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Two Large-Scale Global Studies on COVID-19 Vaccine Hesitancy Over Time: Culture, Uncertainty Avoidance, and Vaccine Side-Effect Concerns

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This article presents one of the largest and broadest investigations into COVID-19 vaccine hesitancy, a burning issue that poses a global threat. First, I provide a timely review of the predictors of COVID-19 vaccine hesitancy identified by prior studies. More importantly, I advance a dynamic, cultural psychological perspective to examine how the cultural dimension of uncertainty avoidance partly explains national differences in initial vaccine hesitancy. To track global vaccine hesitancy over time, I leveraged a daily survey of 979,971 individuals in 67 countries/territories (October 2020 to March 2021) and another daily survey of over 11 million individuals in 244 countries/territories (December 2020 to March 2021). To increase sample representativeness, both surveys used algorithms to correct for nonresponse bias and coverage bias. Consistent with my theoretical perspective, people in higher (vs. lower) uncertainty avoidance cultures had higher vaccine hesitancy *initially* (late 2020) as a function of greater vaccine side-effect concerns, but these differences decreased over time as COVID-19 vaccine uptake became prevalent. These findings were robust after controlling for other cultural dimensions, demographics, COVID-19 severity, government response stringency, socioeconomic indicators, common vaccine coverage, and religiosity. Understanding cultural differences in vaccine hesitancy is important, as delaying vaccination for even a short period can increase morbidity and mortality.

Keywords: cultural psychology, uncertainty avoidance, COVID-19, vaccine hesitancy, vaccine side-effect concerns

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As of May 2022, the coronavirus disease 2019 (COVID-19) has caused over 6 million deaths worldwide and still claims thousands of lives every day (World Health Organization, n.d). Extensive research shows that "COVID-19 vaccines are effective at preventing infection, serious illness, and death" (Centers for Disease Control and Prevention, 2021). Vaccine hesitancy, defined as "delay in acceptance or refusal of vaccination despite availability of vaccination services" (MacDonald & the SAGE Working Group on Vaccine Hesitancy, 2015, p. 4161), increases morbidity and mortality. To reduce the spread of COVID-19, it is vital to understand the predictors of COVID-19 vaccine hesitancy (Dror et al., 2020; Sallam, 2021). To this end, this article (a) provides a timely review of the predictors of COVID-19 vaccine hesitancy, (b) introduces a dynamic, cultural perspective on vaccine hesitancy, and (c) presents one of the largest and broadest investigations into COVID-19 vaccine hesitancy, thereby offering both theoretical and empirical contributions.

The Vaccine Hesitancy Determinants Matrix (MacDonald & the SAGE Working Group on Vaccine Hesitancy, 2015) organizes determinants of vaccine hesitancy into three categories: (a) vaccine-specific factors, (b) individual and group factors, and (c) contextual factors. Using these categories, Table 1 provides a concise yet systematic review of the predictors of COVID-19 vaccine hesitancy identified by prior studies. In terms of vaccine-specific factors, vaccine hesitancy tends to be low if COVID-19 vaccines are considered safe (Orangi et al., 2021), priced inexpensively (Wang et al., 2020), or recommended by health care professionals (Reiter et al., 2020). In terms of individual and group factors, vaccine hesitancy tends to be high among individuals who are female (Lazarus et al., 2021), young (Fisher et al., 2020), less educated (Robertson et al., 2021), low-income (de Figueiredo & Larson, 2021), less knowledgeable about COVID-19 (Paul et al., 2021), without a vaccination history (Schwarzinger et al., 2021), or untrusting of the health care system (Murphy et al., 2021). In terms of contextual factors, vaccine hesitancy tends to be low if

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Table 1
A Review of Predictors of COVID-19 Vaccine Hesitancy (Organized per the Vaccine Hesitancy Determinants Matrix)

Categories	Factors	Tendencies	Example citations
Vaccine-specific factors	Risk/benefit	Vaccines perceived as risky and ineffective are associated with higher vaccine hesitancy.	Fisher et al. (2020), Katoto et al. (2022), Orangi et al. (2021), Paul et al. (2021), Reiter et al. (2020), and Sherman et al. (2021)
	Origin of vaccine	In the United States, foreign (vs. domestic) vaccines are associated with higher vaccine hesitancy.	Kreps et al. (2020)
	Costs	Individuals who consider the price of vaccine important have higher vaccine hesitancy.	Wang et al. (2020)
	Recommendation and/or attitude of health care professionals	Individuals whose health care providers recommend vaccination have lower vaccine hesitancy.	Reiter et al. (2020), Sherman et al. (2021), and Wang et al. (2020)
Individual and group factors	Vaccination history	Individuals who have received vaccines in the past have lower vaccine hesitancy.	Caserotti et al. (2021), Fisher et al. (2020), Lackner and Wang (2021), Paul et al. (2021), Pogue et al. (2020), Schwarzinger et al. (2021), Sherman et al. (2021), and Wang et al. (2020)
	Beliefs and attitudes about COVID-19	Individuals who perceive themselves to be less susceptible to COVID-19 have higher vaccine hesitancy.	Caserotti et al. (2021), Gerretsen et al. (2021), Orangi et al. (2021), Schwarzinger et al. (2021), Wang et al. (2020), and Willis et al. (2021)
	Knowledge/awareness	Individuals who have poor knowledge of COVID-19 have higher vaccine hesitancy.	Mewhirter et al. (2022), Paul et al. (2021), and Sherman et al. (2021)
	Trust in the health care system and government	Individuals who are less trusting of the health care system and government have higher vaccine hesitancy.	Fisher et al. (2020), Goodwin et al. (2022), Jennings et al. (2021), Katoto et al. (2022), Lazarus et al., (2021), Murphy et al. (2021), Paul et al. (2021), and Sherman et al. (2021)
	Education	Less educated individuals have higher vaccine hesitancy.	de Figueiredo and Larson (2021), Fisher et al. (2020), Khubchandani et al. (2021), Kreps et al. (2020), Lazarus et al. (2021), Malik et al. (2020), Paul et al. (2021), Robertson et al. (2021), Savoia et al. (2021), and Schwarzinger et al. (2021)
	Gender	Women have higher vaccine hesitancy.	de Figueiredo and Larson (2021), Fisher et al. (2020), Latkin et al. (2021), Malik et al. (2020), Murphy et al. (2021), Paul et al. (2021), Robertson et al. (2021), Sallam et al. (2021), Schwarzinger et al. (2021), and Wang et al. (2020)
	Race/ethnicity	Racial minorities (e.g., Black people) have higher vaccine hesitancy.	Bell et al. (2020), Fisher et al. (2020), Grumbach et al. (2021), Khubchandani et al. (2021), Latkin et al. (2021), Malik et al. (2020), Nguyen et al. (2022), Paul et al. (2021), Reiter et al. (2020), Robertson et al. (2021), Savoia et al. (2021), and Willis et al. (2021)
	Age	Younger individuals have higher vaccine hesitancy.	de Figueiredo and Larson (2021), Fisher et al. (2020), Lackner and Wang (2021), Latkin et al. (2021), Lazarus et al. (2021), Malik et al. (2020), Murphy et al. (2021), Robertson et al. (2021), and Sherman et al. (2021)
	Income	Low-income individuals have higher vaccine hesitancy.	Bell et al. (2020), Katoto et al. (2022), Khubchandani et al. (2021), Lazarus et al. (2021), Murphy et al. (2021), Paul et al. (2021), Roberts et al. (2022), and Willis et al. (2021)
Contextual factors	Communication and media environment	Exposure to vaccine misinformation and conspiracy theories is positively associated with vaccine hesitancy. Transparent communication about negative (positive) features of COVID-19 vaccines increases (decreases) vaccine hesitancy. For individuals strongly hesitant about COVID-19 vaccines, providing information on personal benefits reduces hesitancy more than information on collective benefits.	Allington et al. (2021), Fisher et al. (2020), Freeman et al. (2021), Jennings et al. (2021), Katoto et al. (2022), Loomba et al. (2021), Murphy et al. (2021), Petersen et al. (2021), and Romer and Jamieson (2020)
	Influential leaders and immunization program gatekeepers	Endorsement by the World Health Organization and Anthony Fauci is negatively associated with vaccine hesitancy.	Bokemper et al. (2021), Kaplan and Milstein (2021), and Kreps et al. (2020)
	Politics	In the United States, individuals with conservative political leanings have higher vaccine hesitancy.	Fridman et al. (2021), Hornsey et al. (2020), Khubchandani et al. (2021), Latkin et al. (2021), Reiter et al. (2020), and Roberts et al. (2022)

COVID-19 misinformation is low (Loomba et al., 2021) and vaccines are endorsed by affiliated political parties (Hornsey et al., 2020), influential leaders (Bokemper et al., 2021), or trustworthy organizations (e.g., World Health Organization; Kreps et al., 2020).

The present research not only examines several of these factors in two global studies, but also identifies culture as a novel *contextual factor* for vaccine hesitancy. Culture affects individuals profoundly, as fundamental aspects of everyday life are contextualized within culture (Kitayama & Cohen, 2010; Lu et al., 2023; Markus & Kitayama, 2010). Although some studies have examined the role of cultural variables in the spread of COVID-19 (Salvador et al., 2020), COVID-19 morbidity and mortality (Gelfand et al., 2021; Kumar, 2021), and mask use (Lu et al., 2021), little research has examined how culture influences *vaccine hesitancy*, a burning issue that poses a global threat. To fill this knowledge gap, I examine the cultural dimension of uncertainty avoidance (Hofstede et al., 2010). As I explain below, I focus on uncertainty avoidance because it is theoretically pertinent to vaccine side-effect concerns, a key driver of vaccine hesitancy (Karafillakis et al., 2017; Piot et al., 2019). To ascertain the unique role of uncertainty avoidance in COVID-19 vaccine hesitancy, my studies control for other cultural dimensions (e.g., individualism, tightness), demographics, COVID-19 severity, government response stringency, socioeconomic indicators, common vaccine coverage, and religiosity.

Methodologically, several constraints have limited the understanding of COVID-19 vaccine hesitancy. First, few empirical studies have examined COVID-19 vaccine hesitancy on a *global* scale (de Figueiredo & Larson, 2021; Hou et al., 2021; Lazarus et al., 2021; World Economic Forum, 2021). For example, one of the broadest studies on COVID-19 vaccine hesitancy only covered 32 countries/territories (N = 26,759; de Figueiredo & Larson, 2021). Therefore, more research is needed to understand how COVID-19 vaccine hesitancy varies across the world. In particular, a sample with a large number of countries is needed to statistically test how the cultural dimension of uncertainty avoidance relates to vaccine hesitancy. Second, many studies on COVID-19 vaccine hesitancy relied on convenience samples and failed to emphasize sample representativeness, so the generalizability of their findings is unclear. Third, past studies have mostly examined COVID-19 vaccine hesitancy at one or several specific points in time, such that the observed levels of vaccine hesitancy could have been due to temporary events (e.g., news that week). Thus, more research is needed to examine how COVID-19 vaccine hesitancy changes over a long and continuous span of time.

To address these methodological limitations, I leveraged two large-scale global studies on COVID-19 vaccine hesitancy. In collaboration with Facebook, Study 1 surveyed 979,971 individuals in 67 countries/territories and Study 2 surveyed over 11 million individuals in 244 countries/territories.[1] To track temporal trends in vaccine hesitancy, both surveys were conducted daily and spanned several months (Study 1: October 2020 to March 2021; Study 2: December 2020 to March 2021). These methodological strengths enable me to provide a theoretically novel and dynamic perspective on COVID-19 vaccine hesitancy: People in higher (vs. lower) uncertainty avoidance countries had higher vaccine hesitancy initially (late 2020) as a function of greater side-effect concerns, but these differences decreased over time as vaccine uptake became prevalent. Thus, I contribute to the psychology of vaccine hesitancy by identifying side-effect concerns as a mediator and time as a moderator for the link between uncertainty avoidance and COVID-19 vaccine hesitancy. These findings have actionable implications for when and how governments and health organizations should allocate their limited resources (e.g., focusing resources to address vaccine side-effect concerns, especially when a vaccine is newly introduced). By analyzing how people in different cultures reacted to the pandemic, I spotlight the importance of cultural psychology in coping with global crises.

A Dynamic, Cultural Perspective on Vaccine Hesitancy

In cultural psychology, uncertainty avoidance is defined as "the extent to which the members of a culture feel threatened by ambiguous or unknown situations" (Hofstede et al., 2010, p. 191). Uncertainty avoidance is a cultural dimension in Hofstede's framework, "an invaluable framework to explain variation in psychological tendencies across societies" (Lawrie et al., 2020, p. 52). As indicated by Hofstede's index, countries differ considerably in uncertainty avoidance (www.hofstede-insights.com/country-comparison).

Although no research has examined the role of uncertainty avoidance in vaccine hesitancy, prior studies have consistently shown that people in high uncertainty avoidance cultures tend to be more hesitant about uncertain situations and unfamiliar things (Chuang et al., 2022; Huynh, 2020; Kreiser et al., 2010; Van den Bos et al., 2007, 2013). For example, people in higher (vs. lower) uncertainty avoidance cultures are less likely to adopt new products (Yeniyurt & Townsend, 2003) and innovations (Van Everdingen & Waarts, 2003). Relatedly, new products tend to take off more slowly in higher uncertainty avoidance cultures (Tellis et al., 2003). Frijns et al. (2013) found that chief executive officers (CEOs) of firms in higher uncertainty avoidance cultures engaged less in cross-border or cross-industry takeovers—which involved high risk and uncertainty—and required higher premiums to pursue such takeovers. Similarly, Kanagaretnam et al. (2014) found that banks in higher uncertainty avoidance cultures were less risk-taking and reported earnings more conservatively. Kozak et al. (2007) found that travelers from higher uncertainty avoidance countries were more inclined to change their travel plans if the destination had elevated risk (e.g., new infectious disease, terrorist attacks). In the context of COVID-19, Huynh (2020) found that the country-level uncertainty avoidance index predicted more social distancing behavior (to avoid infection). Together, these findings point to the possibility that people in higher (vs. lower) uncertainty avoidance cultures were more hesitant about newly developed COVID-19 vaccines.

Vaccine Side-Effect Concerns as a Mechanism

I propose that people in higher (vs. lower) uncertainty avoidance cultures may initially have higher vaccine hesitancy because of greater vaccine side-effect concerns. I focus on vaccine side-effect concerns as a mediator because extensive research suggests that it is an important reason why some people are hesitant to be vaccinated, especially for newly developed vaccines. For example, researchers identified vaccine side-effect concerns as a key driver of hesitancy

[1] For simplicity, I use "countries" to denote "countries/territories" in the rest of the article.

about human papillomavirus (HPV) vaccines, which were approved recently in 2014 (Karafillakis et al., 2017, 2019; Piot et al., 2019). Upon reviewing 29 articles on HPV vaccine hesitancy, Karafillakis et al. (2017) noted that the most common concern about HPV vaccine was safety, particularly given that unknown side effects might develop long after vaccination. Due to the relative newness of the HPV vaccine, many people were worried that "there were too many uncertainties around long-term effectiveness of the vaccine" (Karafillakis et al., 2017, p. 4843).

Similarly, although scientific studies suggest that COVID-19 vaccines are safe and effective (Centers for Disease Control and Prevention, 2021), some people may worry about their unknown side effects, especially because the vaccines were developed and approved at an unprecedented speed (Kreps et al., 2020; Pogue et al., 2020). As a fundamental cultural dimension affecting the everyday life of a given culture, uncertainty avoidance might have influenced vaccine hesitancy when COVID-19 vaccines were first introduced: People in higher (vs. lower) uncertainty avoidance countries might have had higher vaccine hesitancy because they were more concerned that COVID-19 vaccines would have unknown side effects, and preferred to wait and see whether early vaccine adopters would experience any unexpected side effects. In other words, vaccine side-effect concerns might have mediated the link between uncertainty avoidance and vaccine hesitancy when COVID-19 vaccines were initially introduced.

A Dynamic Perspective on Vaccine Hesitancy

Beyond the mediation prediction, I advance the literature by offering a *dynamic* perspective on the psychology of vaccine hesitancy. Past research has mostly taken a static perspective (e.g., Country A was higher than Country B in vaccine hesitancy at a specific point in time), as most studies were cross-sectional and unable to capture *trends* in vaccine hesitancy over a long period of time. In line with recent research indicating the fluctuating nature of vaccine hesitancy (de Figueiredo et al., 2020; Larson & Broniatowski, 2021), I propose that people are sensitive to the benefits and risks of COVID-19 vaccines, such that their vaccine hesitancy changes over time.

As theorized above, when COVID-19 vaccines first arrived on the scene, people in higher (vs. lower) uncertainty avoidance countries might have had higher vaccine hesitancy because of greater side-effect concerns. However, as more adopters received the vaccine, it should have become clear that unknown side effects are rare. As a result, even people in high uncertainty avoidance cultures should have become less concerned about vaccine side effects and thus less hesitant about getting vaccinated. Hence, I hypothesize an interaction effect between uncertainty avoidance and time on vaccine hesitancy: People in higher (vs. lower) uncertainty avoidance countries would initially have higher vaccine hesitancy as a function of greater side-effect concerns, but these cultural differences would decrease over time as vaccine uptake became prevalent.

To test my dynamic, cultural perspective on vaccine hesitancy, I leveraged a daily survey of 979,971 individuals in 67 countries/territories (October 2020 to March 2021) and another daily survey of over 11 million individuals in 244 countries/territories (December 2020 to March 2021). To increase sample representativeness, both surveys carefully applied algorithms to correct for nonresponse bias and coverage bias.

Study 1: Vaccine Hesitancy in 67 Countries

Analyzing a daily COVID-19 survey conducted in 42 languages in 67 countries (Table 2), I tested the hypothesized interaction effect between uncertainty avoidance and time on vaccine hesitancy. I predicted that people in higher (vs. lower) uncertainty avoidance countries would have higher vaccine hesitancy initially, but these cultural differences would decrease over time as vaccine uptake became prevalent.

Method

Transparency and Openness

The survey was a collaboration between Facebook, the Massachusetts Institute of Technology (MIT), and Johns Hopkins University, and received input from experts at the World Health Organization and the Global Outbreak Alert and Response Network (for details, see Collis et al., 2022; Moehring et al., 2022). It was approved by the institutional review board of MIT (Protocol E-2294). All participants were at least 18 years old and provided informed consent. The data do not contain any identifying information. Data and materials can be accessed at https://dataforgood.facebook.com/dfg/tools/covid-19-preventative-health-survey#accessdata.

Sampling Methodology

With over 2.85 billion users, Facebook is the most popular social media platform in the world. Every day, a new sample of adult users received a survey invitation that appeared in their Facebook News Feed (see Supplemental Figure S1). To provide geographic coverage, the survey used stratified random sampling based on administrative boundaries within countries.

A methodological strength is that the entire survey procedure was in the user's default Facebook language. For example, if a person usually used Facebook in Korean, then both survey invitation and survey content would automatically be in Korean. The survey was translated into 42 languages (see Supplemental Table S1).

Weighting Methodology

Based on the "total survey error" framework (Groves & Lyberg, 2010), weights were calculated to minimize errors of representation and increase sample representativeness in two stages (for details, see Collis et al., 2022). As explained below, the first stage adjusted for nonresponse bias (i.e., some users are more likely to respond to the survey than others), and the second stage further adjusted for coverage bias (i.e., not everyone in a country has a Facebook account or uses it actively).

The first stage adjusted for nonresponse bias to make the sample more representative of the Facebook Active User Base. Inverse propensity score weighting (IPSW) was applied because it is a well-established approach that allows for correcting many covariates simultaneously. To model nonresponse, existing Facebook user attributes (e.g., age, gender) were used as covariates. For privacy reasons, the covariates were taken from internal Facebook data rather than from individual survey responses.

Table 2
Study 1: Descriptive Statistics of 67 Countries and Territories Across the Study Period

Country/territory	ISO code	Uncertainty avoidance (Hofstede)	Sample size	Mean age (categorical)	% Male	% Hesitant	Vaccine hesitancy mean	Vaccine hesitancy *SD*
Afghanistan	AFG		3,130	2.57	93.5%	21.6%	1.32	0.65
Algeria	DZA	70	3,242	3.28	77.4%	63.3%	1.98	0.85
Angola	AGO	60	2,971	3.31	71.3%	38.2%	1.49	0.68
Argentina	ARG	86	35,671	3.94	36.3%	37.5%	1.52	0.73
Australia	AUS	51	3,122	4.53	43.5%	31.8%	1.44	0.70
Azerbaijan	AZE	88	2,575	3.37	61.9%	65.7%	2.03	0.84
Bangladesh	BGD	60	34,457	2.61	81.9%	23.6%	1.35	0.67
Bolivia	BOL	87	3,191	3.08	52.2%	36.9%	1.53	0.75
Brazil	BRA	76	35,769	3.58	37.8%	24.6%	1.34	0.65
Cambodia	KHM		2,876	2.94	76.5%	25.7%	1.34	0.62
Cameroon	CMR		3,211	2.92	71.6%	61.7%	2.02	0.89
Canada	CAN	48	3,088	4.28	40.7%	35.8%	1.50	0.73
Chile	CHL	86	3,336	3.82	42.0%	43.0%	1.61	0.77
Colombia	COL	80	36,824	3.38	46.0%	35.1%	1.50	0.74
Ecuador	ECU	67	3,295	3.12	49.7%	34.1%	1.47	0.72
Egypt	EGY	55	38,722	3.12	70.3%	47.4%	1.70	0.81
Estonia	EST	60	2,888	3.38	37.7%	49.9%	1.73	0.81
France	FRA	86	36,949	4.21	41.5%	54.2%	1.82	0.84
Georgia	GEO	85	3,296	3.54	44.8%	49.8%	1.71	0.80
Germany	DEU	65	36,808	4.04	45.8%	38.9%	1.58	0.79
Ghana	GHA	65	3,245	2.83	76.6%	38.2%	1.59	0.81
Guatemala	GTM	98	3,532	2.96	51.1%	29.2%	1.41	0.69
Honduras	HND	50	3,299	3.14	46.3%	31.5%	1.43	0.70
India	IND	40	37,396	2.90	80.9%	27.9%	1.41	0.71
Indonesia	IDN	48	35,673	3.27	65.6%	44.9%	1.64	0.79
Iraq	IRQ	96	3,436	3.19	79.7%	38.0%	1.57	0.79
Italy	ITA	75	35,420	4.17	45.4%	27.3%	1.37	0.65
Ivory Coast	CIV		3,106	3.15	81.5%	44.0%	1.65	0.81
Jamaica	JAM	13	2,780	3.70	34.8%	75.1%	2.11	0.77
Japan	JPN	92	35,927	4.85	64.2%	42.9%	1.54	0.69
Kazakhstan	KAZ	88	3,844	3.88	45.1%	72.8%	2.19	0.84
Kenya	KEN	50	3,114	3.00	69.3%	27.7%	1.42	0.73
Korea (South)	KOR	85	3,972	3.98	65.7%	26.1%	1.39	0.70
Malaysia	MYS	36	37,415	3.48	58.0%	32.0%	1.42	0.67
Mexico	MEX	82	36,621	3.22	46.8%	24.1%	1.32	0.61
Mongolia	MNG		2,253	2.90	49.3%	32.9%	1.44	0.68
Morocco	MAR	68	3,355	3.29	69.4%	59.0%	1.88	0.83
Mozambique	MOZ	44	3,411	3.00	70.6%	37.6%	1.49	0.69
Myanmar	MMR		3,561	2.91	72.1%	15.0%	1.21	0.53
Nepal	NPL	40	3,262	2.65	76.6%	24.9%	1.35	0.66
Netherlands	NLD	53	4,133	4.84	44.0%	39.8%	1.55	0.75
Nigeria	NGA	55	36,550	3.19	78.7%	39.5%	1.61	0.82
Pakistan	PAK	70	36,847	2.74	79.8%	35.0%	1.53	0.78
Peru	PER	87	3,260	3.34	50.1%	35.6%	1.50	0.73
Philippines	PHL	44	35,928	3.18	45.9%	47.7%	1.67	0.78
Poland	POL	93	39,055	4.04	43.4%	46.9%	1.71	0.83
Portugal	PRT	99	3,656	4.01	40.5%	46.3%	1.56	0.67
Romania	ROU	90	36,650	3.94	48.8%	45.6%	1.70	0.83
Senegal	SEN	55	2,020	3.25	73.9%	61.0%	1.99	0.88
Singapore	SGP	8	3,156	3.80	60.9%	34.7%	1.48	0.72
South Africa	ZAF	49	3,370	3.65	42.5%	41.5%	1.64	0.82
Spain	ESP	86	3,778	4.08	40.3%	53.5%	1.74	0.77
Sri Lanka	LKA	45	3,130	3.25	72.7%	32.4%	1.47	0.73
Sudan	SDN		3,496	2.83	74.0%	33.9%	1.50	0.76
Taiwan	TWN	69	3,725	3.71	54.5%	47.0%	1.69	0.81
Tanzania	TZA	50	2,572	2.99	83.6%	36.4%	1.61	0.85
Thailand	THA	64	40,167	3.83	54.6%	24.7%	1.36	0.67
Trinidad and Tobago	TTO	55	3,442	3.84	40.7%	59.3%	1.85	0.80
Turkey	TUR	85	36,834	3.72	74.1%	44.0%	1.65	0.80
Uganda	UGA		3,075	2.73	73.3%	27.9%	1.45	0.76
Ukraine	UKR	95	3,452	3.53	38.0%	59.2%	1.87	0.82
United Arab Emirates	ARE	66	3,371	3.22	67.8%	34.6%	1.51	0.76
United Kingdom	GBR	35	32,251	4.16	39.2%	22.0%	1.31	0.64
United States	USA	46	31,462	4.49	36.4%	37.2%	1.56	0.78
Uruguay	URY	98	3,446	4.12	30.4%	54.3%	1.76	0.79
Venezuela	VEN	76	3,440	4.02	50.5%	44.1%	1.61	0.76
Vietnam	VNM	30	37,662	2.80	59.4%	18.6%	1.24	0.55

Note. Hofstede uncertainty avoidance scores range from 8 (lowest) to 100 (highest). Age categories: 1 = under 20, 2 = 20–30, 3 = 31–40, … 7 = 71–80, 8 = over 80. Vaccine hesitancy: "If a vaccine for COVID-19 becomes available, would you choose to get vaccinated?" (1 = yes, 2 = don't know, 3 = no). % Hesitant = percentage of people who indicated "no" or "don't know".

Continuous variables (e.g., age) were transformed into categorical variables to ensure that the sample matched their full distributions rather than only the mean values. In sum, correcting for nonresponse bias yielded a more representative sample of the Facebook Active User Base.

The second stage further adjusted for coverage bias to make the sample more representative of the adult population in each country. The IPSW output weights from the first stage were used as inputs for post-stratification, a common survey methodology to correct for known differences between the sample and the target population (Little, 1993). Post-stratification was applied using publicly available benchmarks. In sum, correcting for coverage bias yielded a more representative sample of the adult population in a given country (Collis et al., 2022).

Vaccine Hesitancy

Vaccine hesitancy was surveyed daily from October 28, 2020, to March 29, 2021, which enabled me to track changes in vaccine hesitancy over time. A total of 979,971 participants who had not received a COVID-19 vaccine (44% female) responded to a question: "If a vaccine for COVID-19 becomes available, would you choose to get vaccinated?" (1 = yes, 2 = don't know, 3 = no). As many as 36.7% of the participants indicated "no" or "don't know."

Uncertainty Avoidance

I sourced Hofstede's uncertainty avoidance index (www.hofstede-insights.com/country-comparison), which ranges from 8 (lowest) to 100 (highest). The index is available for 59 of the 67 countries in Study 1 (Table 2).

Control Variables

To examine the role of uncertainty avoidance in COVID-19 vaccine hesitancy, I collected a broad set of individual-level and country-level control variables. For detailed sources of country-level variables in this article, see Supplemental Table S2.

Other Cultural Dimensions. To ascertain the unique effects of uncertainty avoidance, I controlled for the other Hofstede cultural dimensions (Hofstede et al., 2010; Lawrie et al., 2020): individualism (how much a culture prioritizes personal interests over collective interests), indulgence (how much a culture allows relatively free gratification of basic and natural human desires related to enjoying life and having fun), long-term orientation (how much a culture focuses on future-oriented values), masculinity (how much a culture emphasizes achievement and material success), and power distance (how much a culture accepts and expects unequally distributed power). In addition, I controlled for cultural tightness–looseness (Gelfand et al., 2011), or the degree to which a culture has "many strongly enforced rules and little tolerance for deviance" (Harrington & Gelfand, 2014, p. 7990).

Because the Hofstede indices for individualism, indulgence, long-term orientation, masculinity, and power distance are unavailable for over a dozen of the countries in Study 1 and the Gelfand tightness index is unavailable for 45 of the countries, controlling for these cultural dimensions in the initial regression models would cause an unnecessary drop in the number of observations for analysis. Thus, I controlled for these cultural dimensions only in the final two models of each regression table (e.g., Models 4 and 5 in Table 3).

COVID-19 Severity. Individuals might be more willing to get vaccinated if COVID-19 is rampant in their country. Thus, I controlled for daily COVID-19 severity for each country. I sourced daily "new confirmed cases of COVID-19 (7-day smoothed) per 1,000,000 people" from Our World in Data. This variable denotes the mean number of new COVID-19 cases per million population in the preceding 7 days and is commonly used in the COVID-19 literature.

Government Response Stringency. I controlled for the government response stringency index because countries vary in the stringency of their COVID-19 policies (e.g., mask usage, private gathering limits, school closures). For each country, I sourced this daily stringency index from Our World in Data.

Population Density. I controlled for population density because people living in sparser regions may perceive vaccination as less necessary. I sourced population density (population per square kilometers) from the United Nations. The variable was skewed, so log transformation was applied.

GDP per Capita. I controlled for gross domestic product (GDP) per capita (U.S. dollar) because it could be a confounding variable simultaneously related to both uncertainty avoidance and vaccine hesitancy. Research suggests that national wealth may be related to uncertainty avoidance (Hofstede et al., 2010). Moreover, people in less wealthy countries may be more hesitant to get vaccinated because they are worried about the cost of vaccines (MacDonald & the SAGE Working Group on Vaccine Hesitancy, 2015). Thus, I sourced data on GDP per capita (U.S. dollar) from Our World in Data. The variable was skewed, so log transformation was applied.

Common Vaccine Coverage. Countries may differ in the degree to which their citizens are familiar and comfortable with vaccines *in general*. Thus, I controlled for country-level coverage of one of the most common vaccines worldwide, DTP3 (diphtheria, tetanus, and pertussis). As the Vaccine Alliance explains, "DTP3 coverage is a standard measure of the strength of immunisation and health systems." I sourced the "WHO-UNICEF estimates of DTP3 coverage" from the World Health Organization.

Religiosity. Past research suggests that religiosity may be positively related to vaccine hesitancy due to the tension between religious doctrines and science (de Figueiredo et al., 2020; Lane et al., 2018; Rutjens et al., 2018). Thus, I sourced the religiosity index from the World Population Review, which indicates the percentage of a country's citizens who consider religion important in daily life.

Education Level. Because individuals with higher education may be more likely to appreciate COVID-19 vaccines (see Table 1), I controlled for self-reported education (1 = less than primary school, 2 = primary school, 3 = secondary school, 4 = college/university, 5 = graduate school).

Age. Prior studies have found that younger individuals tend to have higher COVID-19 vaccine hesitancy (see Table 1), perhaps because COVID-19 is less lethal to them (Brodin, 2021). Thus, I controlled for age (1 = under 20, 2 = 20–30, 3 = 31–40, . . . 7 = 71–80, 8 = over 80).

Gender. Finally, I controlled for self-reported gender (1 = female, 0 = male) because prior studies have shown that women tend to have higher COVID-19 vaccine hesitancy (see Table 1).

Table 3
Study 1: Multilevel Linear Regressions Predicting Vaccine Hesitancy

	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Date (numerical)	−.038***	(.004)	−.041***	(.004)	−.056***	(.004)	−.056***	(.004)	−.017**	(.005)
Uncertainty avoidance	.074*	(.032)	.074*	(.033)	.060	(.037)	.087*	(.041)	.121†	(.062)
Uncertainty avoidance × Date	−.118***	(.004)	−.118***	(.004)	−.126***	(.004)	−.126***	(.004)	−.093***	(.006)
Female			.050***	(.001)	.050***	(.001)	.049***	(.001)	.043***	(.001)
Age (categorical)			−.078***	(.001)	−.078***	(.001)	−.081***	(.001)	−.114***	(.002)
Education (categorical)			−.046***	(.001)	−.046***	(.001)	−.047***	(.001)	−.067***	(.001)
COVID-19 severity					.031***	(.002)	.031***	(.002)	.014***	(.002)
Government response stringency					−.060***	(.002)	−.060***	(.002)	−.036***	(.003)
Population density (log)					−.034	(.032)	−.052	(.034)	.030	(.052)
GDP per capita (log)					.007	(.039)	.031	(.043)	.132	(.124)
Common vaccine coverage					.029	(.042)	.005	(.043)	−.128	(.130)
Religiosity					.0001	(.046)	.027	(.063)	−.106	(.104)
Individualism							.030	(.056)	.148	(.116)
Indulgence							−.032	(.052)	−.149	(.088)
Long-term orientation							.042	(.055)	−.076	(.086)
Masculinity							.012	(.035)	−.015	(.056)
Power distance							.082	(.051)	.176†	(.097)
Tightness									.028	(.114)
Observations (person)	955,263		908,256		902,592		879,726		476,391	
Number of countries	59		59		58		50		22	
Akaike information criterion	2,132,613		2,014,372		2,001,477		1,951,109		1,040,705	
Bayesian information criterion	2,132,684		2,014,477		2,001,653		1,951,342		1,040,937	
Log likelihood	−1,066,301		−1,007,177		−1,000,724		−975,534		−520,331	

Note. Standardized regression coefficients are displayed, with standard errors in parentheses. GDP = gross domestic product; *SE* = standard error. Vaccine hesitancy: "If a vaccine for COVID-19 becomes available, would you choose to get vaccinated?" (1 = yes, 2 = don't know, 3 = no). Age categories: 1 = under 20, 2 = 20–30, 3 = 31–40, … 7 = 71–80, 8 = over 80. Education categories: 1 = less than primary school, 2 = primary school, 3 = secondary school, 4 = college/university, 5 = graduate school.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Results

Descriptive statistics are displayed in Table 2 and bivariate correlations in Supplemental Table S3. Because participants were nested within countries, I conducted multilevel analyses to account for (a) within-country statistical dependence and (b) the fact that different countries had different sample sizes. To demonstrate the robustness of uncertainty avoidance's effects, each multilevel regression table presents a progression of models, with additional controls included at each step.

Cultural Differences in Vaccine Hesitancy Decreased Over Time

As hypothesized, there was a significant Uncertainty Avoidance × Date interaction effect on vaccine hesitancy in a multilevel linear regression (Table 3 Model 1: $\beta = -.118$, $SE = .004$, $z = -29.04$, $p < .001$). This effect remained robust after accounting for individual-level controls (Model 2: $\beta = -.118$, $SE = .004$, $z = -28.56$, $p < .001$), country-level controls (Model 3: $\beta = -.126$, $SE = .004$, $z = -30.30$, $p < .001$), and other cultural dimensions (Models 4 and 5). As illustrated in Figure 1, people in higher (vs. lower) uncertainty avoidance countries had higher vaccine hesitancy initially (October 2020), but these differences decreased over time (as vaccine uptake became prevalent).

Robustness Checks

To ascertain the reliability of the above results, I conducted a variety of robustness checks. First, results were robust when I examined the interaction effect between uncertainty avoidance and *week* (instead of between uncertainty avoidance and *date*) in multilevel linear regressions—whether without controls ($\beta = -.120$, $SE = .004$, $z = -28.97$, $p < .001$) or with controls ($\beta = -.095$, $SE = .006$, $z = -16.41$, $p < .001$).

Second, I recoded the ordinal measure of vaccine hesitancy into a binary variable (1 = "no"/"don't know," 0 = "yes"). In multilevel logistic regressions, the Uncertainty Avoidance × Date interaction effect was robust—whether without or with controls (Supplemental Table S4, all *p*s < .001).

Third, on March 11, 2021, Denmark and Norway paused delivery of the Oxford–AstraZeneca vaccine over blood clot concerns, and some other countries followed suit (The Washington Post, 2021). Because this event could impact COVID-19 vaccine hesitancy, I conducted a robustness check by limiting analyses to dates *before*

Figure 1

Study 1: Vaccine Hesitancy by High Versus Low Uncertainty Avoidance Countries (from October 28, 2020, to March 29, 2021)

Note. Error bars indicate standard errors, which are small because of the large sample size. Based on the median uncertainty avoidance score (i.e., 66), 51% of the countries are categorized as "high uncertainty avoidance countries" and 49% as "low uncertainty avoidance countries." Vaccine hesitancy: "If a vaccine for COVID-19 becomes available, would you choose to get vaccinated?" (1 = yes, 2 = don't know, 3 = no). Higher scores indicate higher vaccine hesitancy. % Hesitant people = Percentage of people who indicated "no" or "don't know" in a given week. See the online article for the color version of this figure.

March 11, 2021: The Uncertainty Avoidance × Date interaction effect on vaccine hesitancy was robust—whether without controls ($\beta = -.128$, $SE = .004$, $z = -30.12$, $p < .001$) or with controls ($\beta = -.110$, $SE = .006$, $z = -18.19$, $p < .001$).

Fourth, besides the above analyses wherein the unit of analysis is the individual (979,971 individuals), I also conducted analyses by aggregating individual responses to the country level for each day (i.e., 67 countries over 153 days): The Uncertainty Avoidance × Date interaction effect on vaccine hesitancy was still robust—whether without controls ($\beta = -.401$, $SE = .037$, $z = -10.74$, $p < .001$) or with controls ($\beta = -.384$, $SE = .050$, $z = -7.74$, $p < .001$).

Other Predictors of Vaccine Hesitancy

As illustrated in Figure 2 and detailed in Table 3, women, younger individuals, and less educated individuals had higher vaccine hesitancy on average (all $ps < .001$). These results are consistent with prior studies on vaccine hesitancy (Fisher et al., 2020; Robertson et al., 2021).

Moreover, people in countries whose governments responded more stringently to COVID-19 had lower vaccine hesitancy on average (Table 3). This finding suggests that governmental response to COVID-19 might relate to people's attitudes toward vaccine uptake.

Discussion

By analyzing a daily survey of 979,971 participants in 67 countries, Study 1 supported my dynamic, cultural perspective on vaccine hesitancy. Consistent with the hypothesized interaction effect between uncertainty avoidance and time, people in higher (vs. lower) uncertainty avoidance countries had higher vaccine hesitancy initially, but these differences decreased over time (as vaccine uptake became prevalent).

Study 2: Vaccine Hesitancy in 244 Countries

Study 2 had two important aims. First, I tested whether Study 1's findings were replicable in an even larger and broader survey of over 11 million participants in all 244 countries (Table 4) where Facebook is available. Study 2 enabled me to leverage Hofstede's uncertainty avoidance index more fully because the survey covered 115 of all 118 countries for which Hofstede's index is available.[2] Second, in line with my theoretical perspective, I tested whether vaccine side-effect concerns mediated the interaction effect between uncertainty avoidance and time on vaccine hesitancy.

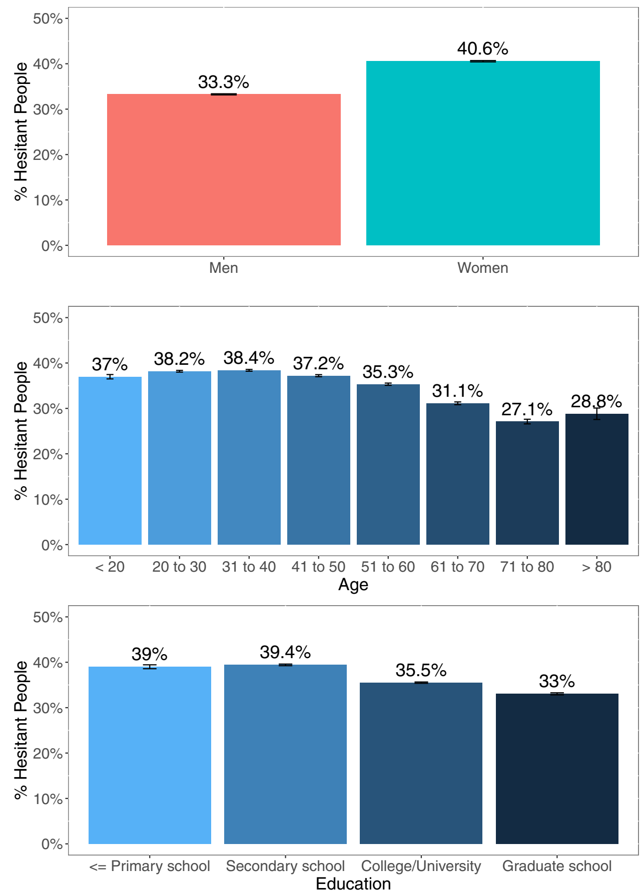
Method

Transparency and Openness

I analyzed data from the COVID-19 Trends and Impact Survey (for details, see Astley et al., 2021; Barkay et al., 2020; Kreuter et al., 2020; Salomon et al., 2021), which was approved by the institutional review boards of Carnegie Mellon University (Protocol 2020_00000162) and University of Maryland (Protocol 1587016-7). All participants were at least 18 years old and provided informed consent. The data do not contain any identifying information. Data and materials can be accessed at https://dataforgood.facebook.com/dfg/tools/covid-19-trends-and-impact-survey#accessdata.

Figure 2

Study 1: Percentage of Hesitant Individuals by Gender, Age, and Education Level



Note. Error bars indicate standard errors, which are small because of the large sample size. Vaccine hesitancy: "If a vaccine for COVID-19 becomes available, would you choose to get vaccinated?" (1 = yes, 2 = don't know, 3 = no). Higher scores indicate higher vaccine hesitancy. % hesitant people = Percentage of people who indicated "no" or "don't know". See the online article for the color version of this figure.

As in Study 1, Facebook applied algorithms to correct for nonresponse bias and coverage bias to increase sample representativeness. The survey was translated into 57 languages (see Supplemental Table S5).

Vaccine Hesitancy

From December 21, 2020, to March 1, 2021, a total of 11,123,364 participants (55% female) who had not received a COVID-19 vaccine answered a question about vaccine hesitancy: "If a vaccine to prevent COVID-19 were offered to you today, would you choose to get vaccinated?" (1 = yes, definitely, 2 = yes, probably, 3 = no,

[2] The only three places missing are mainland China, Iran, and Syria because Facebook is unavailable in those places.

Table 4
Study 2: Descriptive Statistics of 244 Countries and Territories Across the Study Period

Country/territory	ISO code	Uncertainty avoidance (Hofstede)	Sample size	Mean age (categorical)	% Male	% Hesitant	Vaccine hesitancy mean	Vaccine hesitancy *SD*	Side-effect concerns mean	Side-effect concerns *SD*
Afghanistan	AFG		8,167	2.57	89.0%	35.5%	2.18	1.21	2.60	1.19
Aland Islands	ALA		934	3.63	55.1%	27.1%	1.92	1.12	2.33	1.14
Albania	ALB	70	5,861	3.00	58.5%	39.2%	2.27	1.10	2.72	1.08
Algeria	DZA	70	25,175	3.14	74.2%	59.5%	2.75	1.12	2.70	1.16
American Samoa	ASM		1,145	3.18	65.6%	48.7%	2.54	1.24	2.65	1.30
Andorra	AND		1,515	3.43	53.9%	46.6%	2.47	1.23	2.75	1.24
Angola	AGO	60	4,116	2.98	76.9%	33.7%	2.16	1.10	2.98	1.09
Anguilla	AIA		376	3.71	63.6%	47.9%	2.50	1.25	2.65	1.27
Antarctica	ATA		405	3.99	61.1%	63.5%	2.92	1.25	2.58	1.33
Antigua and Barbuda	ATG		301	3.33	58.7%	44.2%	2.44	1.26	2.63	1.31
Argentina	ARG	86	189,367	3.43	37.6%	26.5%	1.95	1.00	2.78	1.10
Armenia	ARM	88	2,661	3.26	51.6%	58.1%	2.78	1.09	2.87	1.08
Aruba	ABW		419	2.90	76.5%	43.9%	2.40	1.22	2.80	1.18
Australia	AUS	51	112,001	3.66	39.7%	22.0%	1.81	0.95	2.44	1.06
Austria	AUT	70	54,336	3.72	47.9%	28.3%	1.93	1.12	2.34	0.97
Azerbaijan	AZE	88	5,906	2.89	64.1%	56.1%	2.68	1.06	2.92	1.10
Bahamas	BHS		267	3.68	57.5%	47.9%	2.48	1.25	2.55	1.27
Bahrain	BHR		348	3.04	64.4%	39.1%	2.24	1.21	2.53	1.26
Bangladesh	BGD	60	31,194	2.06	85.2%	26.8%	1.92	1.01	2.81	1.12
Barbados	BRB		119	3.95	70.5%	50.4%	2.55	1.21	2.51	1.31
Belarus	BLR	95	16,341	3.46	39.2%	58.6%	2.83	1.09	3.16	0.93
Belgium	BEL	94	54,813	3.74	45.8%	25.1%	1.87	1.01	2.37	1.02
Belize	BLZ		280	3.58	40.8%	31.4%	2.04	1.16	2.58	1.25
Benin	BEN		1,523	2.50	85.6%	47.5%	2.46	1.18	3.04	1.14
Bermuda	BMU		119	3.87	68.8%	52.9%	2.63	1.29	2.61	1.33
Bhutan	BTN	28	104	2.94	68.1%	43.3%	2.38	1.23	2.60	1.35
Bolivia	BOL	87	47,067	2.70	52.3%	26.6%	2.01	0.97	3.04	1.02
Bonaire, Sint Eustatius and Saba	BES		83	3.70	57.5%	34.9%	2.19	1.22	2.32	1.23
Bosnia and Herzegovina	BIH	87	8,918	3.17	51.5%	43.0%	2.36	1.08	2.51	1.12
Botswana	BWA		147	3.99	69.0%	59.9%	2.79	1.31	2.71	1.35
Bouvet Island	BVT		30	4.44	53.3%	40.0%	2.33	1.21	3.00	1.26
Brazil	BRA	76	877,735	3.00	39.9%	16.9%	1.62	0.91	2.26	1.14
British Indian Ocean Territory	IOT		150	3.39	61.1%	34.7%	2.07	1.18	2.51	1.31
Brunei	BRN		152	3.00	71.4%	33.6%	2.08	1.18	2.60	1.21
Bulgaria	BGR	85	31,238	3.82	44.7%	50.3%	2.52	1.16	2.61	1.08
Burkina Faso	BFA	55	2,588	2.86	83.9%	48.1%	2.50	1.14	2.95	1.14
Burundi	BDI		85	3.71	70.7%	43.5%	2.53	1.26	2.83	1.30
Cambodia	KHM		3,590	2.74	74.3%	25.9%	1.98	0.95	2.90	1.05
Cameroon	CMR		4,376	2.52	75.5%	58.5%	2.74	1.13	3.22	1.10
Canada	CAN	48	181,312	3.75	39.2%	20.1%	1.71	0.97	2.33	1.06
Cape Verde	CPV	40	83	3.57	52.9%	43.4%	2.35	1.25	2.85	1.17
Cayman Islands	CYM		76	4.10	67.5%	47.4%	2.41	1.25	2.42	1.26
Central African Republic	CAF		89	3.28	56.0%	42.7%	2.34	1.22	2.56	1.29
Chad	TCD		97	3.44	83.0%	35.1%	2.11	1.12	2.63	1.12

(*table continues*)

Table 4 (*continued*)

Country/territory	ISO code	Uncertainty avoidance (Hofstede)	Sample size	Mean age (categorical)	% Male	% Hesitant	Vaccine hesitancy mean	Vaccine hesitancy *SD*	Side-effect concerns mean	Side-effect concerns *SD*
Chile	CHL	86	88,824	3.32	41.3%	24.2%	1.87	1.00	2.91	1.10
Christmas Island	CXR		84	3.79	62.9%	41.7%	2.30	1.23	2.70	1.16
Cocos (Keeling) Islands	CCK		50	4.03	88.5%	36.0%	2.26	1.17	2.85	1.18
Colombia	COL	80	182,595	2.90	47.5%	22.3%	1.86	0.96	2.96	1.09
Comoros	COM		45	3.68	56.5%	40.0%	2.38	1.25	2.67	1.11
Congo, Democratic Republic	COD		2,582	2.95	87.9%	53.9%	2.65	1.18	3.08	1.13
Congo, Republic	COG		148	3.08	61.0%	58.8%	2.77	1.19	2.97	1.24
Cook Islands	COK		33	4.25	53.3%	36.4%	2.27	1.23	2.75	1.49
Costa Rica	CRI	86	31,245	3.15	44.9%	15.6%	1.63	0.88	2.57	1.11
Croatia	HRV	80	23,755	3.58	41.7%	40.4%	2.25	1.08	2.36	1.08
Curaçao	CUW		47	4.09	48.4%	25.5%	1.98	1.03	3.08	1.31
Cyprus	CYP		256	3.02	59.2%	39.1%	2.22	1.08	2.49	1.10
Czech Republic	CZE	74	71,730	3.60	43.1%	34.2%	2.10	1.10	2.13	0.99
Denmark	DNK	23	94,271	4.50	40.2%	7.4%	1.34	0.69	2.08	0.98
Djibouti	DJI		71	3.64	61.8%	45.1%	2.41	1.30	2.53	1.34
Dominica	DMA		284	2.94	46.0%	40.8%	2.39	1.12	3.14	1.17
Dominican Republic	DOM	45	25,516	2.99	49.2%	34.5%	2.16	1.05	3.10	1.08
Ecuador	ECU	67	66,354	2.64	50.7%	27.3%	2.00	1.00	3.07	1.03
Egypt	EGY	55	83,867	2.45	69.6%	39.9%	2.27	1.08	2.91	1.05
El Salvador	SLV	94	29,866	2.74	49.6%	20.6%	1.85	0.92	2.98	1.05
Equatorial Guinea	GNQ		63	3.97	40.6%	38.1%	2.21	1.14	3.10	1.18
Eritrea	ERI		84	3.13	63.8%	36.9%	2.23	1.25	3.10	1.06
Estonia	EST	60	181	3.34	46.9%	32.0%	2.07	1.09	2.75	1.09
Eswatini	SWZ		80	3.51	60.0%	36.2%	2.20	1.12	3.13	0.99
Ethiopia	ETH	55	6,912	2.64	90.9%	26.0%	1.90	1.08	2.88	1.07
Falkland Islands	FLK		47	3.43	45.5%	42.6%	2.32	1.18	2.57	1.44
Faroe Islands	FRO		46	3.12	70.4%	37.0%	2.24	1.16	2.57	1.31
Federated States of Micronesia	FSM		42	4.15	50.0%	47.6%	2.57	1.27	3.27	1.03
Fiji	FJI	48	104	3.98	70.8%	40.4%	2.26	1.28	2.75	1.31
Finland	FIN	59	26,164	3.79	39.9%	14.2%	1.55	0.86	2.17	0.97
France	FRA	86	307,792	3.75	42.0%	39.7%	2.25	1.10	2.57	1.09
French Guiana	GUF		105	3.07	50.7%	31.4%	2.16	1.12	2.33	1.12
French Polynesia	PYF		41	3.18	47.4%	51.2%	2.56	1.12	3.05	1.00
French Southern Territories	ATF		65	4.69	66.7%	46.2%	2.34	1.14	2.97	1.16
Gabon	GAB		210	4.75	43.5%	38.1%	2.25	1.03	2.88	1.09
Gambia	GMB		62	3.78	56.2%	41.9%	2.29	1.18	3.11	1.03
Georgia	GEO	85	135	3.47	50.0%	39.3%	2.37	1.20	2.92	1.16
Germany	DEU	65	330,406	3.55	45.5%	25.9%	1.88	1.05	2.44	0.93
Ghana	GHA	65	15,076	2.46	76.1%	37.9%	2.24	1.11	3.42	0.98
Gibraltar	GIB		69	3.67	54.3%	40.6%	2.20	1.28	2.94	1.09
Greece	GRC	100	55,374	3.61	52.0%	25.2%	1.90	1.00	2.46	0.99
Greenland	GRL		79	3.83	58.5%	35.4%	2.15	1.17	2.57	1.24
Grenada	GRD		47	3.79	38.5%	34.0%	2.13	1.19	2.95	1.20
Guadeloupe	GLP		178	3.98	38.9%	39.3%	2.24	1.09	2.70	1.05
Guam	GUM		54	3.23	69.4%	37.0%	2.19	1.13	2.59	1.14

(*table continues*)

Table 4 (*continued*)

Country/territory	ISO code	Uncertainty avoidance (Hofstede)	Sample size	Mean age (categorical)	% Male	% Hesitant	Vaccine hesitancy mean	Vaccine hesitancy *SD*	Side-effect concerns mean	Side-effect concerns *SD*
Guatemala	GTM	98	27,480	2.54	54.6%	21.4%	1.86	0.96	2.98	1.05
Guernsey	GGY		36	3.46	54.2%	19.4%	1.81	0.89	2.61	0.98
Guinea	GIN		1,686	2.49	91.0%	29.5%	2.04	1.10	2.62	1.21
Guinea-Bissau	GNB		37	3.53	53.3%	48.6%	2.54	1.22	2.71	1.31
Guyana	GUY		45	3.29	50.0%	24.4%	1.98	1.03	3.00	0.94
Haiti	HTI		2,650	2.60	74.7%	57.0%	2.74	1.11	3.04	1.16
Heard Island and McDonald Islands	HMD		42	4.35	70.6%	54.8%	2.76	1.23	2.28	1.32
Honduras	HND	50	22,948	2.75	48.0%	20.1%	1.82	0.94	3.06	1.05
Hong Kong	HKG	29	15,664	3.51	62.4%	37.8%	2.21	0.98	2.79	1.02
Hungary	HUN	82	114,933	4.12	44.3%	29.6%	1.99	1.09	2.42	1.05
Iceland	ISL	50	128	3.49	57.1%	32.0%	2.09	1.21	2.58	1.17
India	IND	40	237,122	2.46	83.1%	29.7%	1.99	1.06	2.57	1.16
Indonesia	IDN	48	142,399	2.63	65.2%	26.6%	2.00	0.98	2.61	1.07
Iraq	IRQ	96	36,634	2.58	79.4%	42.9%	2.33	1.16	2.63	1.10
Ireland	IRL	35	48,862	3.77	38.0%	13.8%	1.53	0.86	2.40	1.04
Isle of Man	IMN		45	3.39	50.0%	40.0%	2.27	1.18	2.45	1.32
Israel	ISR	81	30,467	3.73	47.6%	27.3%	1.88	1.07	2.74	1.12
Italy	ITA	75	331,565	3.62	45.5%	13.6%	1.57	0.83	2.57	0.93
Ivory Coast	CIV		6,310	2.95	81.0%	42.3%	2.36	1.14	2.93	1.15
Jamaica	JAM	13	125	3.80	67.1%	38.4%	2.34	1.12	2.88	1.19
Japan	JPN	92	592,328	4.32	63.7%	23.8%	2.06	0.73	2.97	0.75
Jersey	JEY		62	3.61	64.3%	30.6%	2.10	1.08	2.96	1.02
Jordan	JOR	65	22,137	2.95	68.6%	53.6%	2.59	1.17	2.72	1.12
Kazakhstan	KAZ	88	10,787	3.45	46.7%	66.4%	3.00	1.06	3.08	1.08
Kenya	KEN	50	28,108	2.70	72.3%	27.2%	1.94	1.06	3.32	1.01
Kiribati	KIR		29	3.88	53.3%	34.5%	2.14	1.06	3.00	1.22
Korea (South)	KOR	85	49,476	3.19	66.1%	23.6%	1.89	0.86	2.77	0.93
Kosovo	KOS		140	3.20	51.2%	32.1%	2.12	1.12	3.00	0.95
Kuwait	KWT	80	5,129	3.06	76.3%	32.4%	2.07	1.06	2.73	1.09
Kyrgyzstan	KGZ		4,060	3.16	47.3%	54.8%	2.71	1.08	2.92	1.09
Laos	LAO		2,289	2.48	74.0%	22.8%	1.90	0.94	2.73	1.05
Latvia	LVA	63	147	3.23	53.6%	43.5%	2.32	1.27	2.59	1.20
Lebanon	LBN	57	16,008	2.94	61.2%	37.7%	2.19	1.08	2.77	1.07
Lesotho	LSO		54	3.09	53.3%	44.4%	2.37	1.20	3.27	0.94
Liberia	LBR		91	3.22	79.2%	38.5%	2.16	1.21	2.68	1.30
Libya	LBY	67	15,005	2.83	75.4%	32.1%	2.04	1.11	2.55	1.09
Liechtenstein	LIE		66	3.59	43.9%	51.5%	2.44	1.23	2.28	1.03
Lithuania	LTU	65	125	2.83	60.4%	41.6%	2.28	1.23	2.40	1.12
Luxembourg	LUX	70	259	3.29	52.0%	30.5%	2.01	1.12	2.42	1.04
Macao	MAC		155	4.72	38.6%	36.1%	2.19	1.12	2.48	1.16
Madagascar	MDG		1,433	3.38	62.3%	48.8%	2.50	1.08	2.96	1.03
Malawi	MWI	50	103	3.03	74.2%	36.9%	2.32	1.22	3.06	1.20
Malaysia	MYS	36	63,759	2.77	55.7%	25.0%	1.96	0.91	3.12	0.97
Maldives	MDV		141	3.25	50.6%	34.0%	2.16	1.20	2.40	1.18
Mali	MLI		2,769	2.64	88.2%	40.4%	2.30	1.16	2.80	1.19

(*table continues*)

Table 4 (*continued*)

Country/territory	ISO code	Uncertainty avoidance (Hofstede)	Sample size	Mean age (categorical)	% Male	% Hesitant	Vaccine hesitancy mean	Vaccine hesitancy *SD*	Side-effect concerns mean	Side-effect concerns *SD*
Malta	MLT	96	132	3.23	65.2%	34.1%	2.15	1.19	2.43	1.19
Marshall Islands	MHL		18	4.33	50.0%	33.3%	2.11	1.32	3.40	1.34
Martinique	MTQ		118	3.61	51.2%	41.5%	2.32	1.14	2.71	1.13
Mauritania	MRT		905	2.66	87.8%	40.2%	2.27	1.19	2.66	1.16
Mauritius	MUS		63	3.12	50.0%	23.8%	1.95	0.96	2.69	1.02
Mayotte	MYT		67	3.71	44.2%	44.8%	2.28	1.13	2.78	1.13
Mexico	MEX	82	655,970	2.72	47.0%	11.6%	1.55	0.81	2.79	1.03
Moldova	MDA	95	8,204	3.08	42.5%	52.7%	2.64	1.13	3.09	1.01
Monaco	MCO		64	3.77	50.0%	32.8%	2.14	1.10	2.80	1.40
Mongolia	MNG		67	3.58	58.8%	53.7%	2.69	1.25	2.62	1.23
Montenegro	MNE	90	85	3.08	54.2%	58.8%	2.75	1.13	2.94	1.06
Montserrat	MSR		23	3.62	61.5%	52.2%	2.39	1.12	3.75	0.46
Morocco	MAR	68	17,414	2.94	72.7%	29.4%	2.02	1.05	2.47	1.11
Mozambique	MOZ	44	7,056	2.60	71.8%	28.1%	2.04	0.96	3.41	0.89
Myanmar	MMR		15,379	2.55	69.3%	15.2%	1.64	0.88	2.59	1.01
Namibia	NAM	45	56	4.29	63.2%	33.9%	2.11	1.14	2.39	1.20
Nauru	NRU		31	4.13	46.2%	35.5%	2.16	1.37	2.40	1.24
Nepal	NPL	40	17,421	2.08	74.9%	28.6%	2.00	1.00	2.86	1.12
Netherlands	NLD	53	124,819	4.25	46.4%	17.9%	1.65	0.96	2.18	0.88
New Caledonia	NCL		30	3.06	63.6%	36.7%	2.17	1.12	2.58	1.24
New Zealand	NZL	49	43,997	3.96	36.2%	24.2%	1.85	0.95	2.48	1.06
Nicaragua	NIC		16,204	2.83	50.7%	21.2%	1.85	0.94	3.04	1.05
Niger	NER		72	2.95	70.3%	51.4%	2.43	1.31	2.81	1.21
Nigeria	NGA	55	41,029	2.76	78.2%	35.3%	2.17	1.12	3.16	1.11
Niue	NIU		13	3.25	25.0%	38.5%	2.31	1.18		
Norfolk Island	NFK		18	3.30	12.5%	27.8%	2.28	1.07	2.89	1.36
North Macedonia	MKD	87	167	4.37	40.6%	42.5%	2.26	1.21	2.79	1.22
Northern Mariana Islands	MNP		25	4.15	83.3%	24.0%	1.88	1.05	3.00	1.15
Norway	NOR	50	86,243	4.46	43.1%	12.2%	1.52	0.80	1.98	0.89
Oman	OMN		2,539	3.00	75.7%	28.9%	2.00	1.06	2.61	1.11
Pakistan	PAK	70	40,191	2.33	81.0%	34.9%	2.13	1.12	2.73	1.14
Palau	PLW		57	4.46	29.6%	43.9%	2.28	1.18	2.95	1.13
Palestine	PSE		8,663	2.82	72.0%	47.2%	2.44	1.15	2.76	1.07
Panama	PAN	86	17,227	3.27	42.3%	22.6%	1.85	0.96	2.91	1.08
Papua New Guinea	PNG		56	3.06	79.3%	32.1%	2.07	1.14	2.30	1.26
Paraguay	PRY	85	17,570	2.75	46.0%	32.6%	2.13	1.04	2.75	1.10
Peru	PER	87	91,543	2.81	51.2%	22.8%	1.88	0.97	2.96	1.03
Philippines	PHL	44	104,743	2.49	46.6%	36.8%	2.22	1.00	3.35	0.92
Pitcairn Islands	PCN		21	4.08	63.6%	42.9%	2.43	1.36		
Poland	POL	93	100,561	3.30	49.6%	31.6%	2.02	1.12	2.56	1.03
Portugal	PRT	99	123,966	3.49	42.8%	16.2%	1.67	0.85	2.77	0.92
Puerto Rico	PRI	38	35,815	4.15	35.2%	15.7%	1.58	0.90	2.80	1.13
Qatar	QAT	80	4,934	2.87	70.7%	23.5%	1.83	0.99	2.68	1.11
Réunion	REU		179	3.72	52.0%	43.0%	2.32	1.12	2.61	1.12
Romania	ROU	90	78,944	3.38	50.3%	30.1%	1.99	1.12	2.62	1.10
Russia	RUS	95	86,014	3.65	42.6%	58.0%	2.83	1.14	2.94	1.06

(*table continues*)

Table 4 (*continued*)

Country/territory	ISO code	Uncertainty avoidance (Hofstede)	Sample size	Mean age (categorical)	% Male	% Hesitant	Vaccine hesitancy mean	Vaccine hesitancy *SD*	Side-effect concerns mean	Side-effect concerns *SD*
Rwanda	RWA		69	3.12	86.1%	40.6%	2.19	1.22	2.97	1.26
Saint Barthélemy	BLM		49	4.97	40.0%	34.7%	2.14	1.31	2.80	1.21
Saint Helena	SHN		19	3.44	37.5%	26.3%	2.00	1.20	2.90	1.10
Saint Kitts and Nevis	KNA		18	3.11	25.0%	33.3%	2.00	1.19	2.60	1.34
Saint Lucia	LCA		27	3.36	46.2%	48.1%	2.37	1.24	2.67	1.15
Saint Martin	MAF		53	3.94	58.8%	45.3%	2.32	1.12	2.57	1.14
Saint Pierre and Miquelon	SPM		13	3.75	57.1%	30.8%	1.77	1.24	2.60	1.52
Saint Vincent and the Grenadines	VCT		11	3.40	60.0%	18.2%	1.45	1.04	2.33	1.53
Samoa	WSM		33	2.31	46.2%	39.4%	2.06	1.12	2.88	1.09
San Marino	SMR		91	3.49	55.0%	34.1%	2.11	1.17	2.75	1.22
Sao Tome and Principe	STP	70	19	3.73	72.7%	26.3%	2.05	1.27	2.56	1.51
Saudi Arabia	SAU	64	23,784	3.02	82.3%	29.7%	1.99	1.06	2.56	1.14
Senegal	SEN	55	2,623	3.04	70.9%	46.5%	2.46	1.15	2.84	1.17
Serbia	SRB	92	28,054	3.47	46.7%	43.5%	2.34	1.11	2.41	1.12
Seychelles	SYC		26	3.39	56.2%	34.6%	2.08	1.13	2.89	1.17
Sierra Leone	SLE	50	34	3.48	61.9%	23.5%	2.06	1.13	3.00	1.10
Singapore	SGP	8	11,897	3.20	59.1%	21.0%	1.82	0.88	2.80	1.03
Sint Maarten	SXM		8	4.67	16.7%	25.0%	2.12	1.25		
Slovakia	SVK	51	40,645	3.53	47.5%	25.5%	1.88	1.05	2.20	1.01
Slovenia	SVN	88	15,173	3.96	45.8%	34.3%	2.09	1.11	2.61	1.00
Solomon Islands	SLB		18	3.00	28.6%	44.4%	2.28	1.32	2.17	1.47
Somalia	SOM		122	2.58	85.9%	50.8%	2.51	1.28	2.76	1.25
South Africa	ZAF	49	79,623	3.17	41.5%	37.1%	2.19	1.12	3.04	1.09
South Georgia and the South Sandwich Islands	SGS		9	5.00	40.0%	33.3%	2.11	1.27	3.00	1.00
South Sudan	SSD		203	2.53	70.8%	24.6%	1.87	1.08	2.39	1.13
Spain	ESP	86	211,431	3.59	41.8%	15.7%	1.65	0.85	2.70	1.04
Sri Lanka	LKA	45	10,075	2.84	72.2%	25.6%	1.92	1.00	3.07	1.05
Sudan	SDN		13,301	2.41	76.6%	33.0%	2.07	1.16	2.55	1.17
Suriname	SUR	92	34	3.84	66.7%	23.5%	1.91	0.97	2.53	1.18
Svalbard and Jan Mayen	SJM		31	4.42	43.5%	22.6%	1.74	1.03	2.07	0.88
Sweden	SWE	29	210,819	4.49	41.6%	12.2%	1.50	0.80	2.18	1.00
Switzerland	CHE	58	50,342	3.97	45.1%	33.9%	2.09	1.09	2.46	1.00
Taiwan	TWN	69	137,516	3.00	53.8%	33.3%	2.20	0.81	2.85	0.95
Tajikistan	TJK		64	3.08	82.9%	29.7%	2.12	1.08	2.44	1.32
Tanzania	TZA	50	5,207	2.72	86.2%	38.5%	2.25	1.18	2.96	1.18
Thailand	THA	64	163,930	3.05	52.6%	17.8%	1.80	0.85	2.81	0.99
Timor-Leste	TLS		87	3.10	70.2%	26.4%	2.05	1.11	2.71	1.17
Togo	TGO		95	2.96	72.0%	46.3%	2.35	1.27	2.86	1.20
Tokelau	TKL		18	4.60	100.0%	27.8%	2.11	1.18	2.80	1.10
Tonga	TON		46	3.14	58.8%	21.7%	1.91	0.98	2.67	1.11
Trinidad and Tobago	TTO	55	102	3.43	55.6%	33.3%	2.08	1.07	2.94	1.21
Tunisia	TUN	75	24,517	3.23	60.2%	50.9%	2.54	1.10	2.93	1.04
Turkey	TUR	85	114,833	3.31	70.5%	33.9%	2.14	1.03	2.78	1.02
Turks and Caicos Islands	TCA		62	4.21	63.4%	40.3%	2.23	1.09	2.47	1.22

(*table continues*)

Table 4 (*continued*)

Country/territory	ISO code	Uncertainty avoidance (Hofstede)	Sample size	Mean age (categorical)	% Male	% Hesitant	Vaccine hesitancy mean	Vaccine hesitancy *SD*	Side-effect concerns mean	Side-effect concerns *SD*
Tuvalu	TUV		39	2.57	87.0%	35.9%	2.13	1.24	2.64	1.26
Uganda	UGA		233	3.11	68.5%	27.9%	1.93	1.12	3.13	1.13
Ukraine	UKR	95	105,608	3.33	40.5%	53.0%	2.71	1.12	3.11	0.97
United Arab Emirates	ARE	66	18,684	2.84	62.4%	26.2%	1.91	0.99	2.78	1.10
United Kingdom	GBR	35	197,069	3.39	38.2%	13.0%	1.50	0.84	2.14	1.03
United States	USA	46	2,658,589	4.15	32.9%	27.9%	1.90	1.10	2.49	1.10
United States Minor Outlying Islands	UMI		58	2.78	46.9%	36.2%	2.19	1.16	2.58	1.32
Uruguay	URY	98	44,334	3.74	31.3%	34.4%	2.16	1.02	2.97	1.04
Uzbekistan	UZB		6,043	3.21	56.8%	52.1%	2.65	1.06	2.84	1.11
Vanuatu	VUT		44	3.97	66.7%	29.5%	1.77	1.08	2.90	1.18
Vatican City	VAT		49	3.81	71.4%	59.2%	2.80	1.19	2.33	1.30
Venezuela	VEN	76	53,700	3.64	52.2%	28.0%	2.02	1.00	3.18	1.03
Vietnam	VNM	30	184,100	2.12	59.9%	13.9%	1.72	0.80	2.64	1.03
Virgin Islands, U.K.	VGB		121	3.80	39.5%	33.1%	2.02	1.15	2.62	1.28
Virgin Islands, U.S.	VIR		83	3.40	69.0%	36.1%	2.17	1.23	2.88	1.19
Wallis and Futuna	WLF		58	3.90	58.6%	32.8%	2.21	1.18	2.52	1.34
Western Sahara	ESH		94	3.67	68.5%	51.1%	2.54	1.25	3.00	1.21
Yemen	YEM		5,325	2.51	90.2%	45.2%	2.38	1.24	2.25	1.19
Zambia	ZMB	50	189	2.85	69.3%	49.7%	2.52	1.23	2.87	1.24
Zimbabwe	ZWE		614	3.14	62.5%	44.1%	2.42	1.20	3.01	1.22

Note. Hofstede uncertainty avoidance scores range from 8 (lowest) to 100 (highest). Age categories: 1 = 18–24, 2 = 25–34, 3 = 35–44, 4 = 45–54, 5 = 55–64, 6 = 65–74, 7 = 75 or older. Vaccine hesitancy: "If a vaccine to prevent COVID-19 were offered to you today, would you choose to get vaccinated?" (1 = yes, definitely, 2 = yes, probably, 3 = no, probably not, 4 = no, definitely not). % Hesitant = Percentage of people who indicated "no, probably not" or "no, definitely not". Side-effect concerns: "How concerned are you that you would experience a side effect from a COVID-19 vaccination?" (1 = not at all concerned, 2 = slightly concerned, 3 = moderately concerned, 4 = very concerned). Understandably, some smaller countries had fewer participants, so it is important to interpret their descriptive statistics with caution.

probably not, 4 = no, definitely not). Higher scores indicate higher vaccine hesitancy.

Figure 3 maps the mean vaccine hesitancy across the world on December 21, 2020 (the first day of the study). Notably, among the countries for which Hofstede's uncertainty avoidance scores are available, the ten countries with the highest mean vaccine hesitancy all had high uncertainty avoidance scores (e.g., Kazakhstan, Algeria, Armenia), indicating the potential role of uncertainty avoidance in COVID-19 vaccine hesitancy.

Vaccine Side-Effect Concerns (Mediator)

Starting from January 14, 2021, a question was added to the global survey: "How concerned are you that you would experience a side effect from a COVID-19 vaccination?" (1 = not at all concerned, 2 = slightly concerned, 3 = moderately concerned, 4 = very concerned). 6,498,946 participants who had not received a COVID-19 vaccine answered this question.

Control Variables

I used the same control variables as in Study 1: the other cultural dimensions (individualism, indulgence, long-term orientation, masculinity, power distance, tightness), demographics, COVID-19 severity, government response stringency, population density, GDP per capita, common vaccine coverage, and religiosity. The only exception is that Study 2's survey measured education with an *open-ended* question: "How many years of education have you completed?" The responses were understandably noisy, so I decided not to use this variable to be conservative.

Results

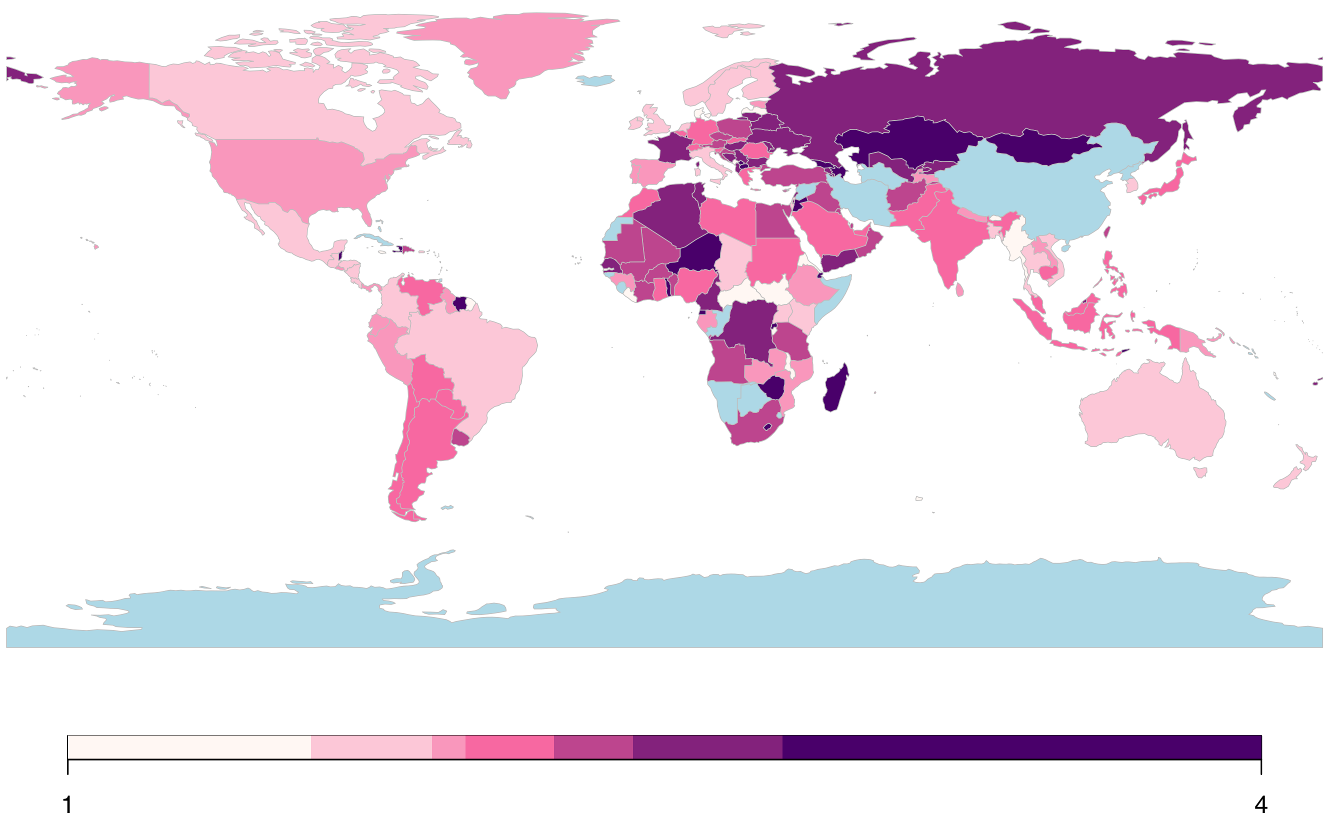
Descriptive statistics are displayed in Table 4 and bivariate correlations in Supplemental Table S6. Because participants were nested within countries, I conducted multilevel analyses to account for (a) within-country statistical dependence and (b) the fact that different countries had different sample sizes.

Cultural Differences in Vaccine Hesitancy Decreased Over Time

Replicating Study 1's findings, there was a significant Uncertainty Avoidance × Date interaction effect on vaccine hesitancy in a multilevel linear regression (Table 5 Model 1: $\beta = -.071$, $SE = .001$, $z = -64.83$, $p < .001$). This effect remained robust after accounting for individual-level controls (Model 2: $\beta = -.068$, $SE = .001$, $z = -55.90$, $p < .001$), country-level controls (Model 3:

Figure 3

Study 2: Mean Vaccine Hesitancy in 244 Countries/Territories on December 21, 2020 (the First Day When Vaccine Hesitancy Was Surveyed)



Note. Vaccine hesitancy: "If a vaccine to prevent COVID-19 were offered to you today, would you choose to get vaccinated?" (1 = yes, definitely, 2 = yes, probably, 3 = no, probably not, 4 = no, definitely not). Darker colors (higher scores) indicate higher vaccine hesitancy. Blue areas indicate countries/territories where data were not available on December 21, 2020. See the online article for the color version of this figure.

Table 5
Study 2: Multilevel Linear Regressions Predicting Vaccine Hesitancy

	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Date (numerical)	−.015***	(.001)	−.009***	(.001)	−.026***	(.001)	−.028***	(.001)	−.013***	(.002)
Uncertainty avoidance	.113***	(.028)	.126***	(.027)	.121***	(.028)	.088**	(.030)	.041	(.052)
Uncertainty avoidance × Date	−.071***	(.001)	−.068***	(.001)	−.038***	(.001)	−.037***	(.001)	−.061***	(.002)
Female			.044***	(.0003)	.043***	(.0003)	.042***	(.0003)	.037***	(.0004)
Age (categorical)			−.124***	(.0003)	−.126***	(.0004)	−.126***	(.0004)	−.134***	(.0004)
COVID-19 severity					−.037***	(.001)	−.040***	(.001)	−.047***	(.001)
Government response stringency					−.046***	(.001)	−.044***	(.001)	−.038***	(.001)
Population density (log)					−.022	(.026)	−.050†	(.028)	−.030	(.057)
GDP per capita (log)					−.063*	(.024)	−.036	(.030)	−.001	(.082)
Common vaccine coverage					.030	(.028)	−.005	(.029)	−.005	(.079)
Religiosity					−.027	(.031)	−.006	(.043)	−.022	(.077)
Individualism							.030	(.055)	−.023	(.088)
Indulgence							−.074*	(.032)	−.072	(.068)
Long-term orientation							.051	(.043)	.051	(.097)
Masculinity							.004	(.029)	.030	(.043)
Power distance							.083*	(.038)	.061	(.060)
Tightness									−.046	(.047)
Observations (person)	10,999,713		8,926,756		8,760,566		8,539,759		6,384,711	
Number of countries	115		115		101		84		28	
Akaike information criterion	30,821,712		24,580,245		24,150,345		23,530,889		17,577,801	
Bayesian information criterion	30,821,797		24,580,357		24,150,541		23,531,154		17,578,075	
Log likelihood	−15,410,850		−12,290,115		−12,075,159		−11,765,426		−8,788,881	

Note. Standardized regression coefficients are displayed, with standard errors in parentheses. GDP = gross domestic product; *SE* = standard error. Age categories: 1 = 18–24, 2 = 25–34, 3 = 35–44, 4 = 45–54, 5 = 55–64, 6 = 65–74, 7 = 75 or older.
† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

β = −.038, SE = .001, z = −27.88, p < .001), and other cultural dimensions (Models 4 and 5). That is, people in higher (vs. lower) uncertainty avoidance countries had higher vaccine hesitancy initially (December 2020), but these differences decreased over time.

Robustness Checks. To ascertain the reliability of the above results, I conducted a variety of robustness checks. First, results were robust when I examined the interaction effect between uncertainty avoidance and *week* (instead of between uncertainty avoidance and *date*) in multilevel linear regressions—whether without controls (β = −.073, SE = .001, z = −64.89, p < .001) or with controls (β = −.064, SE = .002, z = −35.63, p < .001).

Second, I recoded the ordinal measure of vaccine hesitancy into a binary variable (1 = "no, definitely not"/"no, probably not," 0 = "yes, definitely"/"yes, probably"). In multilevel logistic regressions, the Uncertainty Avoidance × Date interaction effect was robust—whether without or with controls (Supplemental Table S7, all ps < .001).

Third, some small countries (understandably) had small samples, so I repeated the analyses for (a) the 111 countries with over 2,000 participants, (b) the 98 countries with over 5,000 participants, and (c) the 85 countries with over 10,000 participants, respectively. In each case, the Uncertainty Avoidance × Date interaction effect was robust—whether without or with controls (all ps < .001).

Cultural Differences in Vaccine Side-Effect Concerns Decreased Over Time

As expected, there was also a significant Uncertainty Avoidance × Date interaction effect on the hypothesized mediator vaccine side-effect concerns (Table 6 Model 1: β = −.096, SE = .002, z = −52.01, p < .001). This effect remained robust after accounting for individual-level controls (Model 2: β = −.096, SE = .002, z = −48.21, p < .001), country-level controls (Model 3: β = −.085, SE = .002, z = −39.43, p < .001), and other cultural dimensions (Models 4 and 5). That is, people in higher (vs. lower) uncertainty avoidance countries had greater vaccine side-effect concerns initially, but these differences decreased over time.

As expected, vaccine side-effect concerns positively predicted vaccine hesitancy in multilevel models—whether without controls (β = .373, SE = .0004, z = 1030.47, p < .001) or with controls (β = .389, SE = .0004, z = 976.31, p < .001).

In an alternative statistical approach, the above results were robust in linear regressions with cluster-robust standard errors (clustered by countries). Mediated moderation analyses found that side-effect concerns mediated the Uncertainty Avoidance × Date interaction effect on vaccine hesitancy, such that the indirect effect was significantly larger in earlier days than in later days (difference in indirect effect = .009, p < .001, bias-corrected bootstrapped 95% CI [.008, .010]).

Other Predictors of Vaccine Hesitancy

Replicating Study 1's findings, women, younger individuals, and individuals whose governments responded less stringently had higher vaccine hesitancy on average (Table 5, all ps < .001).

Discussion

Study 2 replicated Study 1's findings in an even larger and broader global survey in 244 countries. Consistent with the hypothesized interaction effect between uncertainty avoidance and time, people in higher (vs. lower) uncertainty avoidance countries had higher vaccine hesitancy initially as a function of greater side-effect concerns, but these differences decreased over time.

Analyses Across the Two Global Surveys

Because Studies 1 and 2 had overlapping countries and overlapping dates, I was able to conduct additional analyses across the two studies. First, for the 67 overlapping countries in Tables 2 and 4, Studies 1 and 2 were highly correlated in overall mean vaccine hesitancy (r = .73, p < .001). Second, the two studies were also highly correlated for the overlapping dates, such that mean vaccine hesitancy on Day t in Study 1 was highly correlated with mean vaccine hesitancy on Day t in Study 2. For example, on December 21, 2020—the first overlapping date—the correlation between the two studies was r = .90, p < .001. These cross-study results highlight the reliability of my findings.

General Discussion

Methodological Strengths

The present research features unique methodological strengths. First, it is one of the largest (N = 979,971 in Study 1 and N > 11 million in Study 2) and broadest (67 countries in Study 1 and 244 countries in Study 2) investigations into COVID-19 vaccine hesitancy. Second, both studies carefully applied algorithms to adjust for nonresponse bias and coverage bias to increase sample representativeness (as opposed to using convenience samples or Amazon Mechanical Turk samples). Third, *daily* surveys from October 2020 to March 2021 allowed me to track changes in vaccine hesitancy over a long and continuous span of time.

These methodological strengths enabled me to map COVID-19 vaccine hesitancy around the world (Figure 3) and provide reliable insights about vaccine hesitancy in different countries over time. For example, both studies found that vaccine hesitancy was low in the United Kingdom (a low uncertainty avoidance culture) and highest in Kazakhstan (a high uncertainty avoidance culture which had received little attention in previous studies on COVID-19 vaccine hesitancy). Such statistics are valuable for researchers and policymakers when combating vaccine hesitancy.

Theoretical Contributions and Practical Implications

This research offers important theoretical contributions and practical implications. To begin with, I contribute to the psychology of vaccine hesitancy. First, I provided a timely review of the predictors of COVID-19 vaccine hesitancy identified by prior studies and systematically organized this scattered literature in Table 1. This review contributes to the understanding of COVID-19 vaccine hesitancy and offers a useful reference for researchers and practitioners.

Second, by leveraging large samples across the world, I examined demographic and socioeconomic predictors of vaccine hesitancy. Replicating prior studies on a *global* scale, I found that women, younger individuals, and less educated individuals tend to have higher COVID-19 vaccine hesitancy. In doing so, I identified groups that may particularly benefit from behavioral nudges (Campos-Mercade et al., 2021; Legate et al., 2022; Milkman et al., 2021; Pennycook et al., 2020) and evidence-based communication about

Table 6

Study 2: Multilevel Linear Regressions Predicting Vaccine Side-Effect Concerns

	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Date (numerical)	−.031***	(.001)	−.032***	(.001)	−.020***	(.002)	−.022***	(.002)	−.047***	(.002)
Uncertainty avoidance	.093***	(.025)	.077**	(.027)	.101***	(.023)	.065*	(.027)	.038	(.044)
Uncertainty avoidance × Date	−.096***	(.002)	−.096***	(.002)	−.085***	(.002)	−.087***	(.002)	−.114***	(.003)
Female			.129***	(.0004)	.128***	(.0004)	.128***	(.0004)	.127***	(.001)
Age (categorical)			−.046***	(.0004)	−.046***	(.0005)	−.047***	(.0005)	−.044***	(.001)
COVID-19 severity					−.016***	(.001)	−.016***	(.001)	−.012***	(.001)
Government response stringency					.003*	(.001)	.004**	(.001)	.003†	(.002)
Population density (log)					.010	(.021)	−.002	(.024)	−.038	(.048)
GDP per capita (log)					−.094***	(.020)	−.064*	(.026)	.011	(.068)
Common vaccine coverage					−.006	(.023)	.006	(.025)	.031	(.066)
Religiosity					.079**	(.025)	.010	(.038)	−.063	(.065)
Individualism							−.133**	(.047)	−.206*	(.074)
Indulgence							.026	(.028)	−.051	(.057)
Long-term orientation							−.013	(.038)	−.007	(.081)
Masculinity							.024	(.026)	.090*	(.036)
Power distance							.056†	(.033)	.115*	(.050)
Tightness									−.014	(.040)
Observations (person)	6,431,596		5,387,344		5,281,892		5,153,617		3,839,954	
Number of countries	115		115		101		84		28	
Akaike information criterion	18,760,015		15,505,313		15,208,609		14,834,599		11,034,122	
Bayesian information criterion	18,760,098		15,505,421		15,208,797		14,834,854		11,034,385	
Log likelihood	−9,380,002		−7,752,648		−7,604,290		−7,417,280		−5,517,041	

Note. Standardized regression coefficients are displayed, with standard errors in parentheses. GDP = gross domestic product; *SE* = standard error. Age categories: 1 = 18–24, 2 = 25–34, 3 = 35–44, 4 = 45–54, 5 = 55–64, 6 = 65–74, 7 = 75 or older.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

vaccine safety and effectiveness (Betsch et al., 2017; Horne et al., 2015; Jarrett et al., 2015; Petersen et al., 2021). Moreover, both studies found that people in countries whose governments responded more stringently to COVID-19 had lower vaccine hesitancy.

Third, above and beyond the factors examined by prior studies, I contribute a cultural psychological perspective on vaccine hesitancy. To my knowledge, the present research is the first to consider *when* and *why* the cultural dimension of uncertainty avoidance predicts vaccine hesitancy. To answer the *when* question, I provided a dynamic perspective by identifying time as a moderator. My studies revealed that people in higher (vs. lower) uncertainty avoidance cultures initially had higher vaccine hesitancy, but these cultural differences decreased over time as COVID-19 vaccine uptake became prevalent. This dynamic perspective contributes to the vaccine hesitancy literature, as past research has mostly taken a static perspective on vaccine hesitancy (e.g., Country A was higher than Country B in vaccine hesitancy at a specific point in time). To combat vaccine hesitancy efficiently, governments and health organizations could allocate more of their limited resources to the initial phase of a new vaccine's rollout (as opposed to spreading their limited resources evenly across time). To answer the *why* question, I identified vaccine side-effect concerns as a mediator that partly explains why people in higher (vs. lower) uncertainty avoidance cultures had higher vaccine hesitancy initially. Based on this insight, governments and health organizations should focus on addressing people's side-effect concerns to reduce vaccine hesitancy.

Besides contributing to the psychology of vaccine hesitancy, this research also contributes to cultural psychology in several ways. First, I extend the literature on uncertainty avoidance by examining a burning issue in the real world: vaccine hesitancy. Compared to other cultural dimensions, uncertainty avoidance has received less attention from researchers. As of May 2022, there are over 13,900 Google Scholar entries whose titles contain "individualism," whereas there are only about 500 such entries for "uncertainty avoidance." Second, to ascertain the unique role of uncertainty avoidance in vaccine side-effect concerns and vaccine hesitancy, I accounted for a broad set of control variables, including other cultural dimensions. By revealing the robust effect of uncertainty avoidance, I demonstrate that different aspects of culture may play differential roles in everyday life (e.g., uncertainty avoidance is particularly pertinent to vaccine side-effect concerns). Third, I depart from prior studies on uncertainty avoidance by offering a *temporal* perspective. To my knowledge, the current research is among the first to consider an Uncertainty Avoidance × Time interaction effect. This is important because the effect of uncertainty avoidance might have been obscured if I had neglected its interaction with time. In light of my findings, future research on uncertainty avoidance should explore its interplay with time where applicable. For example, although studies have found that people in higher (vs. lower) uncertainty avoidance cultures tend to be less accepting of innovations (Van Everdingen & Waarts, 2003), such cultural differences may dwindle over time.

Overall, by revealing how people in different cultures responded to the pandemic, I underscore the importance of cultural psychology in the face of global crises (Kitayama et al., 2022). Understanding the cultural differences in vaccine hesitancy is important, as delaying vaccination for even a short period can increase morbidity and mortality.

Limitations and Future Directions

The current research has several limitations, which offer opportunities for future research. First, because Hofstede's uncertainty avoidance index is only available for 118 countries (www.hofstede-insights.com/country-comparison), smaller countries without uncertainty avoidance scores were not analyzed in the multilevel regressions. Nevertheless, the large and global samples still provide valuable *descriptive* statistics for countries without the uncertainty avoidance index. For example, although Hofstede's uncertainty avoidance index is unavailable for Cameroon, both Study 1 ($N_{\text{Cameroon}} = 3{,}211$) and Study 2 ($N_{\text{Cameroon}} = 4{,}376$) found that its mean vaccine hesitancy was near the top.

Second, because Hofstede's uncertainty avoidance index is available only at the country level, I was unable to examine the role of uncertainty avoidance in vaccine hesitancy *within* large countries like Russia and the United States (e.g., differences among the 50 U.S. states). While I am cautious not to overgeneralize, I suspect that the observed relationship between country-level uncertainty avoidance and individual-level vaccine hesitancy (in my multilevel analyses) would apply to other levels of analysis, especially given the mechanism of vaccine side-effect concerns. For example, if there were an uncertainty avoidance index for the 50 U.S. states, I would expect a similar relationship between *state-level* uncertainty avoidance and individual-level vaccine hesitancy in multilevel analyses (Lu et al., 2021). Similarly, if uncertainty avoidance were measured at the individual level, I would expect a similar relationship between *individual-level* uncertainty avoidance and individual-level vaccine hesitancy. Indeed, studies measuring individual-level uncertainty avoidance have shown conceptually similar patterns (outside the context of vaccine hesitancy); for example, Gupta et al. (2019) found that individual-level uncertainty avoidance was negatively associated with individuals' willingness to rent out their products to others. Future research could explore within-country variations in uncertainty avoidance and vaccine hesitancy.

Third, given my theoretical focus on the cultural dimension of uncertainty avoidance, I examined vaccine side-effect concerns as a mechanism for changes in COVID-19 vaccine hesitancy—while accounting for factors such as demographics, government response stringency, population density, GDP per capita, common vaccine coverage, and religiosity. Future research is needed to explore other potential mechanisms, such as trust in government and the health care system (Goodwin et al., 2022; Larson, 2016; Larson et al., 2018).

Lastly, while the current studies demonstrated the role of uncertainty avoidance in COVID-19 vaccine hesitancy, future research could examine its role in hesitancy about other vaccines, such as Bacillus Calmette–Guérin, measles–mumps–rubella, hepatitis B virus, and HPV vaccines. This is especially important because vaccine hesitancy was named by the World Health Organization (2019) as one of the top 10 threats to global health.

Conclusion

By analyzing a daily survey of 979,971 individuals in 67 countries and another daily survey of over 11 million individuals in 244 countries, I mapped COVID-19 vaccine hesitancy around the world. On a global scale, I found that individuals who are female, younger, less educated, or in low government-response-stringency countries had higher vaccine hesitancy on average. More importantly, I advanced a dynamic, cultural psychological perspective and uncovered how the cultural dimension of uncertainty avoidance partly explained vaccine hesitancy: People in higher (vs. lower) uncertainty avoidance countries had higher vaccine hesitancy initially (late 2020) as a function of greater side-effect concerns, but these differences decreased over time as COVID-19 vaccine uptake became prevalent. Overall, this research provides valuable insights into COVID-19 vaccine hesitancy and demonstrates the importance of cultural psychology for understanding global crises.

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