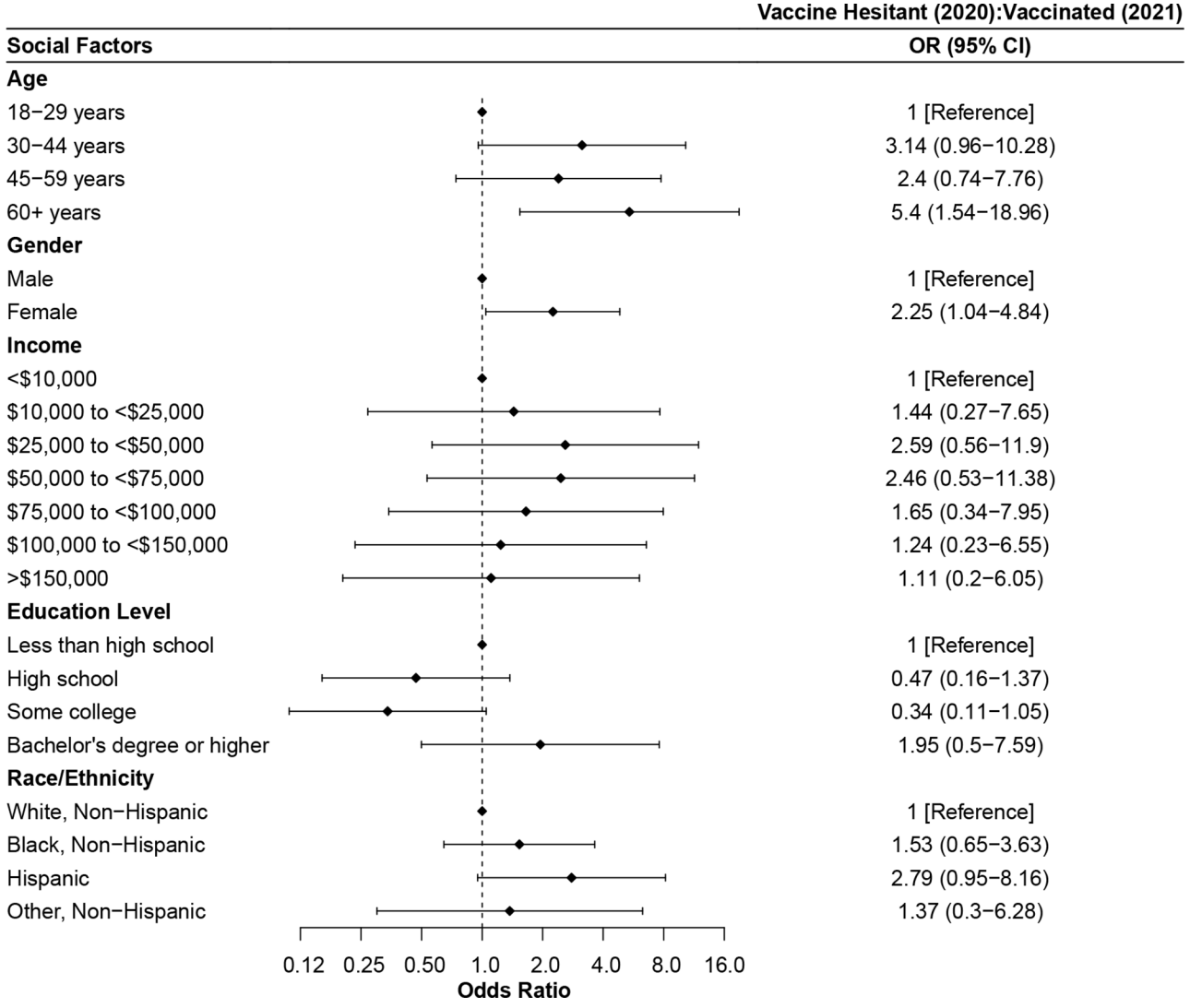

Fig. 4 Odds ratios and 95% Confidence Interval plots for association between social factors and being *vaccinated* (2021) among vaccine hesitant (2020) individuals, after adjusting for gender, age, education, income, and race/ethnicity [OR = Odds Ratio, CI = Confidence Intervals]

people to get vaccinated if they wanted to resume pre-pandemic activities [33].

Despite these numerous measures, by the end of August 2021—when the study was conducted—only 52% of Americans were fully vaccinated [26]. Immunization programs can only be successful in reducing the prevalence and incidence of vaccine preventable diseases if vaccine uptake is high [27]. Our study found that by August 2021, 86% of respondents who we categorized as pro-vaccine in June 2020 and 52% of those who we categorized as vaccine hesitant during the same period were fully vaccinated against COVID-19. This indicates not only that many efforts made in the country were able to encourage most of the pro-vaccine individuals to get vaccinated, but they also were able to convince over half of the previously hesitant individuals to get vaccinated. These findings provide a rationale to explore the factors that distinguish the vaccinated from the unvaccinated among the vaccine hesitant and the pro-vaccine populations. In our study, we examined the association between the intention-behavior gap and key factors associated with health behaviors, particularly vaccination, drawing from a nationally representative longitudinal survey of American adults.

Individual-level factors like risk perceptions and vaccine acceptance can influence health-related behaviors such as disease prevention [6, 34–37]. Our findings suggest that these factors are also associated with vaccination-related intention-behavior gap and can be targeted to promote vaccine uptake among individuals irrespective of previous intentions. Campaigns promoting vaccination could thus highlight personal risks to the disease, including its unpredictability across different population groups. Additionally, cultivating general vaccine

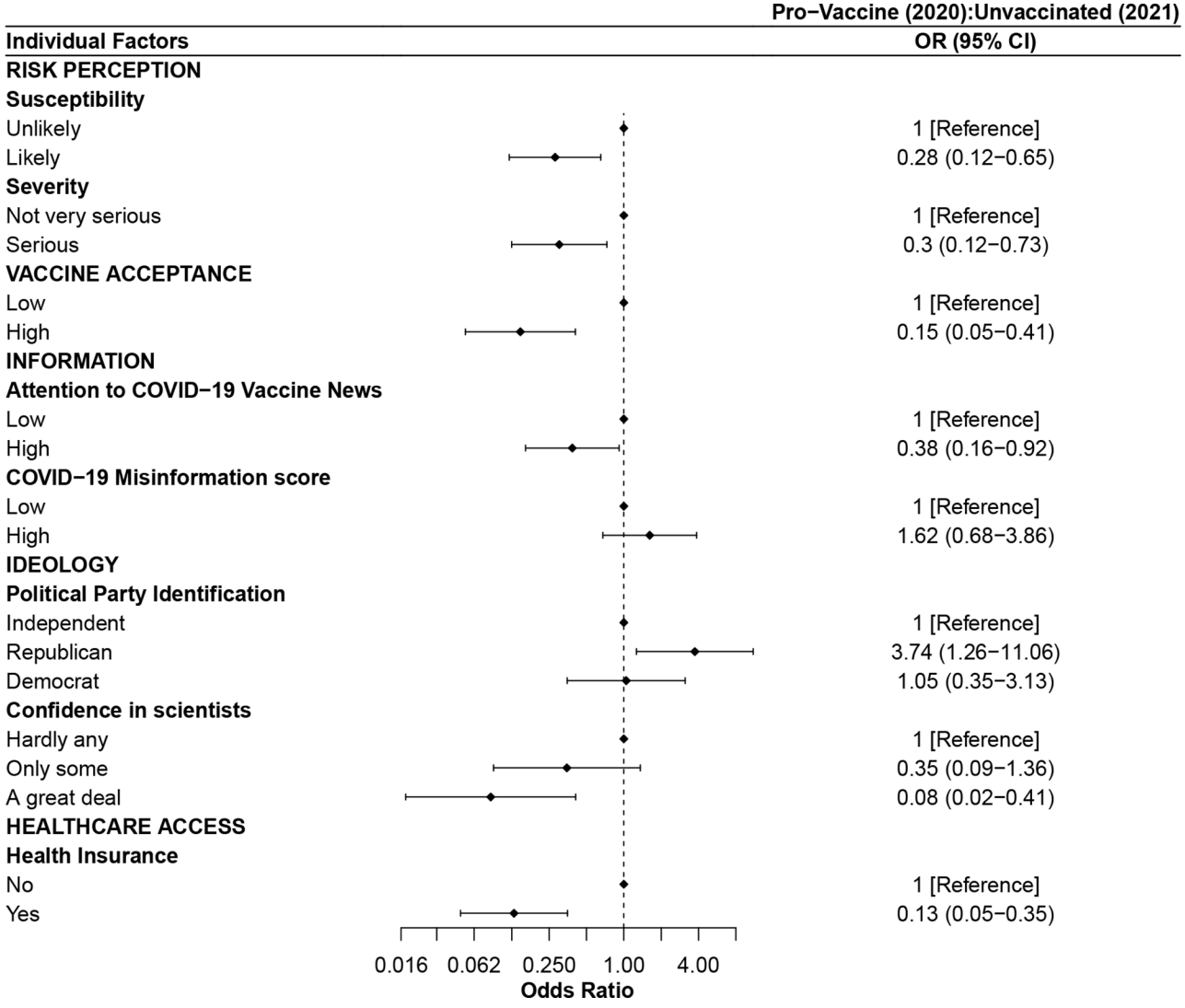

Fig. 5 Odds ratios and 95% Confidence Interval plots for association between predictors of intention-behavior gap and being *unvaccinated* (2021) among pro-vaccine (2020) individuals, after adjusting for gender, age, education, income, and race/ethnicity [OR = Odds Ratio, CI = Confidence Intervals]

acceptance may further enhance uptake of novel and updated vaccines.

People who are less informed or more misinformed are less likely to follow official health advice [38, 39]. Understandably, mass media, news media, interpersonal sources and social media are critical tools in health promotion and are widely used to create awareness about COVID-19 preventive measures, including vaccines [39–43]. Paying attention to COVID-19 vaccine news is one indicator of exposure to COVID-19 vaccine information. However, COVID-19-related misinformation has also been ubiquitous during the COVID-19 pandemic. Previous studies indicate that endorsing misinformation can lower people's confidence related to COVID-19 preventive behaviors and eventually discourage adoption of these behaviors [12, 39, 44, 45]. Whereas, being informed and staying up to date about the vaccine development and approval processes can instill confidence and encourage vaccine uptake [46]. Our findings suggest that these factors can influence the intention-behavior gap and can be targeted to increase vaccination rates among both vaccine hesitant and pro-vaccine individuals. Communication strategies to increase vaccine uptake among unvaccinated individuals should, therefore, continue to communicate correct information and debunk misinformation about COVID-19.

Personal ideologies and beliefs play a crucial role in how individuals interpret information that aligns with or contradicts their pre-existing beliefs and worldviews [47, 48]. For example, when the ideologies of the information sources overlap with an individual's beliefs, the individual is more likely to be receptive [48]. COVID-19 and by extension COVID-19 vaccines have become highly politicized issues. Partisanship modulates people's

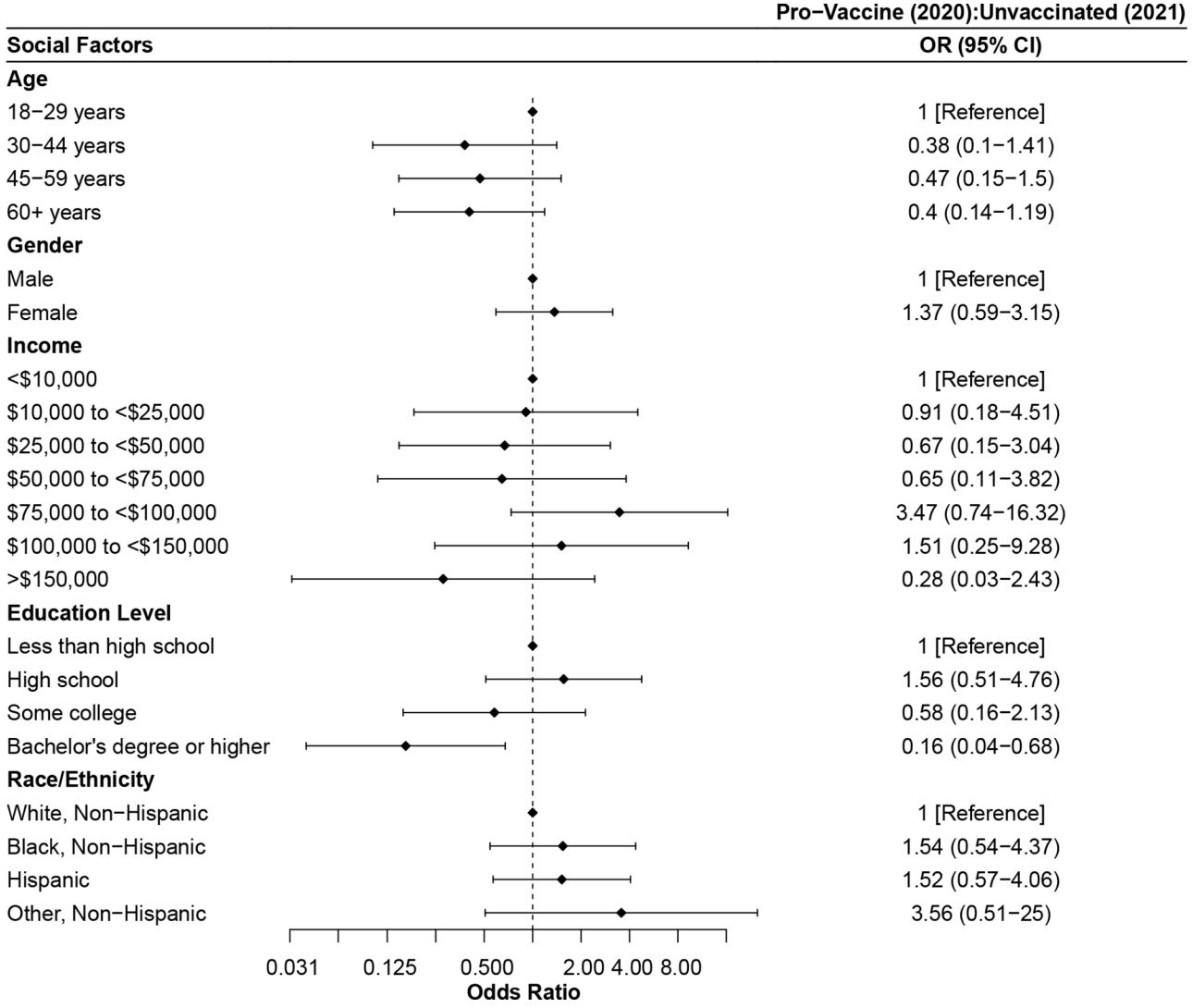

Fig. 6 Odds ratios and 95% Confidence Interval plots for association between social factors and being *unvaccinated* (2021) among pro-vaccine (2020) individuals, after adjusting for gender, age, education, income, and race/ethnicity [OR = Odds Ratio, CI = Confidence Intervals]

response to the pandemic making it a strong predictor of COVID-19 vaccination status, and according to a Kaiser Family Foundation poll, and a National Academies of Sciences Engineering and Medicine's report on *Understanding and Addressing Misinformation about Science*, Republicans make up a disproportionate share of the unvaccinated adult population [3, 9, 12, 49–51]. In our study, among previously pro-vaccine individuals, individuals who identified with the Republican party were more likely to remain unvaccinated. Conservative media has consistently endorsed views that are distrustful of both science as well as scientific expertise and downplayed the risk of COVID-19, which have been found to be associated with lower adoption of COVID-19 preventive measures [39].

Depoliticizing health communication in science is a valuable strategy to prevent public health measures from becoming politicized. While we acknowledge that public health recommendations often involve value judgments and that it is difficult to eliminate ideological differences or prevent politicization by external actors, certain communication strategies can still help mitigate these effects. For instance, encouraging individuals to receive evidence-based information from experts or trusted figures who are not influenced by political agendas, such as primary healthcare providers or highly respected non-political leaders like religious figures [52]. Policy recommendations incorporating behavioral nudging frameworks could also be beneficial [53, 54]. For example, presenting clear and preemptive facts before misinformation spreads can help "pre-bunk" false claims, reducing the need for debunking, which may inadvertently reinforce misinformation [55, 56]. Additionally, using non-partisan language that transcends ideological

barriers and promotes health and well-being without restricting freedom of choice may enhance message effectiveness [57]. Framing health behaviors as practical and community-driven actions rooted in widely accepted values can further reduce political polarization.

Confidence in scientists was also found to be associated with vaccination-related intention-behavior gap, and individuals with a great deal of confidence in scientists, irrespective of their initial intentions were more likely to be vaccinated. There is a strong association between partisanship and confidence in science. However, the gap between partisan identity and confidence in science has been widening over the last few years, with a decreasing percentage of Republicans indicating a great deal of confidence in science [12]. These findings highlight the importance of sustained strategic communication efforts to increase confidence in science and scientists, while countering any efforts that express anti-vaccine sentiments, to increase COVID-19 vaccine uptake. However, other researchers warn that partisan identity alone may not be able to explain trust in science, and in fact trust is patterned across groups, and it is important to explore other factors that may shape individual beliefs associated with science information, specifically those related to vaccination [12, 58].

Health insurance coverage is an important determinant of healthcare access, and lack of health insurance is usually associated with low adult vaccines uptake [30, 34, 36]. In the cases of prior vaccine research involving influenza, HPV and Zika vaccines, the perceived cost of getting vaccinated was negatively associated with vaccine uptake [59–61]. For COVID-19 vaccines, even though they were free, some vaccine scheduling portals requested health insurance information leading to confusion about costs [62]. Insurance-related differences in vaccine uptake among both vaccine hesitant and pro-vaccine individuals, thus, emphasize that perceived costs could be a barrier to vaccination and providing the vaccines for free is conducive for vaccine uptake.

Demographic factors are significant determinants of vaccine uptake [63]. Despite previous hesitation, individuals over 65 and women were more likely to be vaccinated. On the other hand, college educated individuals were more likely to follow through with their pro-vaccination intention and get vaccinated compared to their less educated counterparts. In 2020, 81% of all the deaths from COVID-19 in the U.S. had been of people over 65 years of age [64]. The increased perception of risk from COVID-19 could have contributed to the older age group's decision to get vaccinated. Moreover, women's increased likelihood of seeking preventive health could be a factor leading to a higher vaccine uptake [65]. Education is also a dependable determinant of health, and is strongly associated with life expectancy, morbidity, and health behaviors [66, 67]. Our findings warrant a better understanding of the sociodemographic barriers that lead to low vaccine uptake and highlight a need for targeted public health communication strategies to convince younger individuals, men and those less educated to get vaccinated.

Limitations

One limitation of our longitudinal study is that vaccination acceptance score was measured at T2 whereas the other predictors were measured at T1. However, for our study we assume that the acceptance towards vaccination in general should not differ between T1 and T2. Second, we were unable to include other factors that could potentially be relevant for our study, which could have influenced people's decisions to vaccinate (or not) between June 2020 and August 2021. Particularly, getting sick with COVID-19 multiple times, change in employer mandates, or awareness that the vaccine reduces severity but does not significantly impact transmission. We also did not include how the vaccines attitudes could be shaped by the broader information ecosystem driven by media sources such as social media as we did not conduct specific media analysis in our study. Future research should include this to gain deeper insights into the role of information exposure from different sources on vaccine hesitancy. Third, individuals who did not complete their primary series of COVID-19 vaccines were categorized as vaccine hesitant, which could potentially include those who got at least one dose of the COVID-19 vaccine. This prevents our study from exploring the distinct motivational drivers of completely unvaccinated individuals from individuals who had received one dose. Future studies should explore this further to understand the reasons that some individuals took only one dose and did not complete their vaccination and capture the full spectrum of vaccination behaviors. Fourth, while our findings are based on a nationally representative survey of American adults, they might not be generalizable to countries that have attitudes, vaccine acceptance, sociodemographic architecture different to the United States. Finally, while our longitudinal study design allows us to examine directional influences, it does not definitively establish causality. However, by observing changes over time within the same sample group, it offers stronger causal inference than cross-sectional studies. Future experimental or quasi-experimental research (e.g., randomized interventions or natural experiments) and causal analysis are necessary to confirm causal relationships and contribute to policy recommendations.

Despite limitations, it is important to note that our study captures a critical phase of the pandemic. We used data collected at two crucial timepoints in the pandemic–July 2020, when there were no vaccines for COVID-19

and July-August 2021, when the vaccination drive was in full swing. The vaccine administration started in December 2020 and by April 2021 the entire U.S. adult population was eligible [68]. Our findings add to the empirical evidence on COVID-19 intention-behavior relationships and confirm that intentions are malleable, implying that vaccine hesitant individuals can be convinced to get vaccinated. Our findings also shed light on the intention-behavior relationship of the pro-vaccine individuals and potential barriers that could deter them from realizing their intentions. To increase vaccine uptake among the unvaccinated individuals, informational campaigns and communication strategies should target the factors associated with the intention-behavior gap.

Conclusion

At a crucial point during the pandemic, when there are tools like vaccines available to control its spread, low vaccine uptake can hinder the efforts to control the virus and protect public health. Data from our nationally representative study indicate that the declared vaccine hesitant and pro-vaccine intentions are not set in stone and there is a possibility to convince vaccine hesitant individuals to become vaccinated as well as to discourage pro-vaccine individuals from getting the vaccine. To increase vaccine uptake among the unvaccinated populations, interventions should use empirical evidence to develop strategic communications. Knowing the arguments and the barriers that are most important for the vaccine hesitant and the pro-vaccine individuals to get vaccinated- such as increasing the perception of risk, cultivating vaccine acceptance, disseminating correct information, and debunking misinformation- can help increase vaccine uptake in the country. Such strategies may also be useful to increase uptake of vaccines in potential future pandemic circumstances and other adult vaccines and help reduce disparities.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22911-0.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Author contributions

DD and KV conceived and designed the study. RP and RM contributed to the design of the study. DD analyzed and interpreted the data and wrote the first draft of the manuscript. DD, AKS, RP, RM, and KV contributed to the interpretation ofthe data and revised the manuscript for important intellectual content. All authors provided critical feedback on the manuscript and agreed to be accountable for all aspects of the work.

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Data availability

The datasets analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study obtained ethical clearance from the Institutional Review Board (IRB) of the Harvard T.H. Chan School of Public Health (Protocol number: IRB20-1171). Study participants consented to the research firm Ipsos during empanelment and were required to complete a study-specific consent form only if the study included sensitive questions. As our survey was deemed non-sensitive by the IRB of the Harvard T.H. Chan School of Public Health, the need for study-specific consent to participate was waived. This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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