

Inoculation discourages consumption of news from unreliable sources, but fails to neutralize misinformation

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Abstract

Can inoculation help people avoid misinformation as well as protect them against its effects? Previous research has found that inoculation, which warns people about false information and preemptively refutes it, can reduce misinformation's effects on beliefs. However, past studies focus on a few issues and do not examine inoculation's effects on information consumption. In a preregistered experiment, we test inoculation's effects against dubious expert messages on information choice and belief accuracy for both climate change and GMO safety. Inoculation increased the reliability of the news people chose to consume by making participants less likely to click on unreliable headlines (but not more likely to click on reliable headlines). Inoculation also improved belief accuracy on climate but didn't mitigate misinformation's negative effects on beliefs. These results suggest that inoculation can reduce exposure to misinformation but that its protective effects for belief accuracy may be overstated.

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Misinformation can shape policy attitudes and distort democratic debate on issues like climate change and health care (Nyhan 2010, 2020; Rode et al. 2021). These false and unsupported claims, which frequently circulate in news coverage and on social media, make it difficult for people to know what information to consume or to believe.

These concerns are often especially acute on issues related to scientific expertise. Historically, the general public tends to learn about science through the news media, but journalists often fail to adequately convey the consensus among scientists and other experts (Boykoff and Boykoff 2004; Merkley 2020). These problems may be further exacerbated online, where misinformation about science-related issues is widely accessible.

One influential approach to countering misinformation is inoculation, an intervention that relies on an analogy to biological vaccines. Just as a vaccine exposes the immune system to a weakened virus to strengthen its defenses, inoculation seeks to expose people to weakened versions of false information to boost their cognitive immunity against future persuasive attacks (McGuire 1964). An inoculation is comprised of two main elements: a threat that warns of future misinformation exposure, and a refutation of the anticipated misinformation that provides individuals with the conceptual tools to resist (Lewandowsky and Van Der Linden 2021; Traberg, Roozenbeek, and van der Linden 2022).

Past studies have found that inoculation can reduce people's susceptibility to misinformation (e.g., Cook, Lewandowsky, and Ecker 2017, van der Linden et al. 2017, Roozenbeek et al. 2022) and thereby improve the accuracy of their factual beliefs. However, these studies typically consider a single issue that is highly controversial (most notably, climate change). Additionally, while they examine the effect of inoculation on the accuracy of people's beliefs after misinformation exposure, they do not consider the effect that inoculation may have on the accuracy or credibility of the information that people choose to consume in the first place.

In this article, we examine the effect of inoculation on the information people choose to consume and test whether its effects extend across multiple issues. Replicating the design of Cook, Lewandowsky, and Ecker (2017), we specifically test the effects of an inoculation against the misinformation tactic of "fake experts" — individuals who are presented as knowledgeable on a topic in which they lack real expertise. We build on Cook's study in two ways. First, we test the effects of inoculation on two issues: climate

change (the subject of the original Cook et al. study) and the safety of genetically modified organisms (GMOs). Second, Cook et al. assess belief accuracy by studying whether inoculation decreases people's beliefs in misinformation, but we also consider studying whether inoculation increases people's selection of accurate news with information from real experts rather than misinformation featuring unreliable experts.

Following past research (Cook, Lewandowsky, and Ecker 2017; van der Linden et al. 2017), we hypothesize that inoculation will improve belief accuracy and reduce the effects of misinformation exposure across both issues (climate change and GMOs). Based on this logic, we further hypothesize that inoculation will improve people's information selection, making them more likely to select news headlines that feature reliable experts and endorse the claims attributed to them.

Our results indicate that inoculation makes participants less likely to select headlines featuring fake experts and to believe claims made by them. However, we find no consistent evidence that inoculation makes people more likely to consume or believe accurate headlines featuring reliable experts. Inoculation also measurably increases the accuracy of the beliefs that people express about climate change but not about GMOs. Finally, we find no evidence that inoculation offsets the harmful effects of misinformation exposure on the accuracy of people's beliefs about either issue. Our results suggest that inoculation can discourage people from consuming misinformation but may fail to offset the consequences of exposure to it.

Theoretical expectations

Our study examines the effect of inoculation on information selection and factual beliefs. We thus first review prior research on the effects of inoculation and the mechanisms that promote accurate information selection. We also discuss topic-specific approaches to inoculation and explain how our study will test for cross-issue effects between climate change and GMO safety.

We propose that inoculation should improve the accuracy of the news that people consume, drawing on prior research that identifies accuracy motives and congeniality bias as key factors shaping information exposure (Hart et al. 2009). First, inoculation “provides participants with a counter-argument to immediately dismiss information” (Cook, Lewandowsky, and Ecker 2017, 4). It should therefore help

accuracy-motivated news consumers to identify and avoid misinformation. Second, inoculations focus respondents' attention on accuracy in general, which will encourage respondents to more carefully consider the reliability of the information they encounter when selecting information (Pennycook et al. 2020). Third, inoculation encourages people to think harder about the information that they consume (Cook, Lewandowsky, and Ecker 2017), inducing a deeper level of consideration that should improve people's ability to identify and avoid deceptive headlines (Pennycook and Rand 2018). All of these mechanisms should correspondingly help to offset or minimize congeniality bias. In general, the information that people consume about controversial issues like climate change is often deeply interlinked with their political views (Feldman and Hart 2018; Newman, Nisbet, and Nisbet 2018). By equipping people to identify false claims, inoculation can help prevent people from consuming congenial misinformation that might otherwise be appealing.

We seek to test these expectations about the effects of inoculation on information consumption, and to replicate and extend prior research evaluating the effects of inoculation on factual beliefs. We study these effects in the context of two issues on which misperceptions are common: climate change and GMO safety. Importantly, these issues differ in how polarized they are and in their relationship to pre-existing attitudes.

Studies of the effect of inoculation on climate change beliefs have typically reported positive results (e.g., Cook, Lewandowsky, and Ecker 2017; van der Linden et al. 2017; see Banas and Rains 2010 for an earlier meta-analysis). Most notably, Cook, Lewandowsky, and Ecker (2017), the study on which we modeled our design, tested the efficacy of an inoculation against the misinformation tactic of using fake experts to undermine perceptions of scientific consensus on climate change. They found that the inoculation was successful in mitigating the influence of misinformation on belief accuracy among people with high support for the free market. In other words, inoculation may prevent people from endorsing false claims that align with their political attitudes, beliefs, or identities (James and Van Ryzin 2017; Taber and Lodge 2006), a pattern we observe in public opinion about climate change in the U.S. (Alec Tyson and Kennedy 2023, e.g.).

However, for issues that are less partisan or polarizing, the protective effects of inoculation may be more limited. In Schmid-Petri and Bürger (2022), a replication of Cook, Lewandowsky, and Ecker

(2017) conducted in Germany, inoculation had no effect on people's climate beliefs, barring a small effect on a subset of free-market supporters. To explain this, Schmid-Petri and Bürger (2022) emphasize that polarization over climate beliefs is much lower in Germany, which could have contributed to a ceiling effect among participants who already held accurate beliefs about climate change. In the United States, the safety of GMOs is a less polarized topic in that false and unsupported beliefs do not closely align with partisanship or ideology (Enders et al. 2022). As a result, congeniality bias and motivated reasoning may play a weaker role in information consumption and belief formation, which may be driven instead by factors like emotions such as disgust and a lack of scientific knowledge (Blancke et al. 2015; Wunderlich and Gatto 2015). However, inoculation may still help people identify tactics used to promote false claims about the issue.

In addition to these notable contrasts between climate change and GMO safety, our evaluation of these two topics also allows us to measure whether a single inoculation can counter misinformation across multiple issues (building on Parker, Ivanov, and Compton 2012, who showed that inoculation messages about unprotected sex also protected attitudes against binge drinking). Importantly, however, our inoculation includes brief sections on both climate change and GMO safety; we therefore test whether a combined inoculation can protect against misinformation for two issues rather than directly testing for potential cross-protection resulting from inoculating participants on a single issue.

Based on the theory described above, we preregistered the following hypotheses prior to data collection (<https://osf.io/fuem9>):

- H1a (reliable news consumption): Participants who are randomly assigned to inoculation will be more likely to read stories featuring reliable experts and to select them when asked to choose among headlines on the issue (climate change or GMO safety).
- H1b (headline accuracy): Participants who are randomly assigned to inoculation will rate the claims in article headlines featuring unreliable experts as less accurate and the ones in article headlines featuring reliable experts as more accurate.
- H2a (belief accuracy): Participants who are randomly assigned to inoculation but not exposed to a misinformation article about an issue will express more accurate beliefs about the issue (climate

change or GMO safety).

- H2b (protective effects): Random assignment to inoculation will diminish or reverse any negative effects of exposure to a misinformation article (climate change or GMO safety) about an issue on belief accuracy.

In addition to these hypotheses, we preregistered three research questions in areas where we had weaker theoretical priors. First, findings are mixed on the effects of exposure to misinformation on belief accuracy (see, e.g., Guess et al. 2020 vs. Drummond, Siegrist, and Árvai 2020). We therefore sought to measure the effect of reading a misinformation article on the accuracy of participants' beliefs about the topic of the article (climate change or GMO safety) (RQ1). Second, Republicans and conservatives are more likely to endorse conspiracy theories about climate change, but belief in false claims about GMO safety do not align with partisanship and ideology (Enders et al. 2022). We therefore ask if the effects of inoculation vary by party (Democrats vs. Republicans) or issue (climate change vs. GMO safety). Finally, we examine whether random assignment to inoculation decreases people's confidence in the scientific community per Cook, Lewandowsky, and Ecker (2017) (RQ3).

Methods

Participants

We recruited 3,059 participants in total. Our study was conducted among U.S. residents age 18 or older recruited May 6–11, 2023 from the Prolific and Connect online survey platforms. Because online surveys often overrepresent Democrats, we first recruited 1,000 participants on Prolific. Since over 55% of the first 1,000 participants identified as Democrats or leaned Democrat, we sought to recruit an oversample of 977 Republicans to approximately equalize our sample's partisan composition after 3000 valid responses (following our pre-registration). Due to the limited number of active Republicans on the Prolific platform, we also began offering our survey to identified Republicans on Connect from May 7–11, 2023 (as anticipated in the preregistration).¹

¹We are unable to determine if respondents completed the survey on both platforms but fewer than 20% of Prolific and Connect respondents reported taking surveys on the other platform.

After excluding a handful of respondents who failed a pre-treatment attention check, the final sample consisted of 3,007 participants.² Half are male (50.0%), 71.9% identify as non-Hispanic whites, and 51.2% graduated from college. The median age group is 35–44; 40.0% are 18–34, 22.8% are 35–44, and 37.2% are 45 or older. Most importantly, we achieved near-perfect partisan balance: 44.1% identify as Democrats or lean Democrat, while 46.4% identify as Republicans or lean Republican.

Experimental design

We conducted a between-subjects experiment on the Qualtrics online survey platform. After providing informed consent, participants were asked about their demographic characteristics and completed a pre-treatment battery about their factual beliefs on climate change and GMO safety.

The primary experimental manipulation randomly assigned participants with probability .5 to an inoculation adapted from Cook, Lewandowsky, and Ecker (2017) against “fake experts” — people who are presented as knowledgeable on a topic in which they lack real expertise. For example, American college graduates might appear to be credible, but they lack specific expertise on the science of climate change. Our inoculation seeks to help participants distinguish between fake experts propagating false claims and real experts advocating for the scientific consensus, using examples from the tobacco industry’s efforts to dispute the health risks of smoking. The original inoculation warns that this “fake experts” strategy is being used to spread misinformation about climate change. We modified the original text to add a paragraph to the inoculation about how “fake experts” tactics are also used to spread GMO misinformation (following the stylistic and statistical structure of Cook et al.’s climate paragraph). In this sense, the resulting inoculation is both technique- and fact-based. A technique-based inoculation protects its reader against a persuasion strategy, regardless of the misinformation content, such as warning people about “fake experts” (Roozenbeek, Traberg, and van der Linden 2022). A fact-based inoculation corrects specific misinformation, such as informing the reader that there is a scientific consensus on the existence of climate change and the safety of GMOs. Finally, to ensure that both groups received a stimulus, the control group received a brief article about Delta Airlines. (All stimuli are provided in

²In a slight deviation from our preregistration, we asked each participant to answer two pre-treatment attention checks rather than one to follow Prolific platform rules. Participants who failed either attention check were removed from our sample (n=52). We also removed 59 duplicate responses from Prolific participants, keeping only their first response.

Online Appendix A.)

Participants were then asked about a series of realistic headlines about climate change or GMO safety featuring reliable or unreliable experts (adapted from real headlines or created by the authors with the assistance of ChatGPT). For each topic, two headlines made a valid claim about climate change or GMO safety and two propagated misinformation. The valid claims were attributed to reliable experts (e.g., “Survey Finds 97% of Climate Science Studies Agree Warming Is Man-Made”) while the misinformed beliefs were attributed to unreliable experts (e.g., “Americans with University Degrees in Science Affirm: Human Activities Don’t Cause Global Warming”). To minimize confounds, the headlines were not attributed to specific news outlets.

We first asked participants about the likelihood that they would click each individual headline in separate questions. We then asked participants which headline they would click out of the four presented for each issue (the issues were presented in random order).

We also asked participants to rate the accuracy of the claim in each headline to understand whether participants choose headlines because they find them to be accurate or for another reason (e.g., they want to debunk them). Due to concerns that making accuracy considerations salient can affect subsequent survey responses (Pennycook and Rand 2022), we randomized the placement of these perceived accuracy questions. Specifically, participants were randomized with equal probability to either rate the accuracy of the headlines after the headline click question or at the end of the survey after answering questions measuring the accuracy of their beliefs.

Finally, we randomly assigned participants to read a misinformation article about climate change modeled after Cook, Lewandowsky, and Ecker (2017) or a misinformation article about GMO safety designed to be stylistically similar (see Online Appendix A). The misleading climate article is a modified version of the Global Warming Petition Project, which falsely claims that tens of thousands of American scientists have endorsed the claim that there is no scientific consensus on human-caused global warming (Kasprak 2016). The misleading GMO article is also a petition claiming that hundreds of scientists, physicians, and legal experts dispute the scientific consensus that GMOs are safe. To generate symmetry between the articles, we altered the text to have similar structures and to include a quote from a fictional “fake expert.” We then asked participants to again report their beliefs on climate change and GMO safety

as well as their trust in the scientific community. Participants in the treatment group also completed a manipulation check to test whether they read and understood the inoculation. All participants were debriefed about any misinformation they encountered during the study.

Outcome measures

Our experiment has four primary outcomes: (1) likelihood of clicking an article about reliable experts (four-point Likert scale), (2) choosing to read an article featuring reliable experts out of four headlines offered (binary measure), (3) perceived accuracy of claims attributed to experts in headlines (four-point Likert scale), and (4) accuracy of participant factual beliefs (four-point Likert scale). These are measured separately by issue (climate change and GMO) pre- and post-treatment. Because participants evaluated both accurate and inaccurate statements, we reverse-coded the scales on which participants rated the inaccurate headlines and statements (described further below). Each is therefore coded so that higher values represent increased accuracy and reliability.

We created several indices to simplify our results. First, we created a variable representing a participant's mean likelihood of selecting climate headlines featuring reliable experts and avoiding climate headlines featuring unreliable experts (mean of four measures of the likelihood of choosing climate headlines where 4 = "Very likely to click" and 1 = "Not at all likely to click" for headlines featuring reliable experts and "1 = Very likely to click" and 4 = "Not at all likely to click" for headlines featuring unreliable experts). We repeated this same process for GMO headlines.

We also repeated this process for mean accuracy of claims in climate and GMO-related headlines (where 1 = "Not at all accurate" and 4 = "Very accurate" for valid claims from reliable experts and 4 = "Not at all accurate" and 1 = "Very accurate" for false claims from unreliable experts). The same procedure was applied to post-treatment measures of issue belief accuracy on climate change and GMO safety.

To measure article choice, we created a binary variable for each topic where 1 indicates the participant selected a reliable headline and 0 indicates the participant selected an unreliable headline.

All of these outcome measures thus combine effects on accurate claims and headlines featuring reliable experts with effects on false claims and headlines featuring unreliable experts. For brevity,

however, we describe these outcome measures below as the likelihood a participant indicates they would click on a reliable headline, choose to read a reliable article, or perceive a headline as accurate.

Finally, we also measured trust in scientists on a three-point scale where 1=“hardly any” and 3=“a great deal.”³

Statistical methods

We estimated the effects of our treatments using ordinary least squares (OLS) with robust standard errors. Our primary outcomes are measured at the participant level. Covariates were selected for each outcome variable using the lasso (least absolute shrinkage and selection operator) from a pre-registered set of candidate variables (indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media) to increase the precision of our treatment effect estimate (Bloniarz et al. 2016) Unless otherwise specified, all variable definitions and model results below follow our preregistration, which is available at <https://osf.io/fuem9>.

As noted above, this study randomized the placement of questions about the perceived accuracy of article headlines. We did not find that the order of accuracy questions measurably changed any of our results (see Table B1) so we present results for the full sample below following our preregistration.

Results

In total, 92.8% of the participants who received the inoculation passed our manipulation check at the end of the study, successfully identifying “fake experts” as the misinformation tactic employed by the tobacco industry in the article they previously read. We are therefore confident that almost all participants read and understood the inoculation.⁴

We first consider the effects of inoculation on information choice and headline evaluation. Means by condition and 95% confidence intervals are graphed by issue and condition in Figure 1. Consistent with

³Our outcome variables were coded as specified in our pre-registration (<https://osf.io/fuem9>) with the exception of trust in scientists. On that question, we deviated from our pre-registration and recorded this measure so that higher values indicate greater confidence for the sake of clarity and consistency.

⁴Participants who did not pass the manipulation check are included in all analyses to avoid post-treatment bias (Montgomery, Nyhan, and Torres 2018).

H1, inoculation increased participants’ intention to click on and read stories featuring reliable experts and improved the accuracy of their ratings of the validity of the claims presented in the headlines. As shown in Table 1, being inoculated significantly increased the participants’ likelihood of clicking accurate headlines (0.183, $p < 0.005$ for climate headlines; 0.075, $p < 0.005$ for GMO headlines). Being inoculated also significantly increased the probability that participants would choose to read an article featuring a reliable expert (0.099, $p < 0.005$ for climate headlines; 0.041; $p < 0.05$ for GMO headlines). Being exposed to inoculation also increased the accuracy of participants’ evaluations of the claims featured in headlines (0.075, $p < 0.005$ for climate headlines; 0.054, $p < 0.005$ for GMO headlines). These results provide evidence that inoculation increases preferences for and belief in information from reliable experts compared to fake experts promoting misinformation.

These results are most easily interpreted in substantive terms using the binary headline choice measure. Preferences for a reliable climate headline increased from 63.6% in the control group to 73.4% the inoculation group and from 57.3% to 61.3%, respectively on GMO safety.

Table 1: Inoculation effect on information choice and headline perceptions

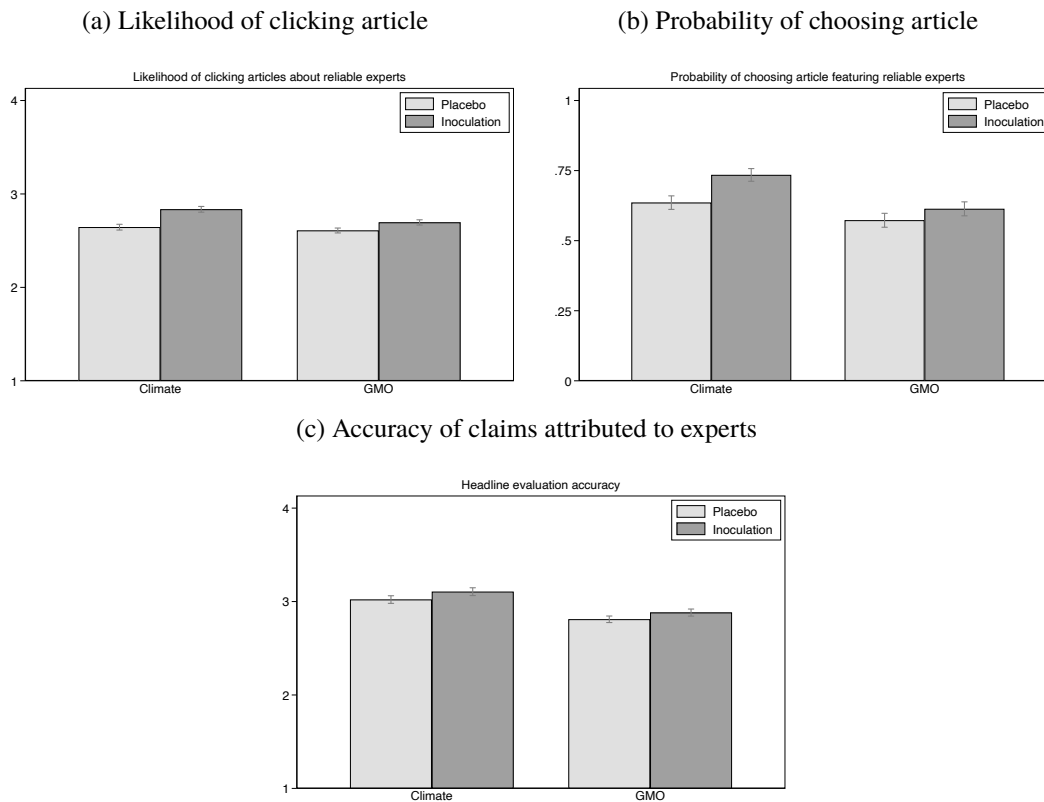
	Likely to click reliable article		Choose to read reliable article		Accurate beliefs	
	Climate	GMOs	Climate	GMOs	Climate	GMOs
Inoculation	0.183*** (0.018)	0.074*** (0.017)	0.099*** (0.017)	0.041* (0.018)	0.078*** (0.018)	0.054*** (0.017)
Control variables	✓	✓	✓	✓	✓	✓
N	2986	2987	2994	2993	2967	2969

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). Likelihood of clicking and perceived headline accuracy were measured on four-point Likert scales; article choice was a binary measure. Headlines featuring unreliable experts were reverse-coded. Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarczyk et al. 2016). See Online Appendix A for stimuli and question wording.

We also present results for the effect of inoculation on participants’ self-reported likelihood to click on a headline or perceptions of the headline’s accuracy. These disaggregated results allow us to explore differences in the effect of inoculation on headlines with reliable or fake experts.

The effect of inoculation on participants’ likelihood to click on headlines and the perceived accuracy for each headline is reported in Table 2. Among the four reliable headlines, there was only one instance

Figure 1: Inoculation effects on choosing information from reliable experts



Means and 95% confidence intervals. Likelihood of clicking and perceived headline accuracy were measured on four-point Likert scales; article choice was a binary measure. Headlines featuring unreliable experts were reverse-coded. See Online Appendix A for stimuli and question wording.

in which the inoculation significantly improved participants’ news consumption or accuracy perceptions — the reliable article titled “Stanford Climate Scientists Demonstrate Carbon Emissions Warming the Planet.” Moreover, the effect is substantively small (0.083 on a four-point scale). For the two reliable headlines emphasizing scientific consensus (“97% of climate scientists ...” and “92% of biomedical scientists...”), there was no effect of inoculation on participants’ likelihood to click or perceived accuracy. In addition, the inoculation backfired for one of the reliable articles titled “90 Nobel Laureates in Physics, Chemistry, and Medicine Say Genetically Modified Foods Have Consistently Been Found to Be Safe.” Inoculated respondents were less likely to click on this reliable headline (-0.072, $p < 0.05$) and perceived it as less accurate (-0.05, $p < 0.05$). One possible reason for this backfire effect is that the phrase “90 Nobel Laureates” might have been perceived as a group of fake experts’ attempt to claim

scientific expertise.

In contrast, the inoculation had strong and normatively positive effects in every instance on participants' likelihood to click and accuracy perceptions for "fake expert" headlines. For example, inoculation made participants less likely to read the two fake climate articles ("Americans with university degrees..." and "Science majors...") and made them believe these articles were less accurate. Similarly, the inoculation made participants less likely to read the GMO articles featuring a "farmer" or "holistic nutrition groups" and caused them to view those headlines as less accurate.

Importantly, the effect sizes of inoculation on unreliable headlines are much larger than those reported above in Table 1, which combines outcomes for reliable and unreliable headlines with reverse-coded values for the latter. Every treatment effect estimate for unreliable headlines in Table 2 is larger than those in Table 1, suggesting that null results for reliable headlines are masking the effects on perceptions of unreliable headlines.

We next consider H2, which concerns the effects of misinformation exposure and inoculation on the accuracy of participants' beliefs on climate change and GMO safety. Figure 2 again presents means and 95% confidence intervals by issue and condition. As shown in Table 3, our ability to reject the null hypothesis for H2a varies by issue. H2a states that inoculation should increase the accuracy of participants' beliefs about an issue among participants who are exposed to misinformation about an issue. We can only reject the null hypothesis for H2a on the issue of climate change (0.041, $p < 0.05$); inoculation did not measurably change the accuracy of participant beliefs on GMO safety among those who were not exposed to misinformation on the issue (-.007, n.s.)

The effects of misinformation exposure were significant. Per RQ1, exposure to a misinformation article about an issue decreases the accuracy of participant's beliefs for that given issue (-0.087, $p < 0.005$ for climate change; -0.115, $p < 0.005$ for GMO safety). Most importantly, as Table 3 indicates, we find no support for H2b — inoculation did not measurably change the effects of misinformation on belief accuracy (0.034, n.s. for climate change; 0.051, n.s. for GMO beliefs). In sum, receiving an inoculation did not significantly diminish the effect of misinformation on participants' beliefs.

The treatment effects we estimated varied in some cases by issue (climate change vs. GMO safety) but not by party (Democrats vs. Republicans). The effects of inoculation on participants' likelihood to

Table 2: Inoculation effects on click behavior and accuracy perceptions by headline

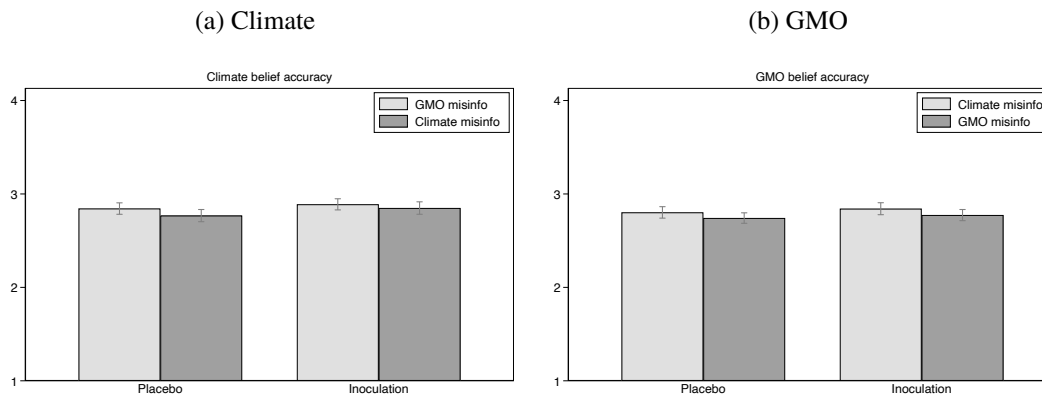
	Likely to click	Perceived accuracy
<u>Reliable headlines</u>		
“97% of Climate Science Studies...”	0.001 (0.035)	0.015 (0.026)
“Stanford Climate Scientists...”	0.083* (0.033)	0.006 (0.022)
“92% of Biomedical Scientists...”	-0.041 (0.033)	-0.007 (0.024)
“90 Nobel Laureates...”	-0.072* (0.034)	-0.050* (0.025)
<u>Unreliable headlines</u>		
“Americans with University Degrees...”	-0.331*** (0.033)	-0.131*** (0.025)
“New Study by Science Majors...”	-0.313*** (0.034)	-0.147*** (0.025)
“Holistic Nutritionist Groups...”	-0.191*** (0.034)	-0.131*** (0.028)
“Farmer Finds...”	-0.224*** (0.036)	-0.137*** (0.027)
Control variables	✓	✓

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). Likelihood of clicking and perceived headline accuracy were measured on four-point Likert scales. Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarz et al. 2016). See Online Appendix A for stimuli and question wording. Full headline-level models reported in Table B2.

click on accurate headlines and select an accurate headline to read were greater for climate change than GMO safety. However, inoculation effects did not vary by issue for headline accuracy or belief accuracy (see Tables B5 and B6. Additionally, we did not find any evidence that the effect of inoculation varied by party for any outcome variable (see Tables B3 and B4).

Finally, RQ3 asked whether inoculation affected participants’ confidence in the scientific community; we found no measurable effect (see Table B7).

Figure 2: Misinformation effects on belief accuracy by inoculation status



Means and 95% confidence intervals. Belief accuracy was measured on a four-point Likert scale (false claims were reverse-coded). See Online Appendix A for stimuli and question wording.

Conclusion

This study investigated the impact of inoculation on headline choice and accuracy perceptions as well as the ability of inoculation to increase belief accuracy and prevent misperceptions caused by misinformation exposure. We examined the effect of inoculation in the context of two distinct issues: climate change and GMO safety. As predicted, inoculation made participants more likely to want to read accurate headlines, more likely to choose them from a set of options, and more likely to evaluate their validity accurately. Contrary to our expectations and prior research, however, we found that the inoculation did not mitigate the negative impact of misinformation on belief accuracy.

Our results suggest that inoculation may sometimes fail to neutralize the persuasive effects of misinformation. Consistent with Schmid-Petri and Bürger (2022), we find no evidence that inoculation can diminish the adverse effects of misinformation on belief accuracy overall or among Republicans even with a much larger sample than Cook, Lewandowsky, and Ecker (2017). One potential explanation for this discrepancy is that introducing an additional issue to the inoculation reduced the strength of the treatment, but this finding is inconsistent with the effects we observe on information choice and headline accuracy evaluation.

At the same time, our paper suggests a potential new role for inoculation in improving the reliability of people's news consumption. For both climate change and GMO safety, inoculation made people

Table 3: Misinformation exposure and inoculation effect on belief accuracy

	Climate	GMOs
Misinformation on issue	-0.087*** (0.022)	-0.115*** (0.023)
Inoculation	0.041* (0.019)	-0.007 (0.024)
Misinformation \times inoculation	0.033 (0.032)	0.051 (0.035)
Control variables	✓	✓
<u>Misinformation effect if inoculated</u>		
Misinfo + misinfo \times inoculation	-0.054* (0.023)	-0.064* (0.026)
N	2976	2977

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). Belief accuracy was measured on a four-point Likert scale (false claims were reverse-coded). Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarz et al. 2016). See Online Appendix A for stimuli and question wording.

more likely to read articles with reliable news headlines. Inoculation also improved people’s assessment of headline (in)accuracy, which is likely an underlying mechanism explaining the improvement in news consumption. By warning people about “fake experts,” inoculation made people suspicious of misleading headlines and nudged participants to consume more reliable headlines. This finding suggests that inoculation has the potential to be a valuable media literacy tool to prevent exposure to misinformation.

These effects did not vary by partisanship, but we found some variation in effects by issue. Specifically, larger effects were observed for climate change than for GMOs. One potential reason for these differences between issues could be that climate change is more polarized and widely covered in the media than GMOs. As a result, individuals are presumably exposed to (mis)information about climate change more frequently. GMOs are also less politically controversial in the U.S. and thus might not generate the same emotional response as climate change. Nonetheless, further research is necessary to understand what causes differences in the effect of inoculation by issue.

Further research is needed to extend this finding outside the realm of scientific issues and to test inoculations featuring techniques other than “fake experts”. It will also be important to test the effects of inoculation in interactive online contexts such as search engines and social media feeds where

individuals are at risk of consuming misinformation.

Future studies should also independently vary information accuracy and expert legitimacy. Our intervention focuses on helping people recognize false experts, but we cannot rule out the alternate interpretation that the treatment made respondents more accurate at identifying false information. If the treatment effects are driven by greater suspicion of experts who are perceived as lacking relevant expertise (our interpretation of the negative effect of the “90 Nobel Laureates...” attribution in the reliable GMO headline), then the inoculation was effective at improving discernment of accurate information on a cross-issue level. However, if the treatment effects are due to respondents’ improved ability to identify accurate claims, then respondents would need to be inoculated separately for each issue.

Finally, our study has a number of other limitations that should be addressed. First, our inoculation was specific to the “fake experts” technique of spreading misinformation on the issues of climate change and GMOs and did not consider other types of (mis)information, issues, or headlines beyond those tested. Secondly, our outcome measures combine evaluations of false or unreliable content and sources with valid or reliable content and sources, complicating interpretation. Third, all measures of headline choice are self-reported behavioral intentions, an imperfect proxy for information choice. Further research could analyze the effect of inoculation on information search and choice using web browsing data to increase the validity of these results. Fourth, inoculation faces challenges of external validity. Simply put, most people will rarely encounter a message of this type in the real world. Researchers should develop realistic ways to inoculate more people in non-experimental settings. Finally, research should further investigate the durability of inoculation effects on information choice as well as factual beliefs (Maertens, Anseel, and van der Linden 2020, e.g.).

Despite these limitations, our study offers important new evidence about the effects of inoculation. While more research is necessary to confirm the applicability of these results and to broaden the scope of issues tested, this paper provides optimistic evidence for the potential of inoculation to reduce misinformation exposure while suggesting the need for caution about its protective effects.

Competing interests

The authors declare they have no competing interests.

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Online Appendix A: Survey instrument and experimental stimuli

[Consent]

This study is being conducted by [REDACTED FOR PEER REVIEW]. The purpose of this survey is to learn about public opinion towards issues in the news.

Your participation is voluntary and you may decline to participate in the survey or withdraw at any time. No information that identifies you will be collected or retained by the researchers.

We take your confidentiality extremely seriously. Any answers you provide in this research survey will be anonymous and confidential. The data from the study will be stored securely on password-protected university computers. However, any online interaction carries some risk of being accessed.

Questions about this project may be directed to:

[REDACTED FOR PEER REVIEW]

You may refuse to answer any particular questions. You are free to end your participation at any time by closing this window (although any answers you have already entered may still be submitted).

By clicking the “yes” button below you agree to participate in this confidential research study.

-Yes

-No

[Demographics and pre-treatment measures]

How old are you?

-Under 18

-18–24

-25–34

-35–44

-45–54

-55–64

-65–74

-75–84

-85 or older

In this survey, we will sometimes ask you about genetically modified foods, which are also known as GMOs.

Please indicate whether each statement below is accurate or not. [grid]

- Human CO2 emissions cause climate change.
- The US currency is called the peso. [attention check]
- The climate is always changing and what we are currently observing is just a natural fluctuation.
- Genetically modified foods have been shown to be harmful to human health.
- It is generally safe to eat genetically modified foods.
- Barack Obama was the first president of the United States. [attention check]

-Very accurate
-Somewhat accurate
-Not very accurate
-Not at all accurate

Here are some institutions in this country. As far as the people running these institutions are concerned, would you say you have a great deal of confidence, only some confidence, or hardly any confidence at all in them? [grid]

- Scientific community
- The news media
- Congress

-A great deal
-Only some
-Hardly any

In what state do you currently reside? [pulldown menu]

What is your gender?

-Male
-Female
-Nonbinary/Two spirit
-Other
-Prefer not to say

Please check one or more categories below to indicate what race(s) you consider yourself to be.

-American Indian or Alaska Native
-Asian or Pacific Islander
-Black or African-American
-White

- Multi-racial
- Other

Are you of Spanish or Hispanic origin or descent?

- Yes
- No

What is the highest degree or level of school you have completed?

- Did not graduate from high school
- High school diploma or the equivalent (GED)
- Some college
- Associate's degree
- Bachelor's degree
- Master's degree
- Professional or doctorate degree

Generally speaking, do you usually think of yourself as a Republican, a Democrat, an Independent, or something else?

- Republican
- Democrat
- Independent
- Something else

[if selected Independent or Something else]

Do you think of yourself as closer to the Republican Party or to the Democratic Party?

- Closer to the Republican Party
- Closer to the Democratic Party
- Neither

[if selected Democrat]

- Would you call yourself a strong Democrat or a not very strong Democrat?
- Strong Democrat
- Not very strong Democrat

[if selected Republican]

- Would you call yourself a strong Republican or not a very strong Republican?
- Strong Republican
- Not very strong Republican

Generally, how interested are you in politics?

- Extremely interested
- Very interested
- Somewhat interested
- Not very interested
- Not at all interested

[Placebo condition; p=.5]

Please carefully read the following article in its entirety. We may ask you questions about it afterward.

Delta Airlines recently announced that employees who speak any of the 300-plus types of sign language will be identified by a notice on their employee nametag. In a press release, the company stated that this update will allow “customers and qualified employees [to] immediately be able to visually recognize when they hold sign language as a common connection.”

Delta becomes the latest major airline to take steps to help their customers who are deaf or hard of hearing have a smoother time traveling. In early 2019, Virgin Atlantic Airways introduced a “hidden symbol,” included on a slip with its tickets or worn as a pin, which allow people with disabilities that are not apparent to identify themselves to employees. The company also offers sign language interpretation in British Sign Language if notified in advance. Those services, however, are only available on international flights.

A number of other airlines, including Southwest, do not list their specific services for deaf and hard-of-hearing passengers on their websites but provide a phone number with relay service or teletypewriter service. Many airlines, including United, ask deaf and hard-of-hearing customers to identify themselves to staff.

[Inoculation condition; p=.5]

Please carefully read the following article in its entirety. We may ask you questions about it afterward.

Promoting “fake experts” to manufacture doubt about science

Sometimes, inconvenient scientific facts threaten the interests of certain groups. For example, the scientific evidence linking smoking with lung cancer threatened the profits of the tobacco industry. Similarly, scientific evidence linking fossil fuel emissions with global warming threatens the profits of the fossil fuel industry. Additionally, the scientific consensus on the safety of genetically modified foods, or GMOs, runs counter to activists’ distrust of large agricultural companies.

In these cases, a common tactic for groups and organizations is to manufacture doubt about the science through the promotion of “fake experts”. Fake experts are spokespeople who convey the impression of expertise in a given area without possessing actual relevant experience. Groups wishing to cast doubt on science often use fake experts to convince the public that the science isn’t settled. Inevitably, the fake expert strategy ends with arguments for or against government action that serve the interests of the group.

The tobacco industry pioneered this approach through ad campaigns featuring long lists of doctors endorsing smoking. These ads conveyed the impression that the scientific case linking smoking to lung cancer was not settled. However, the cited “experts” actually consisted of tens of thousands of non-experts. For example, they featured physicians rather than the scientists who actually conducted research into the health impacts of tobacco use. The tobacco industry dubbed this campaign “The Whitecoat

Project” due to the use of spokespeople dressed in white coats to convey the appearance of scientific expertise.

The fake expert strategy is now widely adopted in the climate change and GMOs arenas. To convey the impression that climate scientists are still debating human-caused global warming, opponents of climate action will publish long lists of dissenting scientists. Similarly, to convey the impression that scientists are still debating the safety of GMOs, opponents of GMOs will publish long lists of dissenting scientists, lawyers, and activists. A telling feature of these petitions is the promotion of the scientific qualifications of the dissenters but close inspection reveals the signatories do not possess the relevant expertise in climate or GMO science. In other words, these lists consist of fake experts — scientists and professionals whose area of expertise is in some domain other than climate change or GMOs.

Drawing upon non-expert opinions on a complex topic such as climate change or GMOs is equivalent to asking a dentist to perform heart surgery. A white coat alone does not make a heart surgeon.



[Post-misinformation article outcomes]

[Climate article choice; issue order randomized]

If you came across the following headlines while searching for information on climate change, how likely would you be to click on each headline?

“Americans with University Degrees in Science Affirm: Human Activities Don’t Cause Global Warming”

- Very likely to click
- Somewhat likely to click
- Not very likely to click
- Not at all likely to click

“New Study by Science Majors Finds Little Evidence of Humans Causing Climate Fluctuations”

- Very likely to click

- Somewhat likely to click
- Not very likely to click
- Not at all likely to click

“Survey Finds 97% of Climate Science Studies Agree Warming Is Man-Made”

- Very likely to click
- Somewhat likely to click
- Not very likely to click
- Not at all likely to click

“Stanford Climate Scientists Demonstrate Carbon Emissions Warming Planet”

- Very likely to click
- Somewhat likely to click
- Not very likely to click
- Not at all likely to click

If you were searching for information on climate change and came across the following headlines, which one would you be most likely to click on to read?

- “Americans with University Degrees in Science Affirm: Human Activities Don’t Cause Global Warming”
- “New Study by Science Majors Finds Little Evidence of Humans Causing Climate Fluctuations”
- “Survey Finds 97% of Climate Science Studies Agree Warming Is Man-Made”
- “Stanford Climate Scientists Demonstrate Carbon Emissions Warming Planet”

[GMO article choice; issue order randomized]

If you came across the following headlines while searching for information on GMOs, how likely would you be to click on each headline?

“Survey Shows 92% of Biomedical Scientists Say GMOs Are Safe to Eat”

- Very likely to click
- Somewhat likely to click
- Not very likely to click
- Not at all likely to click

“90 Nobel Laureates in Physics, Chemistry, and Medicine Say Genetically Modified Foods Have Consistently Been Found to Be Safe”

- Very likely to click
- Somewhat likely to click
- Not very likely to click
- Not at all likely to click

“Holistic Nutritionist Groups Claim Removing GMOs From Diet Decreases High Cholesterol”

- Very likely to click
- Somewhat likely to click

- Not very likely to click
- Not at all likely to click

“Farmer Finds a Diet of GMO Corn Causes Tumors in Rats”

- Very likely to click
- Somewhat likely to click
- Not very likely to click
- Not at all likely to click

If you were searching for information on GMOs and came across the following headlines, which one would you be most likely to click on to read?

- “Survey Shows 92% of Biomedical Scientists Say GMOs Are Safe to Eat”
- “90 Nobel Laureates in Physics, Chemistry, and Medicine Say Genetically Modified Foods Have Consistently Been Found to Be Safe”
- “Holistic Nutritionist Groups Claim Removing GMOs From Diet Decreases High Cholesterol”
- “Farmer Finds a Diet of GMO Corn Causes Tumors in Rats”

[Climate headline accuracy; issue order and placement in study randomized (both p=.5)]

To the best of your knowledge, how accurate are the **bolded claims** in the following headlines? Please rate each one below, evaluating the accuracy of the **bolded claim**.

“Americans with University Degrees in Science Affirm: **Human Activities Don’t Cause Global Warming**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“Stanford Climate Scientists Demonstrate **Carbon Emissions Warming Planet**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“New Study by Science Majors Finds **Little Evidence of Humans Causing Climate Fluctuations**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“Survey Finds 97% of Climate Science Studies Agree **Warming Is Man-Made**”

- Very accurate
- Somewhat accurate
- Not very accurate

-Not at all accurate

[GMO headline accuracy; issue order and placement in study randomized (both p=.5)]

To the best of your knowledge, how accurate are the **bolded claims** in the following headlines? Please rate each one below, evaluating the accuracy of the **bolded claim**.

“Holistic Nutritionist Groups Claim **Removing GMOs From Diet Decreases High Cholesterol**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“Farmer Finds a **Diet of GMO Corn Causes Tumors in Rats**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“90 Nobel Laureates in Physics, Chemistry, and Medicine Say **Genetically Modified Foods Have Consistently Been Found to Be Safe**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“Survey Shows 92% of Biomedical Scientists Say **GMOs Are Safe to Eat**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

[Climate misinformation article; randomized p=.5]

Regardless of which headlines you previously selected, please focus your attention on and read the text below. We may ask you questions about the content of the article.

31,487 American scientists have signed The Petition Project, including 9,029 with PhDs. The purpose of The Petition Project is to demonstrate that the claim of “settled science” and an overwhelming “consensus” in favor of the hypothesis of human-caused global warming and consequent climatological damage is wrong. No such consensus or settled science exists. As indicated by the petition text and signatory list, a very large number of American scientists reject this hypothesis.

Publicists at the United Nations, Mr. Al Gore, and their supporters frequently claim that only a few “skeptics” remain – skeptics who are still unconvinced about the existence of a catastrophic human-caused global warming emergency.

It is evident that 31,487 Americans with university degrees in science, including 9,029 PhDs, are not “a few.” Moreover, from the clear and strong petition statement that they have signed, it is evident that these 31,487 American scientists are not “skeptics.”

These scientists are instead convinced that the human-caused global warming hypothesis is without scientific validity and that government action on the basis of this hypothesis would unnecessarily and counterproductively damage both human prosperity and the natural environment of the Earth.

One signatory is Dr. Arthur Johnson, a Ph.D. in Animal Behavior from the University of Colorado: “The Earth has supported abundant life many times in the geological past when there were much higher levels of carbon dioxide in the atmosphere. It is quite likely that future generations will benefit from the enrichment of Earth’s atmosphere with more carbon dioxide.”

The Petition Project was organized by a group of physicists and physical chemists who conduct scientific research at several American scientific institutions. The petition statement and the signatures of its 31,487 signers, however, speak for themselves. The primary relevant role of the organizers is that they are among the 9,029 PhD signers of the petition.

[GMO misinformation article; randomized p=.5]

Regardless of which headlines you previously selected, please focus your attention on and read the text below. We may ask you questions about the content of the article.

231 scientists, physicians, and legal experts signed the group statement “No scientific consensus on GMO [genetically modified organism] food safety” within its first week online, according to the United States Network of Scientists for Social Responsibility (USNSSR).

The group, which “brings together independent scientific expertise to develop public-good knowledge for the critical assessment of existing and emerging technologies,” posted the petition the week after the World Food Prize was awarded to employees of the GMO seed giants Monsanto and Syngenta.

“This award has provoked outrage worldwide and stands in stark contrast to recent rulings in several countries restricting or banning the field release or commercialization of certain GMO crops,” the organization stated.

The original USNSSR petition reads:

“We feel compelled to issue this statement because the claimed consensus on GMO food safety does not exist. The claim that it does exist is misleading and misrepresents the currently available scientific evidence and the broad diversity of opinion among scientists on this issue.”

One signatory is Dr. Connor Callahan, a Ph.D. in Astrophysics from the University of Denver:

“I wholeheartedly support this thorough, thoughtful and professional statement describing the lack of

scientific consensus on the safety of genetically engineered crops and other GMOs” he wrote. “Society’s debate over how best to utilize the powerful technology of genetic engineering is clearly not over. For its supporters to assume it is, is little more than wishful thinking.”

United States Network of Scientists for Social Responsibility (USNSSR) brings together independent scientific expertise to develop public-good knowledge for the critical assessment of existing and emerging technologies.

[Post-misinformation article outcomes]

Please indicate whether each statement below is accurate or not. [grid]

- Human CO2 emissions cause climate change.
- The climate is always changing and what we are currently observing is just a natural fluctuation.
- Genetically modified foods have been shown to be harmful to human health.
- It is generally safe to eat genetically modified foods.

-Very accurate

-Somewhat accurate

-Not very accurate

-Not at all accurate

Here are some institutions in this country. As far as the people running these institutions are concerned, would you say you have a great deal of confidence, only some confidence, or hardly any confidence at all in them? [grid]

- Scientific community
- The news media
- Congress

-A great deal

-Only some

-Hardly any

[Climate headline accuracy; issue order and placement in study randomized (both p=.5)]

To the best of your knowledge, how accurate are the **bolded claims** in the following headlines? Please rate each one below, evaluating the accuracy of the **bolded claim**.

“Americans with University Degrees in Science Affirm: **Human Activities Don’t Cause Global Warming**”

-Very accurate

-Somewhat accurate

-Not very accurate

-Not at all accurate

“Stanford Climate Scientists Demonstrate **Carbon Emissions Warming Planet**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“New Study by Science Majors Finds **Little Evidence of Humans Causing Climate Fluctuations**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“Survey Finds 97% of Climate Science Studies Agree **Warming Is Man-Made**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

[GMO headline accuracy; issue order and placement in study randomized (both p=.5)]

To the best of your knowledge, how accurate are the **bolded claims** in the following headlines? Please rate each one below, evaluating the accuracy of the **bolded claim**.

“Holistic Nutritionist Groups Claim **Removing GMOs From Diet Decreases High Cholesterol**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“Farmer Finds a **Diet of GMO Corn Causes Tumors in Rats**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“90 Nobel Laureates in Physics, Chemistry, and Medicine Say **Genetically Modified Foods Have Consistently Been Found to Be Safe**”

- Very accurate
- Somewhat accurate
- Not very accurate
- Not at all accurate

“Survey Shows 92% of Biomedical Scientists Say **GMOs Are Safe to Eat**”

- Very accurate
- Somewhat accurate
- Not very accurate

-Not at all accurate

According to the article you previously read, what misinformation tactic was employed by the tobacco industry to convince the public that smoking is safe?

- False balance
- Fake experts
- Deepfakes and synthetic media
- Nothing
- Amplifying conspiracy theories

[End of survey matter and debriefing]

Please select all of the online survey platforms besides Connect on which you have taken at least one survey in 2023 below. Select none of the above if you haven't taken any surveys in 2023 on a platform other than Connect.

- Amazon Mechanical Turk
- Forthright
- OpinionWorld
- YouGov
- Prolific
- None of the above

We sometimes find people don't always take surveys seriously, instead providing humorous, or insincere responses to questions. How often do you do this?

- Always
- Most of the time
- Rarely
- Never

Do you have any comments on the survey? Please let us know about any problems you had or aspects of the survey that were confusing. [open text]

[Debrief for participants in climate misinformation article condition]

Please note that the article you read earlier, titled "Americans with University Degrees in Science Affirm: Human Activities Don't Cause Global Warming," contains misinformation. Read about why this article is misleading below.

An earlier page in this survey presented information adapted from the Global Warming Petition Project website. This information is highly misleading.

The scientific consensus on climate change is robust across published peer-reviewed research and the world's most prestigious scientific organizations, including statements issued by National Academies of Science in 78 countries. There is a consensus among the climate science community with 97% agreement among actively publishing climate scientists.

Given such agreement among an overwhelming majority of climate scientists, a common way to portray a false picture of a divided scientific community is to promote scientists with supposedly impressive credentials who actually possess scant expertise in climate science.

The most prominent example of this strategy is the Petition Project, first published in 2008 by the Oregon Institute of Science and Medicine. This petition lists over 31,000 scientists who dispute that human activity is disrupting our climate.

With 97% consensus among climate scientists, how is it over 31,000 scientists disagree with the consensus? This is because around 99.9% of the signatories on the Petition Project are not climate scientists. Anyone with a Bachelor of Science or higher can be listed. The list includes graduates of computer science, mechanical engineering, zoology and other fields unrelated to climate science.

The survey also demonstrates a lack of quality control. Characters from the television show M*A*S*H and members of the Spice Girls pop band have been added to the list. In response to this, the Oregon Institute of Science & Medicine commented that there was no way of filtering out fake names from their survey.

For the purpose of this study, the article was altered to quote Dr. Arthur Johnson, who is not a real person; his quote was actually stated by Dr. Arthur Robinson, the organizer of the petition, who holds a Ph.D. in biochemistry from Caltech.

[Debrief for participants in GMO misinformation article condition]

Please note that the article you read earlier, titled “Americans with University Degrees in Science Affirm: Human Activities Don’t Cause Global Warming,” contains misinformation. Read about why this article is misleading below.

The article you were presented was adapted from foodprocessing.com to serve the purposes of this study. Here is the original article, which also contains dubious claims about GMOs.

In addition to shortening the original article, the organization United States Network of Scientists for Social Responsibility (USNSSR) was fabricated to parallel the European organization in the article in a context that would be more relevant to survey participants. Dr. Connor Callahan is not a real person; his quote was actually stated by Dr Belinda Martineau, a former member of the Michelmore Lab at the UC Davis Genome Center, University of California.

Scientific consensus strongly supports the safety of genetically modified organisms. 89% of scientists believe that GMOs are safe to eat. GMOs can be beneficial to the environment as they often require fewer natural resources such as water and fertilizer or can be grown with fewer pesticides than non-GMO foods due to genetic resistance to pests. The article from foodprocessing.com overrepresents the opinions of a small subset of the science community.

Please indicate that you have read and understand the above and then proceed to the next page.
-I understand the above.

We thank you for your time.

Please note that this research is not intended to support or oppose any political candidate or office. The research has no affiliation with any political candidate or campaign and has received no financial support from any political candidate or campaign. Should you have any questions about this study, please contact [REDACTED FOR PEER REVIEW].

Important: Please click next to complete the survey.

Online Appendix B: Additional results

Table B1: Misinformation exposure and inoculation effect on belief accuracy by headline accuracy question placement

	Climate	GMOs
Misinformation on issue	-0.114*** (0.028)	-0.146*** (0.033)
Inoculation	0.047 (0.026)	-0.050 (0.034)
Headline accuracy measured first	0.017 (0.027)	-0.051 (0.031)
Misinformation × inoculation	0.040 (0.043)	0.090 (0.048)
Inoculation × headline accuracy first	-0.011 (0.039)	0.083 (0.048)
Misinformation × headline accuracy first	0.050 (0.043)	0.061 (0.047)
Misinformation × inoculation × headline accuracy first	-0.011 (0.063)	-0.077 (0.070)
Control variables	✓	✓
N	2976	2977

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). Belief accuracy was measured on a four-point Likert scale (false claims were reverse-coded). Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarczyk et al. 2016). See Online Appendix A for stimuli and question wording.

Table B2: Headline-level inoculation effects: Full results

(a) Likely to click

	Reliable headlines				Unreliable headlines			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Inoculation	0.001 (0.035)	0.083* (0.033)	-0.041 (0.033)	-0.072* (0.034)	-0.331*** (0.033)	-0.313*** (0.034)	-0.191*** (0.034)	-0.224*** (0.036)
Control variables	✓	✓	✓	✓	✓	✓	✓	✓
N	2993	2993	2998	2993	2993	2987	2994	2996

(b) Claim accuracy

	Reliable headlines				False headlines			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Inoculation	0.016 (0.026)	0.006 (0.022)	-0.006 (0.024)	-0.050* (0.025)	-0.131*** (0.025)	-0.147*** (0.025)	-0.133*** (0.028)	-0.137*** (0.027)
Control variables	✓	✓	✓	✓	✓	✓	✓	✓
N	2978	2977	2978	2979	2976	2978	2979	2978

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). Likelihood of clicking and perceived headline accuracy were measured on four-point Likert scales (higher values indicate increased likelihood of clicking or greater perceived accuracy). Outcome variables: “97% of Climate Science Studies...” (model 1); “Stanford Climate Scientists...” (model 2); “92% of Biomedical Scientists...” (model 3); “90 Nobel Laureates...” (model 4); “Americans with University Degrees...” (model 5); “New Study by Science Majors...” (model 6); “Holistic Nutritionist Groups...” (model 7); “Farmer Finds...” (model 8). Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarz et al. 2016). See Online Appendix A for stimuli and question wording.

Table B3: Inoculation effect on information choice and headline perceptions by party

	<u>Likely to click</u>		<u>Choose to read</u>		<u>Claim accuracy</u>	
	Climate	GMOs	Climate	GMOs	Climate	GMOs
Inoculation	0.183*** (0.028)	0.049** (0.019)	0.078*** (0.025)	0.066* (0.026)	0.014 (0.023)	0.071*** (0.025)
Republican	-0.125*** (0.031)	-0.114*** (0.027)	-0.175*** (0.030)	-0.056 (0.030)	-0.043 (0.029)	-0.054 (0.029)
Inoculation × Republican	-0.007 (0.038)	0.071* (0.031)	0.005 (0.037)	0.017 (0.036)	0.026 (0.034)	-0.032 (0.035)
Control variables	✓	✓	✓	✓	✓	✓
N	2703	2708	2692	2705	2707	2689

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). Estimated among Republican and Democratic identifiers and leaners only (Democrats are the omitted category; pure independents are excluded). Likelihood of clicking and perceived headline accuracy were measured on four-point Likert scales; article choice was a binary measure. Headlines featuring unreliable experts were reverse-coded. Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarz et al. 2016). See Online Appendix A for stimuli and question wording.

Table B4: Misinformation exposure and inoculation effect on belief accuracy by party

	Climate	GMOs
Misinformation on issue	-0.083** (0.031)	-0.178*** (0.036)
Inoculation	0.013 (0.028)	0.023 (0.037)
Republican	-0.138*** (0.032)	-0.031 (0.038)
Misinformation × inoculation	0.020 (0.046)	0.069 (0.053)
Inoculation × Republican	0.055 (0.040)	-0.080 (0.052)
Misinformation × Republican	-0.024 (0.045)	0.096 (0.050)
Misinformation × inoculation × Republican	0.037 (0.066)	0.012 (0.074)
Control variables	✓	✓
N	2696	2697

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). Estimated among Republican and Democratic identifiers and leaners only (Democrats are the omitted category; pure independents are excluded). Belief accuracy was measured on a four-point Likert scale (false claims were reverse-coded). Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarczyk et al. 2016). See Online Appendix A for stimuli and question wording.

Table B5: Inoculation effect on information choice and headline perceptions by issue

	Likely to click	Choose to read	Claim accuracy
Inoculation	0.182*** (0.019)	0.093*** (0.015)	0.070*** (0.021)
GMOs	-0.035* (0.018)	-0.062*** (0.016)	-0.211*** (0.020)
Inoculation × GMOs	-0.106*** (0.026)	-0.059** (0.023)	-0.012 (0.029)
Control variables	✓	✓	
N	5973	5979	5936

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). The GMO variable is a binary indicator where 0 indicates the responses concerned climate change instead. Likelihood of clicking and perceived headline accuracy were measured on four-point Likert scales; article choice was a binary measure. Headlines featuring unreliable experts were reverse-coded. Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarczyk et al. 2016). See Online Appendix A for stimuli and question wording.

Table B6: Misinformation exposure and inoculation effect on belief accuracy by issue

	Belief accuracy
Misinformation on issue	-0.051 (0.031)
Inoculation	0.050 (0.029)
GMOs	-0.021 (0.030)
Misinformation × inoculation	-0.000 (0.044)
Misinformation × GMOs	-0.030 (0.044)
Inoculation × GMOs	-0.037 (0.044)
Misinformation × issue × GMOs	0.024 (0.064)
Control variables	✓
N	5952

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). The GMO variable is a binary indicator where 0 indicates the responses concerned climate change instead. Belief accuracy was measured on a four-point Likert scale (false claims were reverse-coded). Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarczyk et al. 2016). See Online Appendix A for stimuli and question wording.

Table B7: Inoculation effect on confidence in the scientific community

	Confidence
Inoculation	-0.017 (0.012)
Misinformation on climate	-0.012 (0.012)
Control variables	✓
N	2969

OLS with robust standard errors; * $p < 0.05$, ** $p < 0.01$, *** $p < .005$ (two-sided). The misinformation on climate variable is an indicator (where 0 indicates the participant saw misinformation about GMOs instead). Likelihood of clicking and perceived headline accuracy were measured on four-point Likert scales; article choice was a binary measure. Headlines featuring unreliable experts were reverse-coded. Each model includes pre-treatment covariates selected via the lasso from a preregistered set consisting of indicators for education level, age group, gender, party, race, and ethnicity and measures of political interest, climate and GMO belief accuracy, and trust in scientists and the news media (Bloniarczyk et al. 2016). See Online Appendix A for stimuli and question wording.