



Trust in the science behind COVID-19 vaccines as a driver of vaccine acceptance in the United States, 2021–2023

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ABSTRACT

Objectives: To evaluate changes in public trust in the science behind COVID-19 vaccines in the United States (US) from 2021 to 2023, and to assess how loss of a family member or close friend to COVID-19, influences this trust and vaccine acceptance.

Methods: Using stratified random sampling for key demographic variables, including age, gender, race/ethnicity, region, and education level, the study analyzes data from a series of cross-sectional surveys conducted in 2021, 2022 and 2023. Descriptive statistics were employed to summarize the socio-demographic characteristics of the respondents and their levels of trust in science and vaccine acceptance. Weighted logistic regression models were applied to assess the relationships between trust in science, vaccine acceptance, and socio-demographic factors. These models controlled for potential confounding variables and allowed for the estimation of adjusted odds ratios (aOR) and 95% confidence intervals (CI), highlighting the key predictors of vaccine acceptance and willingness to receive future recommended boosters.

Results: The results indicate that trust in science remained relatively stable over the study period and continued to be a strong predictor of vaccine acceptance, which was higher among male respondents, those with university degrees, and those with higher than median income. Notably, the experience of personal loss was significantly related to an individual's trust in science and vaccine acceptance.

Conclusions: Trust in the science behind COVID-19 vaccines appears to have been a crucial factor in US vaccine acceptance, with respondents who expressed higher trust being significantly more likely to accept the vaccine and express willingness to take future boosters. To maintain and enhance public trust in vaccination programs, trust in health communication from public sources, particularly the CDC, must be strengthened, as trust in the CDC was also found to be significantly correlated with both vaccine acceptance and future booster uptake. Personal experiences of loss due to COVID-19 were important predictors of trust in science and vaccine acceptance, highlighting the need for public health communications to be sensitive to the emotional impact of loss and grief along with the diverse socio-economic and educational backgrounds of the US population.

Introduction

The COVID-19 pandemic was officially recognized as a public health emergency in the United States from January 31, 2020, to May 11, 2023 [1]. Throughout the course of the pandemic, the rapid development and distribution of COVID-19 vaccines sparked widespread and often rancorous discourse on the safety and effectiveness of these vaccines and public trust in science generally. Prior studies have established a complex and nuanced relationship between socio-demographic factors and vaccine acceptance that includes levels of education and income,

personal loss due to the disease, and political affiliation [2,3]. Moreover, as the pandemic evolved, the significance of general trust in science emerged at the forefront of public health discussions as a pivotal factor influencing vaccine uptake and particularly the willingness to receive future COVID-19 vaccine boosters [4].

The impact of the loss of a family member or close friend due to COVID-19 infection has been increasingly recognized as a significant factor potentially influencing vaccine acceptance and trust in science. Studies suggest that experiencing such a loss can paradoxically lead to either an increase and a decrease in trust in scientific institutions and

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vaccines [4–6]. On one hand, direct confrontation with the severity of a disease may heighten an individual’s appreciation for the need for new or more effective scientific efforts to combat it, thus enhancing trust in science and the willingness to accept vaccines [6,7]. On the other hand, grief and the perception of failure to protect loved ones can erode trust in the very scientific endeavors meant to safeguard the public’s health [6,7]. This dichotomy underscores the complex and deeply personal nature of trust in the context of a global health crisis, highlighting the need for research to inform public health strategies that are sensitive to the perceptions of individuals experiencing personal losses during a pandemic.

The relationship between public trust in new scientific discovery and vaccine uptake emerged as a critical area of investigation during the pandemic [8]. The ongoing dialogue surrounding vaccine acceptance underscores the critical role of trust in science-based solutions in navigating public health crises. Examining the fluctuations in public trust over time may enable researchers to formulate more sophisticated messages and communication strategies to rebuild public trust in science and increase vaccine coverage. This study aims to evaluate changes in the trust in the science behind COVID-19 vaccines in the United States from 2021 to 2023 and its recent socio-demographic correlates (i.e., age, gender, education, and income) and the possible impact of losing a family member or close friend to COVID-19. It also explores the association between trust in science and trust in CDC as a source of information about COVID-19 vaccines with vaccine acceptance and the willingness to receive future recommended vaccine boosters.

Methods

Study design

This study employed random stratified sampling in cross-sectional design using online panels recruited by Consensus Strategies/Emerson College Polling. The surveys were conducted in 2021 [7], 2022 [9] and 2023 [10] as part of a larger study to identify determinants of COVID-19 vaccine acceptance in 23 countries. Items from these surveys that were analyzed in the present study are presented in Table 1.

Study sample and recruitment

Adults residing in the U.S. were recruited to online panels via email address, telephone and direct mail solicitation, and real, unique registration was verified using IP address or mobile phone number. Stratified random sampling was used to ensure that key demographic groups were adequately represented in the sample. Five strata were established for age, gender, race/ethnicity, statistical regions, and level of education for random sampling within the online panel [7,9,10]. A minimum quota of 50 participants per stratum and target probabilities were established for each stratum, working from n = 1000 total responses, to equal the strata characteristics according to the latest available census data, ensuring that the sample was representative of the broader U.S. population [11]. Respondents were then randomly selected from online panels to meet these quotas, and additional controls (e.g., IP address and mobile number verification) were applied to prevent duplicate entries. As a result, approximately half of respondents were female (50.9 %) and one-third (35.7 %) were university graduates. In 2023 one-third of respondents reported income above (36.1 %) and below country median (36.1 %). One-fifth of respondents reported no income (20.7 %). Nearly one-third (31.5 %) reported losing a family member or a close friend to COVID-19 disease and one in ten reported loss within the past year (Table 2).

Statistical analysis

Descriptive statistics were used to summarize the key characteristics of the sample, including age, gender, education, income, and personal

Table 1
Study variables.

Item	Response options	Year(s) of survey data
1. Age	1. 18–24 years	2021, 2022, 2023
	2. 25–54 years	
	3. 55–64 years	
2. Gender	4. 65 years or older	2021, 2022, 2023
	1. Male	
	2. Female	
	3. Prefer not to say	
3. Education	4. Other	2021, 2022, 2023
	1. Less than High School	
	2. High School degree or GED	
	3. Some College	
	4. Associate or Vocational degree	
	5. Bachelor Degree	
4. Income	6. Post-Graduate Degree (Master’s, Lawyer, Doctor)	2021, 2022, 2023
	1. My monthly income is more than [Country median calculated from World Bank Data]	
	2. My monthly income is less than [Country median calculated from World Bank Data].	
	3. I do not have an income.	
5. Race/Ethnicity	4. Refused/ Did not answer	2021, 2022, 2023
	1. Hispanic or Latino of any race	
	2. White or Caucasian	
	3. Black or African American	
	4. Asian	
6. Statistical Region	5. Other or multiple races	2021, 2022, 2023
	1. Northeast	
	2. South	
	3. Midwest	
	4. West	
7. Have you received at least one dose of a COVID-19 vaccine?	1. Yes, I received one dose	2023
	2. Yes, I received two or more doses	
	3. No	
8. Have you received at least one dose of a COVID-19 vaccine?	1. Yes, partially vaccinated	2022
	2. Yes, completely vaccinated	
	3. Yes, completely and received at least one booster dose	
9. Have you received at least one dose of a COVID-19 vaccine?	1. Yes	2021
	2. No	
10. Have you lost a family member or close friend to COVID-19 disease?	1. Yes, within the past year	2022, 2023
	2. Yes, more than a year ago	
	3. No	
11. Have you lost a family member to COVID-19 disease?	1. Yes	2021
	2. No	
12. How much do you trust the following sources of information about COVID-19 vaccines: the Centers for Disease Control and Prevention.	1 (trust completely) to	2023
	10 (do not trust at all)	

(continued on next page)

Table 1 (continued)

Item	Response options	Year(s) of survey data
13. I trust the science behind the COVID-19 vaccines.	1. Strongly disagree	2021, 2022, 2023
	2. Disagree	
	3. Neutral/Unsure	
	4. Agree	
	5. Strongly agree	

Legend: None.

Table 2

Sample socio-demographic characteristics and loss of family or close friend to COVID-19 disease.

	2021	2022	2023
<i>Age Groups</i>			
18–29	17.1	17.1	17.1
30–39	15.8	15.8	15.8
40–49	17.1	17.1	17.1
50–59	18.4	18.4	18.4
60+	31.6	31.6	31.6
<i>Gender</i>			
Man	48.9	48.7	48.8
Woman	51	50.8	50.9
<i>Race/ethnicity</i>			
Hispanic or Latino of any race	Not asked	Not asked	18.1
White or Caucasian			59.9
Black or African American			13.6
Asian			6.3
Other or multiple races			2.1
Prefer not to say/ Other	0.1	0.5	0.3
<i>Education (university degree)</i>			
No	64.3	64.3	64.3
Yes	35.7	35.7	35.7
<i>Income (country median)</i>			
Above Median	42	43.8	36.1
Below Median	46.1	46.7	36.1
No income	11.9	9.5	20.7
Refused	Not asked	Not asked	7.1
<i>Lost a family member or close friend to COVID-19 disease</i>			
Yes	11.3	14.8	31.5
Within the past year	Not asked	11.6	10.8
More than a year ago	Not asked	3.2	18.9
Within the past year & more than a year ago	Not asked	Not asked	1.8
No	88.7	85.2	68.5

Legend: Values represent percentages of N = 1000 respondents.

experience with COVID-19-related loss. These statistics provided insights into the distribution of socio-demographic variables and their relationship with vaccine acceptance and trust in science. Means, frequencies, and percentages were reported for categorical variables, and confidence intervals (CI) were calculated to provide estimates of the precision of these statistics. Descriptive statistics and independent sample t-tests were used to quantify and compare trust in the science behind the COVID-19 vaccine over the years 2021, 2022, 2023. Weighted logistic regression models were used to assess socio-demographic (i.e. age, gender, education, income) and pandemic-related correlates (loss of family member or friend to COVID-19 disease) of trust in the science behind the vaccines in 2023. Finally, weighted logistic regression models were used to estimate the 2023 association between trust in the science behind the vaccines and vaccine acceptance as well as willingness to take future recommended boosters. Trust in CDC as a source of information about COVID-19 vaccines was assessed as an independent correlate on a ten-point scale with responses

1–5 coded as low-moderate trust and responses 6–10 coded as high trust. Adjusted odds ratios and corresponding 95 % confidence intervals are reported. Alpha for all significance testing was set at $p < 0.05$. Analyses were conducted in R, version 4.3.3 (R Project for Statistical Computing).

Results

Trust in the science behind the COVID-19 vaccines 2021–2023

Trust in the science behind the COVID-19 vaccines was reported by 63.9 %, 95 %CI (59.9 %-67.9 %), of respondents in 2021, 67.2 %, 95 %CI (64.0 %-70.4 %) in 2022 and 63.8 %, 95 %CI (60.2 %-67.5 %) in 2023. These changes were not statistically significant ($p > 0.05$).

Correlates of trust in science behind the COVID-19 vaccines 2023

In 2023 trust in the science behind the COVID-19 vaccines was statistically significantly higher in males (aOR = 1.42, 95 %CI (1.02, 1.99), respondents with university degree (aOR = 2.37, 95 %CI (1.67, 3.37) and respondents reporting income higher than the median, relative to no income (aOR = 1.74, 95 %CI (1.04, 2.89)). Trust in science was not statistically significantly correlated with age or race/ethnicity. Trust in science was statistically significantly higher in respondents reporting losing a family member or a friend to COVID-19 disease within the past year (aOR = 3.91, 95 %CI (1.87, 8.18) and more than a year ago (aOR = 2.20, 95 %CI (1.43, 3.37), relative to not losing a family member or a friend during the pandemic (Table 3).

Vaccine acceptance, trust in science behind the COVID-19 vaccines and trust in CDC as a source of information about COVID-19 vaccines 2023

Fig. 1 illustrates the relationship between trust in the science behind COVID-19 vaccines and both vaccine acceptance and willingness to take

Table 3

Trust in science by sociodemographic variables 2023.

	aOR	95 % CI for aOR		p-value
<i>Age Group</i>				
18–29	0.78	0.50	1.22	0.222
30–39	0.71	0.41	1.23	0.162
40–49	0.68	0.40	1.17	0.424
50–59	0.82	0.50	1.34	0.051
<i>Sex</i>				
Male	1.42	1.02	1.99	0.039
<i>Educational Attainment</i>				
University Degree	2.37	1.67	3.37	0<.0001
<i>Race/Ethnicity</i>				
Asian	1.11	0.53	2.33	0.776
Black	1.12	0.66	1.90	0.685
Hispanic or Latino	1.78	0.95	3.32	0.071
Other or multiple races	0.57	0.20	1.61	0.291
<i>Income</i>				
Monthly income more than Country median	1.74	1.04	2.89	0.035
Monthly income is less than Country median	1.14	0.75	1.73	0.531
Refused	0.98	0.50	1.93	0.948
<i>Reported Loss</i>				
Lost a family member or close friend to COVID-19 disease within the past year	3.91	1.87	8.18	<0.001
Lost a family member or close friend to COVID-19 disease more than a year ago	2.20	1.43	3.37	<0.001

Legend: Weighted logistic regression models yielded adjusted odds ratios (aOR) and 95 % confidence intervals (CI). Dependent Variable: I trust the science behind the COVID-19 vaccines available to me (Yes, No (reference)). References: Age 60+, Female, No University Degree, White or Caucasian, No income, Did not lose a family member or close friend to COVID-19 disease. Due to small sample size (n = 18), models exclude respondents who reported loss a family member or close friend to COVID-19 disease within the past year & more than a year ago. N = 1000 respondents.

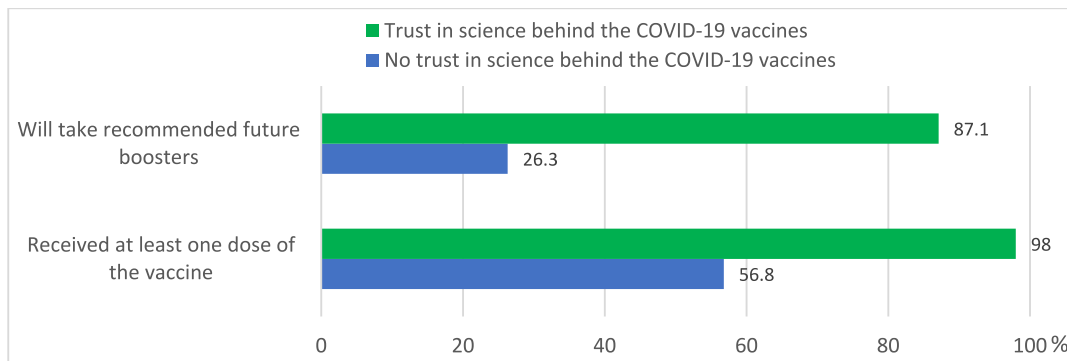


Fig. 1. Vaccine acceptance and willingness to take future recommended boosters by trust in science in 2023 Legend: Values represent percentages of N = 1000 respondents.

future recommended booster doses in 2023. In 2023 vaccine acceptance was reported by 83 %, 95 %CI (80.3 %-85.8 %), of respondents. Among those vaccinated, 72.2 %, 95 %CI (68.4 %-75.7 %), reported willingness to the future recommended COVID-19 boosters (Fig. 1). Fig. 2 illustrates vaccine acceptance based on whether respondents experienced the loss of a family member or close friend to COVID-19. Vaccine acceptance over time was consistently higher among respondents who reported loss of family/friend to COVID-19 disease, with 89.9 % acceptance in 2023. (Fig. 2). Those who did not experience personal loss exhibited significantly lower acceptance rates, especially in 2021 (63.5 %), though their rates increased over the study period, reaching 80 % in 2023.

. Trust in CDC as a source of information about COVID-19 vaccines was statistically significantly related to vaccine uptake (aOR = 3.11, 95 %CI (2.03, 4.77)), however it was not a factor once the model was adjusted for trust in the science behind the vaccines. However, trust in CDC as a source of information about COVID-19 vaccines remained statistically significantly related to willingness to take future recommended boosters even after adjustment for trust in the science (aOR = 3.77, 95 %CI (2.33, 6.09)) (Table 4).

Discussion

This study explored the changes in trust in the science behind COVID-19 vaccines in the United States from 2021 to 2023 and found that while levels of trust fluctuated only slightly over those years, they were lower than global averages reported in our previous studies (2021: 63.9 %, 2022: 67.2 %, 2023: 63.8 %), lower than averages for the 23-

country (2021: 69.8 %, 2022: 70.2 %, 2023: 71.6 %) and high-income country samples (2021: 67.6 %, 2022: 66.8 %, 2023: 68.4 %). [7,9] Americans who reported greater trust in science more readily accepted the COVID-19 vaccine throughout the study period and the first booster doses, which were tracked in 2023. [7,9] The proportion of the US population who expressed trust in science remained almost constant, ranging from 64-67 % over the three years covered in our studies [7,9,12] Conversely, almost one third of the US population do not share this trust.

Males, individuals with a higher income profile and those who have completed a university degree are statistically more likely to trust the science behind vaccines, which may suggest that science literacy needs to be fostered more vigorously among younger age and less affluent groups in our society. Science education in lower, middle, and high schools could be a powerful learning platform to explain the contributions of scientific thinking towards human well-being and promote science literacy. A better baseline of public understanding and trust in the scientific method generally could well have helped support acceptance of the unprecedented speed with which innovative mRNA technology was used for the first time to develop a safe, effective vaccine against COVID-19 [13,14].

Prior loss of family members or close friends to COVID-19 strongly correlated with trust in science and to a lesser degree with vaccine acceptance, indicating a possible effect between personal loss due to COVID-19 and increased trust behind the science that led to new vaccine discovery. Non-cognitive (e.g. emotional) factors triggered by such a loss may also help drive the decision to accept a vaccine independently

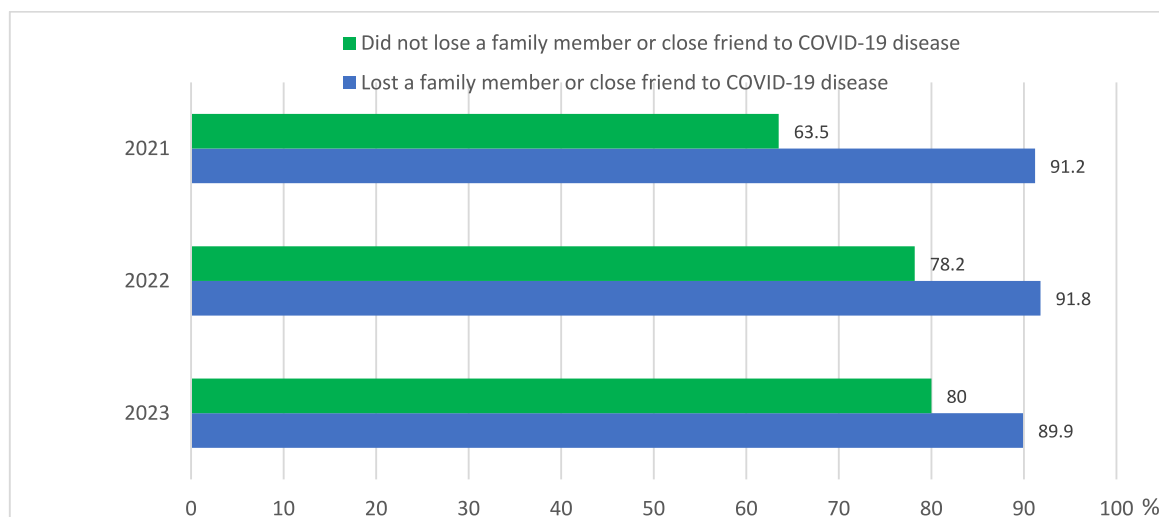


Fig. 2. Vaccine acceptance by loss of family/friend to COVID-19 disease Legend: Values represent percentages of N = 1000 respondents.

Table 4

Vaccine acceptance and willingness to take future recommended boosters by trust in CDC as a source of information about COVID-19 vaccines and trust in the science behind the COVID-19 vaccines in 2023.

	Vaccine acceptance			Willingness to take future recommended boosters				
	aOR	95 % CI for aOR	p-value	aOR	95 % CI for aOR	p-value		
<i>Model 1</i>								
<i>Trust in CDC as a source of information about COVID-19</i>								
Yes	3.11	2.03	4.77	0.001	6.65	4.45	9.92	<.001
<i>Model 2</i>								
<i>Trust in CDC as a source of information about COVID-19</i>								
Yes	1.05	0.64	1.70	0.851	3.77	2.33	6.09	<.001
<i>Trust in the science behind the COVID-19 vaccines</i>								
Yes	31.77	16.69	60.50	<.001	13.88	8.40	22.92	0.001

Legend: Weighted logistic regression models yielded adjusted odds ratios (aOR) and 95 % confidence intervals (CI). Dependent Variables: Vaccine acceptance (Yes, No (reference)); Willingness to take future recommended boosters(Yes, No (reference)). References: Low-moderate trust in CDC as a source of information about COVID-19; No trust in the science behind the COVID-19 vaccines. All models were adjusted for Age Group, Sex, Educational Attainment, Race/Ethnicity, Income, Reported loss of a family member or close friend to COVID-19 disease. Due to small sample size (n = 18), models exclude respondents who reported loss a family member or close friend to COVID-19 disease within the past year & more than a year ago. N = 1000 respondents.

from increased trust in science.

Access to the vaccine, trust in the health care system in general, prioritization of a preventive health behavior in the face of many other conflicting life priorities, and underlying cultural influences such as fatalism are also significant mediators of health-related decisions at a personal and community level [15]. How such factors rank when compared to trust in science was not in the purview of this study, but clearly they cannot be ignored.

The consistent finding of higher uptake of vaccines among respondents who reported trust in science that we observed in 2021 and 2022 led us to test for a further correlation between trust in science generally and trust in public health authorities as a potential explanation for the higher level of vaccine acceptance reported in 2023 data. Indeed, we identified a strong association between trust in science and trust in US public health authorities, specifically the CDC. Furthermore, we found that individuals with a higher level of trust in science may also be more likely to base their health-related decisions on trust in healthcare professional recommendations based on scientific evidence. The strong correlation between trust in the CDC and higher acceptance of vaccines that we observed confirms this pathway as a possible mediator for vaccine acceptance and underscores the importance of sustaining the credibility of CDC.

Interestingly, while prior studies have demonstrated that COVID-19 vaccine acceptance varied significantly between white and non-white groups, our study did not find a significant association between race/ethnicity and trust in science, although we did observe somewhat less trust in science among Latino respondents [16,17].

The COVID-19 pandemic was a powerful reminder of the complexity that public health practitioners face in assessing and understanding the population's response to public health recommendations and government directives. In previous publications, we demonstrated the reluctance of many segments of the US population to embrace recommendations to control the spread of the infection, such as shutdowns of businesses and indoor activities, mask wearing in public, and last but not least acceptance of vaccination against the newly identified virus that were deemed essential at the time [7,9,12,16].

Encroachment on personal freedoms was reported as an important mediator of such resistance, especially amongst groups with right-leaning political affiliation, which contributed to often stark regional differences in vaccine acceptance in the US. [16,18,19] Predictors of COVID-19 vaccine hesitancy identified in the US—particularly earning a low income and holding conservative political views—further accentuate the interplay between socioeconomic factors and public trust in vaccine efficacy and safety, and underscore a compelling immediate need for targeted interventions to rebuild confidence in the scientific community and vaccination efforts [16]. The novelty of the vaccine technology used in producing the first vaccines (mRNA) was also

identified as a contributor [20] and mistrust in the science behind its discovery perpetuated disinformation that was widely disseminated and not infrequently adopted [21–23].

Our results show that trust in science is a distinct cognitive/intellectual domain that plays an important role in vaccine acceptance over time, with almost a twofold higher acceptance amongst those that trust science as compared to those that do not, that rose even higher, over threefold, for acceptance of the future recommended vaccine booster. The troubling lack of vaccine compliance observed as the pandemic wore on was certainly fueled to a substantial degree by the relative ease of spreading disinformation widely among those who mistrust science. Conversely, trust in science and particularly in specific sources of scientific information, such as the CDC in the US, continued to correlate significantly with vaccine acceptance over the course of our annual studies, even the most recent one, where it was observed that pandemic fatigue seemed to have set in widely among all our respondents [24]. It is critical to maintain, or rebuild where necessary, trust in public health information sources.

Moreover, as initially hypothesized, the loss of a family member or friend to COVID-19 remained a key predictor of vaccine acceptance. The exact mechanism behind this is unclear. Those affected by such a loss may simply have been more emotionally inclined to accept the vaccine and less resistant to the science behind it, or perhaps the tragedy encouraged them to spend more time trying to learn about COVID-19 and understand the risks and benefits associated with the COVID-19 vaccines, as well as the science behind their discovery [25]. Trust in the science behind COVID-19 vaccines appears to have been a crucial factor in US vaccine acceptance [7,9,16]. In the present study, trust in science was significantly higher amongst those with a college degree; future communications relaying scientific evidence should consider levels of education and comprehension in order to win their trust and influence their health decision-making.

While personal or familial history of COVID-19 infection may not be as a potent a motivator for vaccine acceptance as it was early in the pandemic [16], the specter of personal or familial loss continues to be a strong motivator [25]. These findings could indicate a potential effectiveness in personal testimonies and community-focused communication strategies in overcoming vaccine hesitancy and enhancing public trust in scientific advice [26–28]. These results highlight the importance of considering both broad socio-demographic trends and individual experiences of grief and loss in efforts to understand and enhance public trust in vaccination programs. Further, they underscore the necessity for public health communications to be sensitive to these people's varied backgrounds and experiences to effectively address hesitancy and improve vaccine coverage rates.

Building on these findings, several areas warrant further investigation. First, while our study provided cross-sectional insights, future

research could benefit from a longitudinal approach to better understand how trust in science evolves over time within the same individuals, particularly in relation to personal experiences such as loss due to COVID-19. Additionally, the emotional and psychological mechanisms underlying the observed correlation between personal loss and vaccine acceptance merit deeper exploration. Qualitative studies, such as interviews or focus groups, could provide valuable insights into how grief and other non-cognitive factors influence trust in science. Future research should incorporate political affiliation as a variable to better understand its impact on trust in science and vaccine acceptance, providing a more comprehensive view of the socio-political factors that shape public health behaviors. Furthermore, given the significant impact of misinformation on public trust and vaccine acceptance, future research should focus on strategies to combat misinformation and restore trust in scientific recommendations. Investigating the specific cultural and socioeconomic factors that shape trust in science, especially among diverse populations, could also inform more effective public health interventions. Finally, exploring the role of public health institutions in maintaining or rebuilding trust, as well as evaluating the impact of educational programs designed to enhance science literacy, would be critical steps toward improving public health communication and vaccine uptake.

One limitation of our study is that, because it was based on a cross-sectional design, we cannot make definitive conclusions about the cause-and-effect relationships between the factors we studied. There may also be a bias in who chose to participate in the survey. For example, people who were more or less likely to be hesitant about vaccines might have been more motivated to respond—or to avoid responding—once they knew the survey's focus, which could have influenced the results. Another limitation is the variation in how we asked about the loss of family and friends in different years of the study. However, we believe these differences did not significantly impact the overall conclusions. This study also did not include an analysis of the relationship between political affiliation and trust in the science behind COVID-19 vaccines, which prior research has shown to be a significant factor influencing vaccine acceptance in the U.S.

Ethical Considerations

This study was approved and the survey administered by Emerson College, Boston, USA under institutional review board protocol no. 20–023-F-E-6/12. Written, informed consent was obtained by all participants.

CRedit authorship contribution statement

Trenton M. White: Writing – review & editing, Writing – original draft, Visualization, Validation, Formal analysis. **Katarzyna Wyka:** Visualization, Validation, Methodology, Formal analysis, Data curation. **Kenneth Rabin:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Ayman El-Mohandes:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Study funding was provided by Moderna, Inc., to the City University of New York (CUNY) Research Foundation. Authors retained full autonomy in the design of the study; the development of the survey instrument; the collection, analysis, and interpretation of data; the presentation of results; and the decision to submit the article for publication. All authors declare no competing interests.

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Data availability

The raw data generated in this study are available for download at <https://doi.org/10.5281/zenodo.10568582>. All authors had access to the raw data.

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