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Research Report

When the one true faith trumps all: Low religious diversity, religious intolerance, and science denial

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Abstract

Past theories have linked science denial to religiosity but have not explained its geographic variability. We hypothesize that it springs not only from religious intensity but also from religious intolerance, which depends greatly on the experience of religious diversity and hence on geography. The belief that one's religion trumps other faiths precipitates the stance that it trumps science too. This psychological process is most likely to operate in regions or countries with low religious heterogeneity. We measure the rejection of science not only in people's refusal to follow specific health recommendations, such as taking COVID-19 vaccines, but also in general measures of scientific engagement and attainment. We rule out alternative explanations, including reverse causality and spurious correlations, by conducting controlled experiments and running robustness checks on our statistical models.

Keywords: science denial, religious diversity, religious intolerance, religiosity, objective and experienced diversity

Significance Statement

Past research has examined cognitive and social preconditions of science denial, including religiosity. We propose that science denial independently arises from religious intolerance, and that this orientation of rejecting other faiths depends on experience of a lack of religious diversity and thus on geography. In our conceptualization, a socioecological risk factor (i.e. lack of religious diversity in one's neighborhood and network) precipitates religious intolerance and, in turn, engenders dismissal of science. Across seven studies (countries $n > 140$; US counties $n > 3{,}000$; individual participants $n > 15{,}000$) that operationalize the key constructs in different ways, we find that lower religious diversity in a region, or in an individual's experience, predicts higher religious intolerance and higher science denial. The findings have policy implications for science education and for managing compliance with scientific guidance such as public health recommendations.

Introduction

The Peoples Temple cult isolated itself from outsiders, followed delusional practices, such as faith healing, and ultimately trusted Reverend Jim Jones's instructions to drink cyanide kool-aid. Science denial with hazardous consequences also arises in more mainstream religious sects. The Amish and other closed religious communities tended to forgo vaccines and suffer excess mortality during the COVID-19 pandemic. Larger groups such as Evangelical Christians—not "closed" but concentrated in particular geographic regions—similarly tended to disregard scientific public health recommendations during the pandemic. This science denial is not just problematic for the groups who practice it; the lack of buy-in by a few groups in society can undermine collective action to control an epidemic (1–3). The science denial associated with religious communities is both a psychological puzzle and a societal problem.

A standard explanation for the link between religion and science denial focuses on the intensity of faith. Intense faith is theorized to generate high motivation to reject scientific conclusions that conflict with the religion's teaching. Certainly, cults, the Amish, and white Evangelical sects inculcate intense faith. However, while Protestants and Catholics are underrepresented in STEM (science, technology, engineering and mathematics) fields, there are many devout believers among the Quakers who have long been overrepresented in science; similarly, Jewish believers are prominently represented in science (4, 5). This suggests that intensity of faith is only one way that religion affects science denial.

Another possible mechanism can be illustrated by the example of "closed" religious sects. These groups tend to regard their dogma as more valid than other faiths and sustain this rejection by

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discouraging members' interactions with and learning from outsiders (6, 7). From this sectarian supremacism, it is a small step to also reject science, another rival belief system. This alternative process, focused on religious *intolerance*, helps to understand science denial in some mainstream groups like Evangelicals as well. Whether by choice or birth, their members tend to live in areas that afford less interaction with people of other faiths, reducing the learning of tolerance from social experience. Members of geographically concentrated sects are thus more inclined to presume that their dogma is the only true faith and to reject conflicting religious claims. This epistemic stance makes them susceptible to rejecting conflicting scientific claims as well. The sectarian intolerance mechanism generates science denial through a different social and psychological process. It might help explain the under-explored sociological questions about science denial: why it varies widely across religious groups, across regions of the United States, and across the different countries of the world.

The social cognition of science denial

Religious groups do not reject *all* of science; they selectively deny certain scientific claims. For instance, Christian fundamentalists reject the theory of evolution more than they reject nuclear technology, as evolution conflicts more directly with the Bible. Behavioral scientists propose that this reflects motivated reasoning: faith creates a motivation to reject conclusions that maintain one's religious worldview (8). This account predicts that science denial would be associated with private religiosity, the intensity of a person's faith (9, 10). However, evidence for this is mixed (11).

Religious intensity cannot explain why some groups of believers reject science much more than others. White evangelical groups rejected scientific information about vaccines more than other Christian groups in the United States. Similar differences exist across the world: Muslims see more conflict between religion and science than do Hindus (12). Another issue is that standard measures of religious intensity may not apply as well to non-Western faiths that prioritize orthopraxy—correct conduct—over orthodoxy—correct belief (13). Religious groups differ in many ways, such as orientations toward dissent that are potentially relevant to attitudes toward science (5).

All this suggests that intensity of faith, and the motivation to maintain it, may not be the only psychological mechanism underlying science denial. Hints about another relevant attribute come from studies that have focused on fundamentalism. Fundamentalists construe their scripture as inerrant and unrivaled (14). They are high not only in religious intensity but also in religious intolerance or dogmatism. The belief that one's religion trumps other faiths creates a cognitive susceptibility to the belief that it trumps science as well. Dismissing other religious beliefs makes one cognitively susceptible or attracted to dismissing science's claims (15, 16). Past research on fundamentalist groups finds some support for this sort of process. Studies over time have consistently found that Evangelicals, compared with other Christian believers, reject atheism—and they also deny homosexuality (17).

We propose that religious intolerance may be an independent psychological pathway to science denial. In this view, religious intolerance should predict science denial over and above religious intensity.

The socioecology of science denial

Where does religious intolerance come from? We propose that it is a function of social experience. Just as cults control their members' social milieu to limit their contact with outsiders, so too do closed religious communities such as the Amish (18, 19).

Religious tolerance or relativity arises in part from the social experience of interacting with people of other religions (20–22). Individuals embedded in a network of high religious diversity develop the ability and habit of acknowledging different perspectives. For example, a study of ministers' social networks found that greater religious diversity correlated with greater religious tolerance (23). Those who seldom interact with people of differing faiths find it easier to dismiss the validity of other faiths. The traditions of religious tolerance by minority sects such as Quakers and Jews may reflect the fact that their members frequently interact with people of other faiths.

More generally, the religious diversity of a region or country conditions people's experience of religious diversity. Regions with low religious diversity, as reflected in the number of different religions practiced by one's neighbors and friends, may be fertile soil for sects that claim a monopoly on truth. Lack of exposure to people of other religions makes it easier to demonize believers of other religions and paint them as "infidels." We hypothesize that actual and experienced religious diversity in one's neighborhood can lead to an increase in religious tolerance and hence, foster acceptance of science. Tolerance for other religions implies tolerance for other belief systems, and this is the mechanism by which we expect that religious tolerance translates to science acceptance.

Of course, at a personal and historical level, low diversity communities and high intolerance beliefs exist in reciprocal causation but that's not to deny the link from structure and perceived structure to intolerance. In this article, we posit that science denial may be related to religious tolerance, defined as one's acceptance of other religions. Previous research on contact theory also supports our argument that the experience of religious diversity ultimately conditions not just acceptance of other religions but other kinds of acceptance as well (24).

Contact theory argues that intergroup contact can reduce intergroup prejudice, under optimal conditions. For instance, researchers have found that a higher frequency of contact with Muslims generally improved other religious believers' opinions about Islam in the United States and contact between religious believers and gay individuals increased support for same-sex marriage (25, 26). Meta-analyses have revealed that intergroup contact "typically reduces prejudice" (27, 28), but there is a "lack of research that systematically investigates the scope conditions suggested by Allport (1954) under which contact is most influential" (24). Also, a large literature on contact theory has focused on racial and ethnic interactions. Our article focuses on contact between followers of different religions and examines how lack of such contact influences religious intolerance and hence, science denial.

Overview of current studies

We report seven studies—with different religions in different regions—that test these effects on science denial, both rejection of scientific recommendations and general disapproval.[1] We find that religious intolerance predicts science denial over and above the effect of religiosity (studies 1 and 2). We also find that (both objective and experienced) low religious diversity predicts science denial through religious intolerance (studies 3 and 4). Evidence for this path comes from correlational analyses as well as experiments that manipulate religious intolerance (studies 5 to 7).

Study 1 examines whether objective religious diversity in US counties ($n = 3{,}093$) influenced residents' practice of social

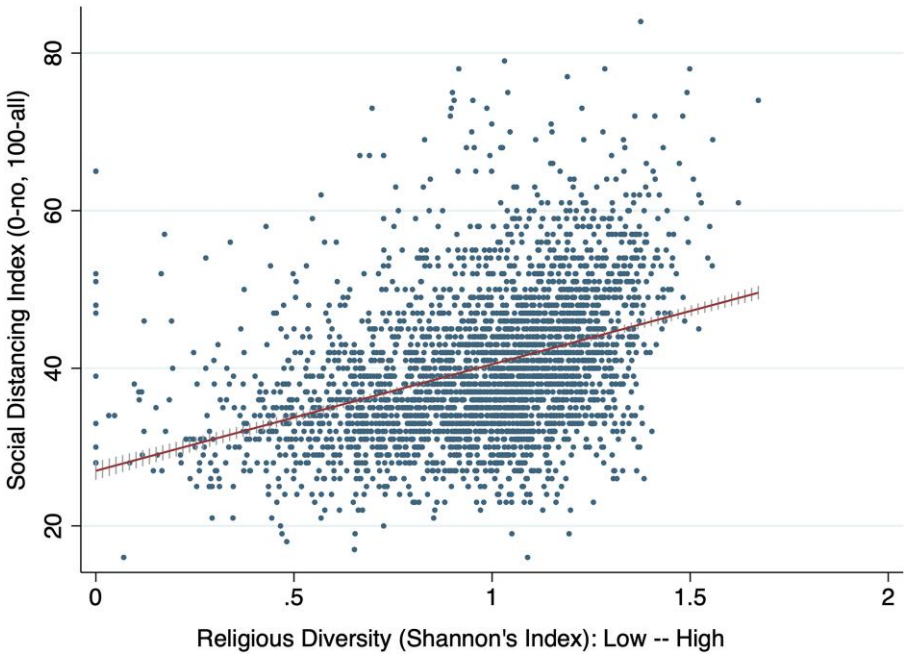

Fig. 1. US county-level social distancing index as a function of religious diversity in study 1.

distancing at the beginning of the COVID-19 pandemic. Study 2 expands the scope by looking across countries and at general measures of science engagement, educational attainment (study 2a, $n = 71$), and innovation performance (study 2b, $n = 141$). Study 3 further tests the proposed effect using worldwide data from 58 countries and 62,599 believers within various religious groups. Study 4 examines whether a Christian individual's experienced religious diversity influences their plan (study 4a, $n = 396$) and actual celebration (study 4b, preregistered, $n = 390$) behaviors during the Easter Sunday 2020 that followed the social distancing recommendation. Study 5a ($n = 493$) validates scales for religiosity, religious intolerance, and science denial attitudes. Study 5b ($n = 392$) also compares religious intolerance with other tolerance-related constructs, such as intellectual humility, receptiveness to opposing views, and openness to experience as personal traits, and study 5c ($n = 598$) tests its mediating role in Christian, Muslim, and Hindu populations. Study 6 tests the proposed mechanism by experimentally manipulating participants' religious intolerance and thus provides causal evidence for its effect on science denial ($n = 400$). Study 7 investigates how a consequential example of scientific denial (COVID-19 vaccine objection) depends on religious intolerance (study 7a, $n = 388$) and replicates the effect with a panel survey targeting US residents (study 7b, $n = 12{,}520$). The primary effects of religious diversity and religious intolerance on science denial hold across various robustness checks, including those that control for political orientation within the US samples (studies 1, 4–7), where Democrats show lower levels of science denial.

Across all studies, additional analyses and details about materials and methods are reported in the SI Appendix.

Results

Study 1: County-level religious diversity and COVID precautions

Study 1 examines whether county-level religious diversity in the United States had an impact on adherence to scientific recommendations during the COVID-19 pandemic focusing on actual behaviors, such as practicing social distancing and getting vaccinated.

Just before April 2020, many US states began implementing stay-at-home and social distancing orders (29). These were not centrally enforced, however, and adherence varied from place to place. We examine whether this form of science denial depended on the local level of religious diversity. We use the aggregated cellphone location data to measure the degree of social distancing in each US county (30). We use county-level data from the US Religion Census and compute an index of diversity following Shannon's procedure (31, 32), based on the probabilities of one particular believer subscribing to each religion (i.e. Evangelical Protestant, Black Protestant, Mainline Protestant, Catholic, Orthodox, and Other) within a county.

As shown in Fig. 1, we find that greater county-level religious diversity predicts more social distancing in April 2020 ($n = 3{,}093$, $B = 13.51$, $SE = 0.59$, $t(3{,}091) = 22.97$, $P < 0.001$, $\eta_p^2 = 0.146$). The effect holds ($n = 3{,}071$, $B = 2.09$, $SE = 0.48$, $t(3{,}056) = 4.31$, $P < 0.001$, $\eta_p^2 = 0.006$) when controlling for the percentage of residents who are religious believers ($t = -5.99$, $P < 0.001$, $\eta_p^2 = 0.012$), religious congregation density ($t = -5.88$, $P < 0.001$, $\eta_p^2 = 0.011$), demographic variables such as population density ($t = 13.28$, $P < 0.001$, $\eta_p^2 = 0.055$), percentage of male residents ($P = 0.12$), percentage of residents older than 60 years ($t = 5.97$, $P < 0.001$, $\eta_p^2 = 0.012$), percentage of college degree holders ($t = 15.73$, $P < 0.001$, $\eta_p^2 = 0.075$), median income ($t = 9.28$, $P < 0.001$, $\eta_p^2 = 0.027$), residential mobility of the county ($P = 0.115$), percentage of democratic voters ($t = 11.51$, $P < 0.001$, $\eta_p^2 = 0.042$), as well as other diversity variables such as income inequality ($P = 0.408$), racial diversity ($P = 0.109$), political diversity ($t = -6.89$, $P < 0.001$, $\eta_p^2 = 0.015$), and percentage of residents who voted in 2020 election ($t = -5.12$, $P < 0.001$, $\eta_p^2 = 0.009$). The results of all models are presented in Table 1. Descriptive statistics and correlations among variables are presented in Table S1a and b.

We find a similar effect with religious diversity resulting in a higher county rate of vaccination in late April 2021 ($t(2{,}791) = 4.56$, $P < 0.001$, $\eta_p^2 = 0.007$) based on the Community Profile

Table 1. Models predicting social distancing scores within US counties in study 1.

	Model 1	Model 2	Model 3	Model 4
Intercept	47.295[a]	−38.594[a]	29.718[a]	−51.781[a]
	(0.937)	(7.407)	(2.146)	(9.111)
Predictors				
Religious diversity (Shannon Index)	8.017[a]	1.797[a]	6.153[a]	2.087[a]
	(0.554)	(0.475)	(0.568)	(0.484)
Religiosity (believer percentage)	−13.070[a]	−3.178[a]	−12.213[a]	−4.592[a]
	(0.834)	(0.760)	(0.813)	(0.767)
Religious congregation density	−1.662[a]	−0.313[a]	−1.637[a]	−0.380[a]
	(0.054)	(0.064)	(0.059)	(0.065)
Controls: demographics				
Population density		1.649[a]		1.462[a]
		(0.109)		(0.110)
Gender (male percentage)		14.253[b]		8.180
		(5.200)		(5.201)
Age (older than 60%)		5.237[c]		17.925[a]
		(2.300)		(3.002)
Education (college degree percentage)		0.326[a]		0.324[a]
		(0.019)		(0.021)
Income		5.116[a]		7.254[a]
		(0.661)		(0.782)
Residential mobility		7.118[d]		6.462
		(4.135)		(4.102)
Political orientation (democratic voter percentage)		9.376[a]		13.726[a]
		(0.967)		(1.193)
Controls: other types of diversity				
Income inequality (Gini Index)			12.063[b]	2.931
			(3.573)	(3.540)
Racial diversity (Shannon Index)			5.439[a]	0.741
			(0.528)	(0.462)
Political diversity (Shannon Index)			−0.321	−9.784[a]
			(1.462)	(1.419)
Political engagement (voter percentage)			19.474[a]	−10.917[a]
			(1.711)	(2.132)
Observations (n)	3,091	3,072	3,071	3,071
Root mean square error (RMSE)	7.561	5.904	7.115	5.825
Adjusted R^2	0.349	0.594	0.410	0.605

Model 1—key predictors; Model 2—with demographic covariates; Model 3—key predictors with other diversity predictors; Model 4—full model with all predictors and covariates. [a]$P < 0.001$. [b]$P < 0.01$. [c]$P < 0.05$. [d]$P < 0.10$.

Report data, and in early May 2021 ($t(2,791) = 4.75$, $P < 0.001$, $\eta_p^2 = 0.008$) based on the Centers for Disease Control and Prevention data. Results of the robustness checks with different dependent variables and different predictors are presented in Table S1c.

We also find that not all types of diversity predict science acceptance. Specifically, we measured three other types of diversity: income inequality, racial diversity, and political diversity. Income inequality is measured by the Gini Index. Racial diversity, computed in a similar way as religious diversity, is based on the probabilities of one particular resident belonging to each racial category (Hispanic or Latino, White, Black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, Other one race, Two or more races) within a county. Political diversity, computed similarly, is based on the probabilities of one particular resident voting for each party (Democrat, Republican, and Other) in the 2020 presidential election. Those three diversity measures do not show consistent patterns as compared to religious diversity. Income inequality does not predict social distancing or the rate of vaccination (Ps > 0.13, η_p^2s < 0.001). Greater racial diversity does not predict social distancing ($P = 0.11$) but predicts a lower rate of vaccination (Ps < 0.001, η_p^2s > 0.083). Greater political diversity predicts less social distancing ($P < 0.001$, $\eta_p^2 = 0.015$) but predicts a higher rate of vaccination (Ps < 0.001, η_p^2s > 0.027). Religious diversity is positively correlated with racial diversity ($r = 0.24$, $P < 0.001$) and political diversity ($r = 0.44$, $P < 0.001$), and is not correlated with income inequality ($P = 0.53$).

It is worth mentioning that we find similar effects of religious diversity on residents' self-reported mask-wearing ($t(3,087) = 2.82$, $P = 0.005$, $\eta_p^2 = 0.003$) based on a New York Times national survey in July 2020, and reduced hesitancy toward vaccination in April 2021 ($t(3,087) = -8.66$, $P < 0.001$, $\eta_p^2 = 0.024$) based on the White House COVID-19 Team Data. However, these effects do not hold when we control for the county's political orientation, which seems to be a stronger predictor than religious diversity for those attitude measures (ts > 13.65, Ps < 0.001, η_p^2s > 0.057).

Study 2: Country-level religious diversity and science engagement

Study 2 examines the consequences of science denial attitude at the country level and tests the effects of religious diversity on scientific engagement worldwide. Study 2a uses data from Programme for International Student Assessment (PISA), which measures high-schoolers' attainment in scientific-educational outcomes for 71 countries (33). We hypothesize that low religious diversity precipitates science denial in the form of lower attainment of PISA scores. As in study 1, we compute the country-level religious diversity based on the distribution of religions within a country (from Pew Research). The results show that controlling

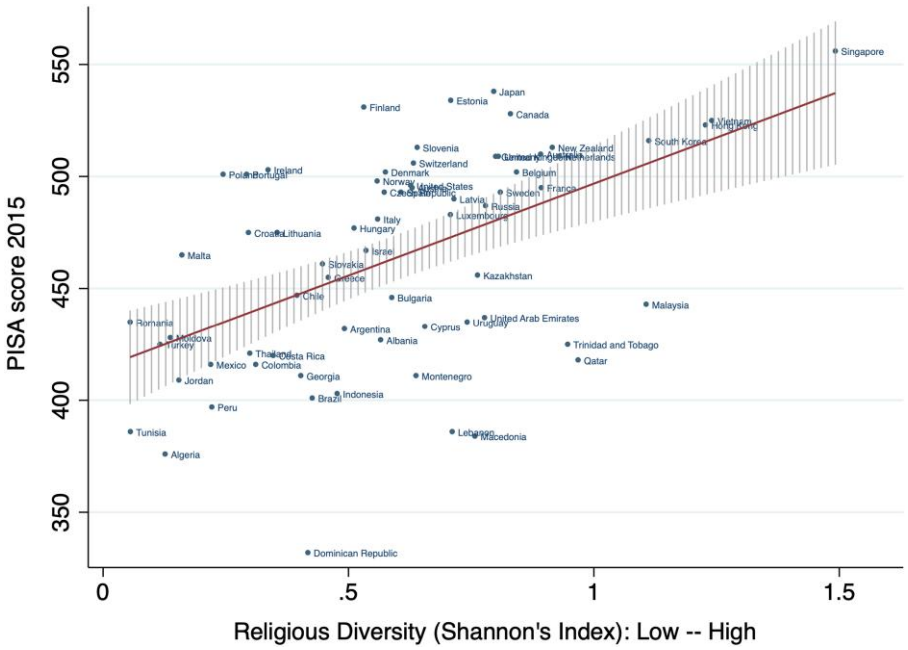

Fig. 2. Region/country-level PISA score as a function of religious diversity in study 2a.

for religiosity ($t = -7.56$, $P < 0.001$, $\eta_p^2 = 0.472$), higher religious diversity predicts a higher PISA score ($n = 67$, $B = 33.07$, SE = 14.40, $t(64) = 2.30$, $P = 0.025$, $\eta_p^2 = 0.076$), as shown in Fig. 2. The effect also holds ($t(67) = 2.74$, $P = 0.008$, $\eta_p^2 = 0.101$) when controlling for total population ($t = 1.94$, $P = 0.056$, $\eta_p^2 = 0.053$) and GDP (gross domestic product) per capita ($t = 6.59$, $P < 0.001$, $\eta_p^2 = 0.393$).

Study 2b replicated the findings of study 2a using data from the (Global Innovation Index [GII] 2015) which scores innovation through tallying patents and other metrics for 141 countries (34). Results show that controlling for religiosity ($t = -10.30$, $P < 0.001$, $\eta_p^2 = 0.471$), higher country-level religious diversity predicts higher GII scores ($n = 122$, $B = 5.25$, SE = 2.63, $t(119) = 2.00$, $P = 0.048$, $\eta_p^2 = 0.032$). The effect also remains ($t(126) = 2.64$, $P = 0.009$, $\eta_p^2 = 0.052$) when controlling for total population ($P = 0.27$) and GDP per capita ($t = 14.57$, $P < 0.001$, $\eta_p^2 = 0.627$).

Next, in studies 3 and 4, we test the full model that religious diversity predicts science denial through religious intolerance.

Study 3: Country-level religious diversity, religious intolerance, and science denial

Study 3 aimed to test the proposed effect that religious diversity predicts science denial through religious intolerance across countries. Study 3 used measures of religion distributions (to measure religious diversity) and measures of religiosity (e.g. "How often do you attend religious services?"), religious intolerance ("The only acceptable religion is my religion."), and science subordination ("Whenever science and religion conflict, religion is always right.") from the World Values Survey (2010–2014) in 59 countries (35). At the country level, controlling for religiosity ($t = 9.82$, $P < 0.001$), higher religious diversity predicts lower science subordination ($n = 56$, $B = -0.37$, SE = 0.10, $t(53) = -3.71$, $P < 0.001$, $\eta_p^2 = 0.206$), as shown in Fig. 3. The effect remains ($t(48) = -2.55$, $P = 0.014$, $\eta_p^2 = 0.119$) controlling for population ($P = 0.99$) and GDP per capita ($P = 0.37$). Further, religious intolerance mediates the effect of diversity on science subordination (average causal mediation effect [ACME] = −0.38, 95% CI [−0.57, −0.20], sensitivity $\rho = 0.70$). Individual-level analyses replicate the findings and can be found in the SI Appendix for study 3. All results replicate with the most recent data from the World Value Surveys (2017–2021), analyzed separately or combined.

Study 4: Individual-level experienced religious diversity, religious intolerance, and COVID precautions

Studies 4a and 4b examine whether an individual's perceived religious diversity in their neighborhood has an impact on their behaviors following scientific recommendations to practice social distancing on Easter Sunday 2020 during the COVID-19 pandemic. During the COVID lockdown, a particularly worrisome form of science denial was holiday group gatherings. Study 4a asks for people's plan for the Easter holiday activities; study 4b is preregistered and conducted after the holiday to test people's real holiday behaviors.

In studies 4a and 4b, we surveyed people's behavior on Easter 2020, a time of stay-at-home orders (36). Instead of county-level measures of diversity, we obtained subjective measures of the religious diversity in participants' neighborhoods (e.g. "There are many people around me believing in the same religion as I do."). We surveyed US Christians about their intentions (prospectively) and actual behaviors (retrospectively), and we also measured religiosity and religious intolerance. In study 4a, participants were asked if they were planning to celebrate Easter Sunday through four group (e.g. "Attend services in person with a small group of people") and four nongroup activities (e.g. "Enjoy the spiritual time alone by myself"). Favoring group activities was negatively correlated with experienced religious diversity ($n = 396$, $B = -0.25$, SE = 0.12, $z = -2.14$, $P = 0.033$, incident rate = 0.78) but not significantly correlated with religiosity ($z = 1.09$, $P = 0.28$, incident rate = 1.12). The negative effect of high perceived religious diversity on group activities was mediated by religious intolerance (ACME = −0.03, 95% CI [−0.05, −0.01], sensitivity $\rho = 0.23$).

In study 4b, we replicated the findings in study 4a with a preregistered survey[2] conducted after Easter, asking about actual activities. Higher experienced religious diversity predicted fewer group activities ($n = 390$, $B = -0.20$, SE = 0.09, $z = -2.35$, $P = 0.019$, incident

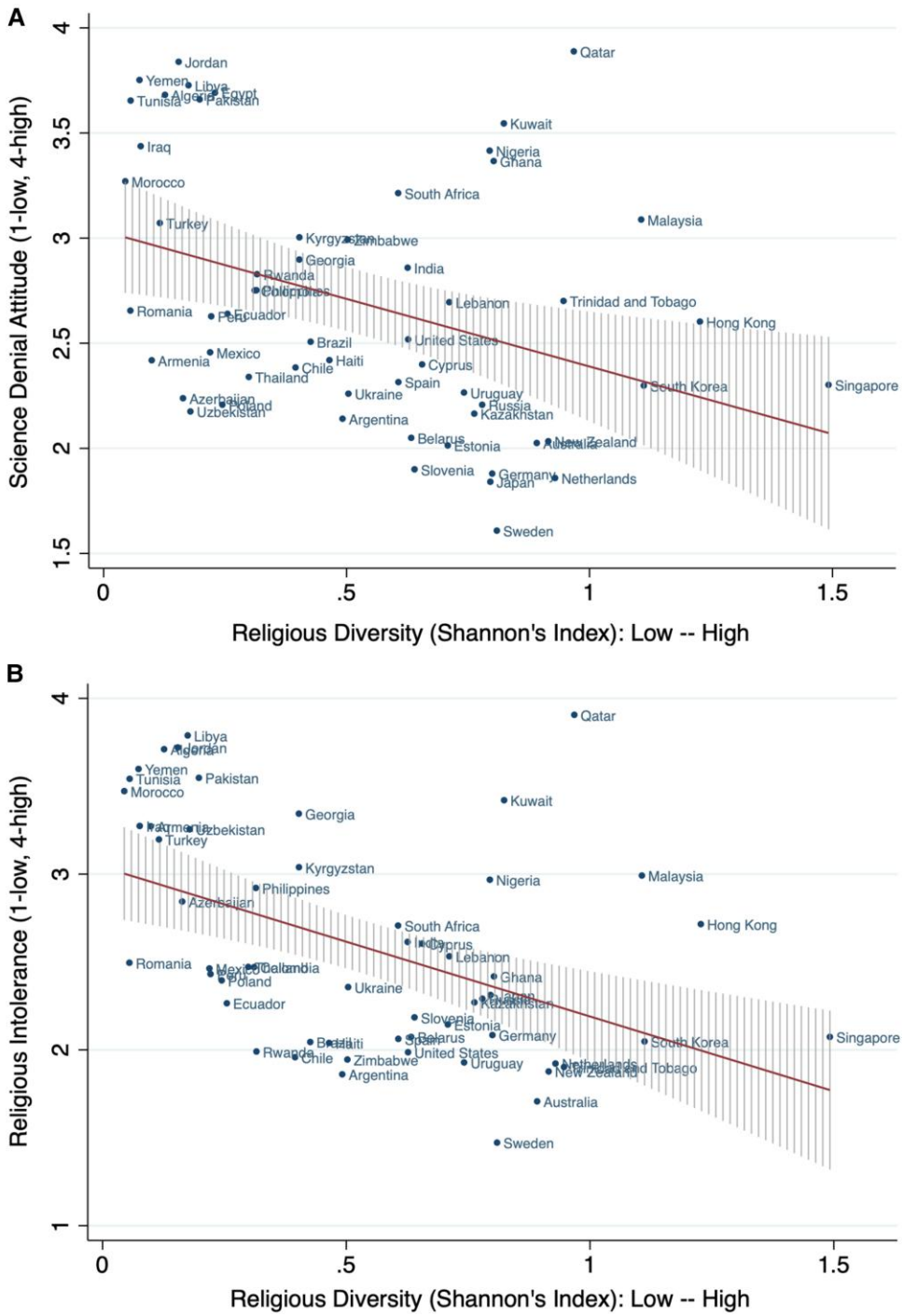

Fig. 3. Region/country-level science denial attitude (A) and religious intolerance attitude (B) as a function of religious diversity in study 3.

rate = 0.82), whereas higher religiosity predicted more nongroup activities ($B = 0.11$, SE = 0.04, $z = 2.54$, $P = 0.011$, incident rate = 1.12). Different from study 4a where there was no effect, higher religious diversity also predicted fewer nongroup activities ($B = -0.09$, SE = 0.04, $z = -2.13$, $P = 0.033$, incident rate = 0.91). Consistent with study 4a, higher intolerance mediated the effect of perceived religious diversity on the number of group activities (ACME = −0.03, 95% CI [−0.05, −0.01], sensitivity $\rho = 0.14$). In studies 4a and 4b, neither religiosity (Ps > 0.17) nor religious diversity (Ps > 0.08) predicted participants' self-reported support for the social distancing policy. However, political ideology did predict support, with liberal leanings correlating with greater support—significantly so in study 4a ($P < 0.001$, $\eta_p^2 = 0.036$) and marginally in study 4b ($P = 0.057$, $\eta_p^2 = 0.009$). Higher perceived religious diversity indirectly predicted greater policy support via reduced religious intolerance (study 4a: ACMEs = 0.09, 95% CI [0.05, 0.13], sensitivity $\rho = -0.31$; study 4b: ACME = 0.10, 95% CI [0.06, 0.16], sensitivity $\rho = -0.38$). Another measure of science denial attitude (i.e. science subordinates to religion) also revealed a consistent pattern across both studies: greater religious diversity perception predicted lower levels of science denial ($P \leq 0.031$, $\eta_p^2 \geq 0.012$), and the effect was mediated by lower religious intolerance. We will continue the examination of various science denial attitudes in the following study 5.

In studies 4a and 4b, reverse causality is a potential problem; our proposed mediator, intolerance, may influence neighborhood choice, which could directly influence science denial behavior. We ruled this out by conducting alternative mediation models with religious intolerance as the predictor and neighborhood diversity as the mediator. This alternative causal path does not predict group activities in both studies (37, 38).

Next, studies 5 to 7 focus on the link between religious intolerance and science denial at the individual level.

Study 5: Individual-level religiosity, religious intolerance, and science denial in the context of different faiths

Study 5 broadens the believer populations beyond US Christians to other faiths. For comparison, we look at the majority faiths in other nations. Two pretests confirmed that our measures of religious intolerance and religiosity, as well as other intolerance measures, had discriminant validity (see studies 5a and 5b in SI Appendix). For instance, study 5b[3] with Christians from the United States found that although our measures of religious intolerance are correlated with other types of intolerance such as intellectual humility ($rs < 0.36$), receptiveness to opposing views ($rs < 0.30$), and openness to experience personal traits ($rs < 0.22$), the main effect of religious intolerance on science denial attitude ($n = 384$, $B = 0.25$, SE = 0.04, $t(363) = 6.92$, $P < 0.001$, $\eta_p^2 = 0.117$), and the mediating role of religious intolerance for the effect of religious diversity on science denial attitude, both hold when controlling for those other intolerance constructs. In the main study 5c, we recruited Christians from the United States, Hindus from India, and Muslims from Pakistan. All participants rated their religious intolerance, religiosity, and attitude toward science. Note that our theory would argue that religious intolerance predicts higher science denial—whether assessed by disfavoring science that conflicts with religion or by general disapproval of science (e.g. opposition to scientific research). Both indicators of science denial showed supporting evidence. Controlling for religiosity and demographics (i.e. gender, age, education, income, and social class), religious intolerance predicts higher science denial—both with regard to science that directly conflicts with their religion and with regard to general disapproval of science. These patterns held for Christians (science subordinates to religion: $n = 265$, $B = 0.47$, SE = 0.05, $t(255) = 9.94$, $P < 0.001$, $\eta_p^2 = 0.279$; general science disapproval: $n = 265$, $B = 0.36$, SE = 0.05, $t(255) = 7.68$, $P < 0.001$, $\eta_p^2 = 0.188$), Hindus (science subordinates to religion: $n = 206$, $B = 0.47$, SE = 0.05, $t(198) = 15.04$, $P < 0.001$, $\eta_p^2 = 0.533$; general science disapproval: $n = 206$, $B = 0.21$, SE = 0.05, $t(198) = 4.66$, $P < 0.001$, $\eta_p^2 = 0.099$), and Muslims (science subordinates to religion: $n = 125$, $B = 0.40$, SE = 0.13, $t(117) = 3.13$, $P = 0.002$, $\eta_p^2 = 0.077$; general science disapproval: $n = 125$, $B = 0.27$, SE = 0.08, $t(117) = 3.28$, $P = 0.001$, $\eta_p^2 = 0.084$). Religiosity predicts both forms of science denial for the US Christians and Indian Hindus ($Ps < 0.05$), but not for Pakistani Muslims ($Ps > 0.47$).

Study 6: An experimental test of the effect of religious intolerance on science denial

Study 6 provides causal evidence for the effect of religious intolerance on science denial in an experimental setting by manipulating the cognitive salience of religious intolerance, our presumed mediating mechanism. We recruited 400 Evangelical Protestants and randomly exposed half of them to a New Testament verse that discounts the validity of other religions. Endorsement of science denial attitudes was higher in the intolerance-primed condition ($M = 4.34$, SD = 2.11) than in the control condition ($M = 3.72$, SD = 1.93), $t(398) = 3.09$, $P = 0.002$, $d = 0.31$. See the details on manipulations and analyses in SI Appendix S6.

Study 7: Religious tolerance among nonbelievers and COVID precautions

In study 7, we explored a broader religious tolerance construct—attitude to religious diversity—that can be measured for both believers and nonbelievers. Studies 7a and 7b collect data from over 6,000 Americans to explore how religious tolerance (in this broad sense) predicts vaccine acceptance. In study 7a, it predicts acceptance of the COVID-19 vaccine in February 2021 ($n = 388$, $B = 0.33$, SE = 0.06, $t(385) = 5.32$, $P < 0.001$, $\eta_p^2 = 0.069$) whereas religiosity does not ($t(385) = 0.14$, $P = 0.89$, $\eta_p^2 < 0.001$). Study 7b uses a longitudinal survey design to rule out carryover effects across survey questions and finds similarly that religious tolerance in February 2021 predicts vaccine acceptance in March 2021 ($n = 6{,}172$, $B = 0.31$, SE = 0.02, $t(6{,}170) = 18.38$, $P < 0.001$, $\eta_p^2 = 0.052$). See the details on measures and analyses in SI Appendices S7a and S7b.

Discussion

Across seven studies that operationalize the key constructs in different ways, we find that lower religious diversity precipitates religious intolerance, which, in turn, engenders science denial. Tests of mediation are consistent with this causal model and not alternative configurations. We also experimentally test the causal relationship between religious intolerance and science denial.

Among all studies, 23 out of 27 analyses involving religious diversity show significant effects on science denial, with a medium effect size of $\eta_p^2 = 0.065$ (controlling for religiosity). Similarly, 21 out of 21 analyses involving religious intolerance show significant effects on science denial, with a large effect size of $\eta_p^2 = 0.225$ (controlling for religiosity). On the other hand, only 18 out of 28 analyses involving religiosity show significant effects on science denial, with an average effect size of $\eta_p^2 = 0.195$ (controlling either for religious diversity or intolerance depending on the study). Note that the effect size of religiosity is smaller compared to that of religious intolerance. Regarding the effect of political ideology, 13 out of 18 analyses involving political orientation show significant effects on science denial with Democrats and liberal-leaning participants showing lower science denial, with an average effect size of $\eta_p^2 = 0.051$ (controlling for religious measures depending on the study).

We covered a wide range of topics of science denial in this article, such as when religious requirements directly conflict with scientific recommendations (e.g. in the context of stay-at-home advice during the COVID-19 pandemic and attitude toward stem cell research), and general disengagement with science (e.g. disapprove of funding scientific research, attitude toward COVID-19 vaccination, as well as countries' performance in scientific education and innovation).

These findings have implications for how we understand and respond to the problem of science denial or, more broadly, engagement with and acceptance of science. This behavioral syndrome is often traced to religiosity (the intensity of faith and practice), but an independent contributor is religious intolerance. Policymakers cannot (and should not) reduce religious intensity but they can (and should) work to reduce religious intolerance. Our findings showing that religious diversity correlates positively with religious tolerance suggest one path forward may be to enhance such diversity (e.g. Singapore's Ethnic Integration Policy [EIP]).

The only past research on effects of people's religious openness has relied on the construct of fundamentalism (14), which has

also been found to influence people's general motivation for cognitive closure (39). Furthermore, our data suggest that a unique contributing factor to the rejection of a scientific understanding of the world is an intolerant attitude toward other religions, over and beyond other general intolerance constructs such as intellectual humility, receptiveness to opposing views, or openness to experiences as personality traits. We suspect that willingness to revise and update one's beliefs, rather than mere respect for other faiths, is more closely related to science acceptance, and we encourage future researchers, particularly in cross-cultural studies, to measure more specific dimensions of religious attitudes.

Ethnographic studies have also suggested that science denial is tied to people's experience of community (40). The current studies identify a dimension of community experience that critically matters. It is religious diversity, not just racial diversity or income diversity.

A related topic is religious extremism. Scholars have critiqued the journalistic tendency to contrast "good" moderate religions with "dangerous" extreme religions and advocated comparing religions on more dimensions (41). Research among Muslim groups in several countries has found that personal intensity of faith is negatively associated with support for political violence although collective-level measures of religious conformity are positively associated (42). The mechanism of religious intolerance may be more relevant than that of religious intensity.

Some limitations in our studies can be addressed in future research. For instance, in study 2, although we controlled for overall religiosity in our analyses, we acknowledge the potential for additional cross-country factors beyond our current scope, presenting avenues for future research. One such intriguing aspect could be the interaction between religious involvement and religious diversity, as well as how religious diversity influences science acceptance among different religious groups. The tolerance toward religious diversity measure in study 7 also captures individuals' tolerance toward any form of diversity (e.g. gender or ethnic diversity), or, more broadly, general tolerance as an individual difference trait (e.g. intolerance of uncertainty, need for cognitive closure). Rooted in the literature on how religion and religiosity influence the acceptance of science, our focus was on religious intolerance as an antecedent to science denial. Future research is needed to further investigate the role of intolerance more broadly, as well as general intolerance traits, in predicting science denial.

Another direction for future research is to examine whether increasing the salience of religious tolerance can reduce science denial. Our experiment found that increasing the salience of religious intolerance increased science denial (43). But for applied reasons, it is important to reduce religious intolerance so as to enable science acceptance. Future research could also directly test the causal relationship between religious diversity and science denial by exploiting natural shocks or interventions of religious diversity in a region or in one's life (e.g. through a sudden influx of Islamic refugees into a Christian majority county). Interesting questions concern whether sudden diversity could create intolerance rather than tolerance as shown by recent work on culture mixing (44).

The current findings are analogous to the contact hypothesis about prejudice reduction (28), which has been studied primarily with regard to ethnicity (27). The extent to which societies reap the rewards of their religious diversity likely depends on the degree to which local communities are diverse and promote contact. An example is Singapore's EIP introduced in 1989 to diversify public housing where more than 80% of residents live. Given that its Chinese, Malay, and Indian residents tend to differ in religions, it has also created inter-religious contact, which may have contributed to its outstanding PISA scores and innovation metrics (study 2). Our findings also have implications for science communication and education. One might reach science-resistant groups by identifying and highlighting the viewpoint diversity within their communities, even if it involves merely diverse sects of the same religion, diverse superstitions such as horoscopes versus numerology, or diverse avocations such as dowsing or cryptozoology.

In sum, social environments with low religious diversity precipitate religious intolerance. While many dangers of this are well-understood, we have identified an additional nefarious consequence: science denial.

Materials and methods

Additional details about materials and methods for all studies are reported in the SI Appendix. This research obtained IRB approval from Columbia University Human Subjects Protocol (ID: AAAR6317) for studies in which the authors collected data from human participants, and informed consent was obtained from all participants. Data are available at the OSF (open science framework).

Notes

[1] In all online studies (studies 4a, 4b, 5a, 5b, 5c, 6, and 7a), only multiple responses from the same IP address were excluded because they could have originated from the same individual(s). No other participants were excluded. The data used in this manuscript are available at https://osf.io/m2whz/?view_only=927c4c038dd04472b0f91bcfa4117744.

[2] The preregistration can be found at: https://osf.io/9tvua/?view_only=efc7937927f5442d94784a282903a489.

[3] The preregistration can be found at: https://osf.io/jm5b8/?view_only=4e06a608003c4b1882a3e4ea9390efd0.

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Supplementary Material

Supplementary material is available at *PNAS Nexus* online.

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Author Contributions

All authors contributed equally to this manuscript by designing and performing the research, analyzing data, and writing the article.

Data Availability

All data, results, and materials of studies will be available upon publication via OSF: https://osf.io/m2whz/?view_only=927c4c038dd04472b0f91bcfa4117744.

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