A JOURNAL BY SISSA MEDIALAB

ARTICLE

Comparing the efficacy of narrative and didactic inoculation in combating climate change misinformation: impact on misbeliefs and intention to share misinformation

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Abstract

Previous research has suggested that incorporating emotional language and exemplars within inoculation messages could enhance their effectiveness in inducing resistance to climate change misinformation. We conducted a between-subject experiment with four conditions (negative narrative inoculation, positive narrative inoculation, didactic inoculation, and misinformation only condition) to test the effectiveness of inoculation. We found that didactic inoculation increased perceived threat significantly more than both types of narrative inoculations. However, there were no significant differences across these three types of inoculation messages in conferring resistance to misinformation regarding counterarguing against misinformation, belief in misinformation, perceived credibility of misinformation, or intention to share misinformation.

Keywords

Environmental communication; Public understanding of science and technology; Digital science communication

Received: 21st August 2024
Accepted: 17th May 2025
Published: 21st July 2025

1 ▪ Introduction

Misinformation can be defined as factually inaccurate information that is not supported by expert opinion or clear evidence [Nyhan & Reifler, 2010]. Widespread belief in science-related misinformation has led to public distrust of scientific experts and climate change misinformation has decreased public support for mitigation policies [Cook et al., 2017; van der Linden et al., 2017]. Despite corrections that have been used to debunk public misbeliefs about climate change, numerous studies have found the continued influence of misinformation: falsehoods are challenging to retract and correct once they become deeply embedded in human memory [Lewandowsky et al., 2012; Walter & Tukachinsky, 2020]. Even when a correction is successful in updating beliefs, it does not necessarily translate into attitude change or behavioral change because individuals continue to rely on debunked information [Thorson, 2016]. Considering these challenges, researchers suggest that a preemptive approach, namely inoculation or prebunking, might better educate and prepare individuals to resist the impact of misinformation before they are exposed to it [Roozenbeek & van der Linden, 2019b, 2019a].

Inoculation theory posits that preemptively exposing individuals to weakened or refuted arguments, an individual can build up more resistance to future persuasive attacks [McGuire, 1964]. The inoculation process is likened to a biomedical immunization which offers a proactive approach to fight misperceptions of science. Classic inoculation research focuses on "cultural truism" issues such as brushing teeth [McGuire, 1964]. Current research emphasizes the need to investigate whether inoculation messages can be applied to controversial issues [Compton, 2020; Cook et al., 2017], so-called "therapeutic inoculation" for individuals already "infected" [Compton, 2020]. Although some research studies have found that inoculation can bolster resistance to persuasion among individuals with initially neutral or opposing attitudes, even when misperceptions have already taken root and prevention is not feasible [Ivanov et al., 2017; Wood, 2007], the question remains whether inoculation can help reduce the negative impact of misinformation on misbeliefs regardless of preexisting attitudes.

Scholars have proposed the potential effectiveness of narratives as an inoculation treatment strategy [e.g., Biddlestone et al., 2023; Compton & Pfau, 2005]. Narrative is commonly recognized as a powerful persuasive strategy [Slater & Rouner, 2002]. It is able to convey threats when individuals are exposed to identifiable characters within an inoculation message [Pfau et al., 1992]. When narratives are used within inoculation messages, they can elicit negative emotions such as fear or positive emotions such as happiness, which later impact the inoculation process [Pfau et al., 2001, 2004]. Although narrative techniques have been employed in constructing emotional inoculation messages, little is yet known about how narrative inoculation might aid or dampen resistance and how that differs from non-narrative (didactic) inoculation [Compton & Mason, 2020].

To answer these questions, we test whether an inoculation message embedded with a narrative can better "immunize" public audiences against misinformation compared with messages that do not contain a narrative. A between-subject online experiment with four conditions (negative narrative inoculation, positive narrative inoculation, didactic inoculation, and a misinformation-only condition) was employed. We strived to unveil the differences among the three types of inoculation messages in terms of counterarguing against misinformation, belief in misinformation, perceived credibility, intention to share

misinformation, and how preexisting attitudes about climate change impact individuals' resistance to misinformation.

2 ▪ Theoretical background

2.1 ▪ *Inoculation against misinformation*

Inoculation theory proposes that individuals will be better able to resist a persuasive attempt if they are inoculated ahead of time [McGuire, 1964]. The process of inoculation begins with giving audiences weaker doses of counterarguments, enabling them to build resistance against stronger versions of future persuasive messages. This is likened to receiving an annual flu shot that contains a weakened form of the flu virus, but the inoculation is strong enough to generate antibodies without overwhelming it. While the initial focus of inoculation was on cultural truisms and non-controversial issues, it has proven successful for dealing with various other issues and contexts, including politics [Compton & Ivanov, 2013], health [Niederdeppe et al., 2015], marketing [Compton & Pfau, 2004], animal rights issues [Nabi, 2003], conspiracy propaganda [Banas & Richards, 2017], and combating misinformation [Basol et al., 2020]. Numerous studies have shown inoculation to be efficacious when combating misinformation that concerns highly contested issues, such as climate change [Cook et al., 2017] and vaccination [Amazeen et al., 2022; Jolley & Douglas, 2017].

Inoculation treatments consist of two essential components: threat or forewarning, and refutational preemption [Banas, 2020; Compton & Pfau, 2005]. The threat or forewarning component aims to inform individuals that their attitudes or beliefs may be susceptible to persuasion, thereby motivating them to develop resistance against persuasive attacks. Refutational preemption provides individuals with specific content and a method to strengthen their counterargument ahead of time [McGuire, 1964]. This is achieved by employing a two-sided message introducing and refuting potential challenges to one's attitude or beliefs [Banas, 2020]. Refutational preemption is included to help individuals practice how to defend their attitude or beliefs through counterarguing.

Recent research has found that technique-based inoculation focusing on informing people about misinformation techniques could increase individual literacy in dealing with misinformation, which is another form of a refutational-different message [Roozenbeek & van der Linden, 2019b, 2019a; Roozenbeek et al., 2022]. For instance, fake expertise is a common technique used in spreading misinformation and deception, where a source or an individual is presented as an expert in a certain field or topic, while in reality they may have no credentials, qualifications, or expertise in that area [Cook et al., 2017]. This technique can be a powerful tool for manipulating individuals' beliefs and opinions, as people tend to trust and rely on information that comes from perceived authorities. Technique-based inoculation can help individuals become aware of this technique and develop their media literacy skills to be able to identify and reject such false claims.

2.2 ▪ *Potential of different types of narrative inoculation*

Considering encouraging findings, researchers have acknowledged the importance of further exploring and refining technique-based inoculation approaches to enhance the ability of public audiences to detect and counteract misinformation [Roozenbeek et al., 2022]. Some

studies have incorporated narrative techniques into inoculation messages to explore the role of affect in the inoculation process across different contexts [Compton & Pfau, 2008; Pfau et al., 2001]. However, there is yet to be a direct comparison between the effectiveness of narrative inoculation and didactic inoculation messages in resisting persuasive attacks. Recent research suggests that narrative inoculation can indirectly decrease belief in conspiracy theories by reducing susceptibility to the conjunction fallacy — a cognitive bias where individuals erroneously perceive specific conditions as more probable than a single general one [Biddlestone et al., 2023]. This finding highlights the potential of narrative strategies for strengthening cognitive resilience against misleading information by targeting underlying cognitive processes.

Furthermore, previous research predominantly utilized negative narratives to counteract misinformation, which highlights the adverse consequences of believing in misinformation [Huang & Wang, 2022; Wang & Huang, 2021]. However, positive narratives emphasizing hope and progress may be more effective in promoting prosocial behaviors compared with negative narratives [Fitzgerald et al., 2020]. Incorporating emotional shifts from negative to positive [Nabi & Green, 2015] could enhance the efficacy of individuals processing refutational preemption messages after being forewarned. For instance, when individuals read stories that emphasize the suffering of those who believe in health misinformation, they may experience an increased threat but might not necessarily feel more capable [Nabi & Myrick, 2019] of effectively dealing with misinformation. On the other hand, when individuals read stories that highlight the resilience and hope of individuals addressing the same issue [Fitzgerald et al., 2020], or those facing vaccine misinformation, they may initially feel the threat but subsequently experience hope for positive change.

The present study aims to investigate how different types of narrative, specifically negative and positive narrative inoculation, might generate resistance towards misinformation. Negative narrative inoculation involves highlighting the negative consequences of failing to identify misinformation techniques, while positive narrative inoculation emphasizes the positive outcomes of successfully identifying misinformation techniques.

2.3 ▪ *Conferring resistance against misinformation*

The question of whether narrative inoculation messages can enhance or diminish resistance to persuasive attacks remains unanswered [Compton & Mason, 2020]. Previous research has shown that inoculation messages inducing both positive and negative affect can generate resistance [Pfau et al., 2009]. However, these emotional inoculation messages were found to be less effective than cognitive inoculation messages in eliciting counterarguing [Pfau et al., 2001]. It is worth noting that the measurement of counterarguing immediately after the inoculation messages may have captured counterarguing towards the inoculation messages themselves rather than counterargumentation towards persuasive attacks [Pfau et al., 2001, 2009]. Moreover, while narratives were employed in affective inoculation messages to evoke positive and negative affect, they were not directly compared with cognitive (didactic) inoculation messages [Pfau et al., 2001, 2009]. Therefore, further investigation is needed to determine the effectiveness of narrative-based inoculation messages in countering future persuasive attacks.

One rationale for why narrative can serve as an effective inoculation message is that narrative can induce higher levels of threat. Compared with rhetorical arguments, narratives

often incorporate emotionally evocative language, leading to a stronger emotional impact on individuals' beliefs, attitudes, and behaviors [Green, 2006; McQueen et al., 2011]. For example, exposure to a narrative video advocating for breast cancer screening resulted in heightened negative and positive emotions, which subsequently reduced perceived barriers to undergoing screening [McQueen et al., 2011]. Similarly, individuals who watched videos featuring personal stories of breast cancer survivors were more likely to remember information about mammograms, perceive breast cancer as a significant issue, and express higher intentions to undergo mammography [Kreuter et al., 2010]. Studies involving cervical cancer-related films also found that viewers perceived a higher risk of cervical cancer, increased their knowledge about the disease and developed positive attitudes towards Pap tests [Murphy et al., 2013]. By harnessing the emotional power of narratives, inoculation messages can effectively heighten individuals' sense of threat, leading to more impactful changes in resistance to persuasive attacks. Compared with didactic inoculation, narrative inoculation will be more effective in inducing perceived threat. Therefore, we propose the following hypothesis:

H1: Compared with didactic inoculation, (a) negative and (b) positive narrative inoculation will induce higher levels of threat.

Another rationale for why narrative inoculation can serve as an effective inoculation message is that it might induce higher levels of counterarguing in response to persuasive attacks. The way narrative messages and inoculation messages deal with counterarguing seems contradictory. Narrative techniques have the power to reduce counterarguing, which results in better persuasive outcomes [Green, 2006; Moyer-Gusé & Nabi, 2010]. Whereas inoculation aims to generate higher levels of counterarguing towards persuasive messages [Compton, 2013]. However, it is important to differentiate between counterarguing towards inoculation and counterargumentation in response to persuasive attacks. Research suggests that psychological reactance to didactic inoculation can hinder the effectiveness of resistance conferred by the inoculation treatment [Miller et al., 2013]. Despite the intention of refutational preemption in an inoculation message to stimulate counterarguments, individuals may choose to avoid such refutation if they perceive their freedom being threatened [Miller et al., 2013]. In comparison to didactic inoculation, narrative inoculation could decrease resistance to the initial inoculation, subsequently motivating individuals to counterargue against misinformation. Therefore, we propose the following hypothesis:

H2: Compared with didactic inoculation, (a) negative and (b) positive narrative inoculation will induce higher levels of counterarguing against misinformation.

According to the theoretical arguments above, when individuals generate more counterarguments, they can better resist persuasive attacks. In the context of inoculation against misinformation, it can be assumed that individuals involved in higher levels of counterarguing are less likely to believe in misinformation, less likely to perceive misinformation as credible, and less likely to share misinformation. Recent research has provided compelling evidence indicating that individuals not only engage in reflective thinking about certain issues following inoculation but also express their intention to discuss these matters, a phenomenon commonly referred to as post-inoculation talk [Compton, 2013; Ivanov et al., 2009]. With the advent of digital platforms and the widespread use of social media, individuals now can express their thoughts, opinions, and newly acquired knowledge about various topics through online channels. The intention to share information online can

be viewed as a contemporary manifestation of post-inoculation talk. The intention to share misinformation has also been recognized as a crucial factor in evaluating the effectiveness of psychological inoculation in countering misinformation [e.g., Lu et al., 2023; Roozenbeek et al., 2022]. Understanding whether inoculation can reduce the intention to share misinformation is not only theoretically significant but also has important practical implications. Therefore, we propose the following hypotheses:

H3: Compared with those exposed to didactic inoculation, individuals exposed to negative or positive narrative inoculation will (a) have a lower level of belief in misinformation, (b) perceive misinformation to be less credible, and (c) have a lower intent to share misinformation.

2.4 ▪ *The impact of preexisting attitude*

While classic inoculation strategies traditionally focus on reinforcing positive attitudes toward cultural truisms like daily teeth brushing, recent research suggests the need to differentiate between prophylactic inoculation and therapeutic inoculation [Compton, 2020]. Drawing inspiration from medical practices, prophylactic measures aim to prevent diseases, while therapeutic measures are employed to cure diseases that have already been acquired. In the relevant case, prophylactic inoculation involves messages designed to prevent individuals from developing negative or false opinions. On the other hand, therapeutic inoculation can be utilized to target individuals who already hold initial beliefs about a topic, with the goal of reversing or mitigating the impact of misbeliefs [Compton, 2020].

Wood [2007] has tested the effects of inoculation on individuals in favor of or against agricultural biotechnology. In contrast to the traditional inoculation research design, participants in Wood's [2007] study were not assigned to a condition consistent with their initial attitude. Instead, all the participants were exposed to the same inoculation message, which included a threat and refutation preemption regarding the potential health and environmental risks of agricultural biotechnology [Wood, 2007]. The findings revealed that inoculation enhanced resistance to future message attacks about agricultural biotechnology among individuals who were initially supportive, neutral, or opposed to the issue [Wood, 2007]. Further research demonstrated that inoculation could also induce resistance among individuals who were initially opposed to or neutral toward the issue [Ivanov et al., 2017]. This expanded the scope of inoculation research and demonstrated the potential benefits of inoculation for individuals who have already been influenced by opposing views [Compton, 2020]. For instance, van der Linden et al. [2017] found that inoculation against the fake expert technique — used to create the illusion of scientific disagreement — was effective across the political spectrum, regardless of individuals' initial attitudes toward climate change. Similarly, Cook et al. [2017] demonstrated that inoculation targeting misleading argumentative techniques can mitigate the influence of worldviews on the acceptance of misinformation. A registered replication study of van der Linden et al. [2017] by Maertens et al. [2020] supported these findings, showing that exposure to inoculation messages about the fake expert technique can effectively protect individuals from climate change misinformation, particularly when directly confronted with such content.

While individuals may still receive inoculation even if the inoculation message contradicts their existing beliefs, there remains uncertainty about its effectiveness in countering climate

change misinformation. Extensive research has demonstrated that people tend to exhibit confirmation bias, actively avoiding information that contradicts their preexisting attitudes and beliefs [Taber & Lodge, 2006]. We anticipate that this bias may also come into play when individuals process inoculation messages. Therefore, we posit that individuals who perceive climate change as a highly pressing issue will exhibit greater resistance to climate misinformation compared with those who view it as less pressing. We formulate the following hypothesis:

H4: Individuals who are more concerned about climate change will be more likely to (a) perceive a threat, (b) counterargue against misinformation, (c) have less belief in misinformation, (d) perceive misinformation as less credible, and (e) express a lower intent to share misinformation compared with those who are less concerned about climate change.

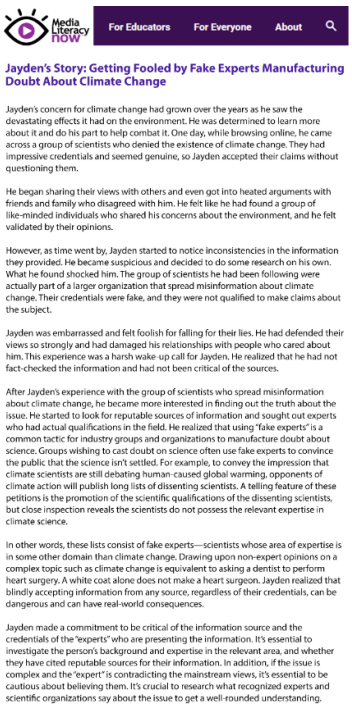
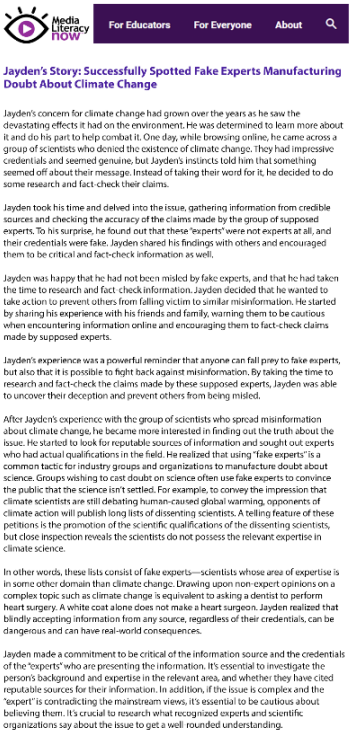
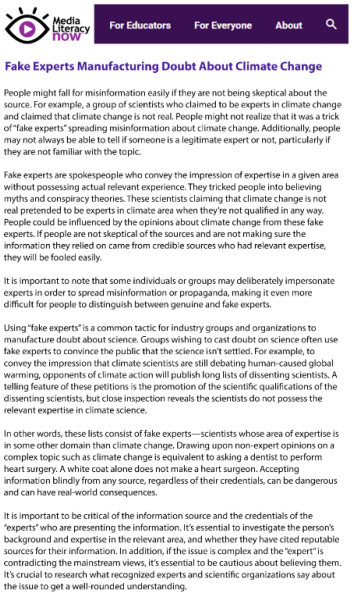
3 ▪ Method

To investigate the impact of different types of inoculation messages on conferring resistance to misinformation, we conducted an online between-subjects experiment with four conditions. Participants were randomly assigned to view one of the following four set of stimuli: (a) negative narrative inoculation preceding a misinformation attack; (b) positive narrative inoculation followed by a misinformation attack; (c) didactic inoculation preceding a misinformation attack; and (d) irrelevant message (no inoculation) followed by a misinformation attack. In the misinformation-only group, participants were not exposed to an inoculation message but an irrelevant message and the misinformation. This study was approved by the Human Research Ethics Committee at the authors' affiliated University. The whole online experiment was embedded in Qualtrics, and took participants about 10 to 15 minutes to complete the study.

3.1 ▪ *Participants*

A priori power analysis was conducted using G*Power (Cohen's $f = .25$; $\alpha = .05$; power = .95, $df = 3$) and indicated that a minimum sample size of 279 participants was required for F-tests. The study obtained a total of 296 valid responses from adults in the United States, gathered on the online platform CloudResearch (MTurk Toolkit). Among the participants, 51.7% were male and 48.3% were female. The majority of the participants (79.4%) identified themselves as White, while 7.4% were Asian/Pacific Islander, 6.4% were African American, 6.1% were Hispanic/Latino(a), and 0.3% were American Indian/Native American. In terms of political affiliation, 43.2% self-identified as Democratic, 52.4% as Republican, and 3.4% as Independent. The average age of participants was 43 years old ($SD = 13.46$). The median household income before tax fell within the range of US$50,000–$74,999. Furthermore, the participants had a median education level of a master's degree. The adequacy of randomization was confirmed through one-way ANOVAs and Chi-square tests (see Table 1). The results of the one-way ANOVAs indicated that there were no significant differences in age ($F(3, 292) = .43$, $p = .74$), education level ($F(3, 292) = 1.73$, $p = .16$), household income ($F(3, 292) = .45$, $p = .72$), political ideology ($F(3, 292) = .63$, $p = .60$), and prior attitude towards the issue of climate change ($F(3, 292) = .69$, $p = .56$) across the conditions. Furthermore, the distribution of participants across the conditions did not differ significantly in terms of

Table 1. Stimuli.

Negative narrative inoculation (546 words)	Positive narrative inoculation (586 words)	Didactic inoculation (473 words)
		

gender ($\chi^2(3, N = 296) = 2.40$, $p = .49$), race ($\chi^2(15, N = 296) = 13.45$, $p = .57$), or political party affiliation ($\chi^2(12, N = 296) = 14.11$, $p = .29$). These results confirmed no significant differences in individual characteristics among participants exposed to different conditions.

3.2 ▪ *Procedure*

First, after giving their consent participants were asked to report their demographics, political ideology, and prior attitude towards the issue of climate change before being exposed to the stimuli. Then, participants were randomly assigned to one of four conditions: (1) negative narrative inoculation with a character who successfully identified misinformation, followed by a misinformation attack; (2) positive narrative inoculation with a character who failed to identify misinformation, followed by a misinformation attack; (3) didactic inoculation followed by a misinformation attack; (4) no inoculation (irrelevant message) followed by a misinformation attack.

The inoculation messages were presented as media literacy messages on a simulated website page. These messages addressed the threat of fake experts spreading misleading claims that climate change was not caused by humans and provided ways to identify them. The misinformation attack was initially presented as a petition message on social media, followed by a simulated petition website that detailed a group of supposed climate science experts signing a petition denying human-caused climate change and advocating for increased drilling to lower gas prices. For participants not exposed to an inoculation

message, an irrelevant message discussing how to protect digital privacy was presented. Participants were required to view each stimulus from the simulated websites for at least 60 seconds and the social media posts for at least 15 seconds before proceeding. The specific details of stimuli can be found in Table 1.

After viewing the inoculation message or the irrelevant message (no inoculation), participants were asked to rate items that measure their perceived threat. Subsequently, after reading the misinformation attack, participants were asked to provide ratings on counterarguing against the message, belief in the misinformation, perceived credibility of the message, and intention to share the message. At the end of the study, all participants were provided with a debriefing stating that the information suggesting that climate change is not real was misleading. Debriefing is crucial in misinformation research as previous exposure to misinformation can potentially harm participants and inadvertently contribute to the spread of misinformation.

3.3 ▪ *Measures*

Prior to participant exposure to the inoculation message, demographic information, political party affiliation, political ideology, and prior attitude towards climate change were measured.

Prior attitude towards climate change. Participants' prior attitude towards climate change was assessed in a manner that would not sensitize participants to the climate change issue. Participants were asked to rate their attitudes towards a series of issues, including health care, climate change, vaccination, gun control, and abortion. Participants were asked to indicate the importance of each issue (1 = *not important at all* to 7 = *very important*) and their level of support for government action on each issue (1 = *do not support at all* to 7 = *to extremely support*). The responses to the two items related to the climate change issue were highly correlated ($r = .84$, $p < .001$). These two items were combined to form a measure of prior attitude towards the climate change issue ($M = 4.76$; $SD = 2.15$), where higher scores indicated greater involvement and support for actions addressing climate change. In other words, higher scores indicated individuals are concerned about climate change more (1 = *not concerned about climate change at all* to 7 = *extremely concerned about climate change*).

After exposure to the inoculation message, several variables were measured, including manipulation checks and perceived threat.

Manipulation check. Participants were asked to indicate whether the inoculation message read like a story. This was assessed using items such as "There is a plot in the message" and "The message reads like a story" [Huang & Wang, 2022]. These two items were combined into an index ($r = .64$; $M = 4.42$; $SD = 1.75$). In addition, participants were asked to rate the agreement with the following statements: (a) This message emphasizes someone who fails to identify misinformation ($M = 3.40$; $SD = 2.14$); and (b) This message emphasizes someone who successfully identify misinformation ($M = 4.20$; $SD = 2.15$).

Perceived threat. Adapted from Burgoon et al. [1978], Pfau and Burgoon [1988] and Pfau et al. [1997], participants were asked to indicate their perception of the threat of misinformation in a five-item bipolar scale including: not risky/risky, nonthreatening/threatening, unintimidating/intimidating, not harmful/harmful, and safe/dangerous. These five items were combined into an index ($\alpha = .92$; $M = 5.09$; $SD = 1.46$).

After exposure to the misinformation attack, participants were asked to complete an attention check to ensure their engagement with the material. Subsequently, participants were assessed on counterarguing, belief in misinformation, perceived credibility of the petition message, and behavioral intention to share the petition message.

Attention check. Participants were asked to select the issues depicted in the messages from the following choices: (a) vaccination issue, (b) climate change issue, (c) genetically modified food issue, and (d) Internet privacy and artificial intelligence. Participants who did not identify the correct issues were eliminated from the study sample.

Counterarguing. A counterarguing scale was used to measure counterarguing against misinformation [Moyer-Gusé & Nabi, 2010]. Participants were asked to think about the petition message they had just read and rate the extent to which they disagreed or agreed with the following statements: (a) I found myself actively disagreeing with the message; (b) I was looking for flaws in the message's arguments; (c) I found myself actively agreeing with the message's points; and (d) It was easy to agree with the arguments made in this message. After reverse coding items (c) and (d), these four items were combined into an index ($\alpha = .88$; $M = 4.77$; $SD = 1.77$).

Belief in misinformation. Participants were asked to indicate the degree to which they believed each statement is true at this moment: (a) Climate change is a hoax that the government uses to increase taxes paid by citizens; (b) Climate change is a natural event. The science behind the human cause of climate change has been distorted or misused by scientists and politicians for ideological or financial reasons; (c) Developed countries use climate change as an excuse to slow down the rising economic power of developing countries; (d) Extreme weather is not linked to climate change at all; (e) It is solar changes that are causing the Earth to warm but not us; and (f) Climate change is a made-up catastrophe. Items a, b, and c were adapted from the existing belief in climate change conspiracy theories scale [Chan et al., 2023]. Items e and d were based on the misinformation stimuli in the current study. These six items were combined into an index ($\alpha = .94$; $M = 2.66$; $SD = 1.69$).

Perceived credibility. Adapted from Appelman and Sundar [2016], participants were asked to think about the petition message they had just read and indicate their evaluation of the message they had read on a six-item bipolar scale including: inaccurate/accurate, inauthentic/authentic, unbelievable/believable, not concise/concise, unprofessional/professional, and unbiased/biased. After reverse coding one item (unbiased/biased), these six items were combined into an index ($\alpha = .92$; $M = 3.42$; $SD = 1.68$).

Intention to share misinformation. Participants were asked to think about the petition (misinformation) message they just saw and how likely they were going to engage in the following behaviors (1 = *very unlikely* to 7 = *very likely*): (a) I will share the petition message to others in person; (b) I will share the content depicted in the petition message with others; (c) I will share the petition message online; (d) I will sign this petition online; and (e) I will talk about this petition message with others. These five items were combined into an index ($\alpha = .96$; $M = 2.11$; $SD = 1.60$).

4 ▪ Results

Participants' responses on prior attitude towards climate change (1 = *not concerned about climate change at all* to 7 = *extremely concerned about climate change*) were used to categorize them into a low climate concern group (scored 1 to 4, including 4) or a high climate concern group (scored above 4 to 7). Ultimately, 106 participants were classified in the low climate concern group, while 190 participants were classified in the high climate concern group. The mean and standard deviation of key dependent variables across conditions is presented in Table 2.

Table 2. Mean and standard deviation of key dependent variables across conditions.

	Negative narrative inoculation		*Positive narrative inoculation*		*Didactic inoculation*		*Misinformation only*	
	Low climate concern	*High climate concern*	*Low climate concern*	*High climate concern*	*Low climate concern*	*High climate concern*	*Low climate concern*	*High climate concern*
Perceived threat	4.65 (1.44)	5.09 (1.57)	4.21 (1.83)	5.35 (1.31)	4.87 (1.34)	5.90 (1.00)	4.53 (1.48)	5.3 (1.42)
Counterarguing	4.38 (1.74)	5.49 (1.52)	4.14 (1.76)	5.59 (1.61)	4.54 (1.58)	5.48 (1.65)	3.81 (1.68)	5.91 (1.25)
Belief in misinformation	4.00 (1.40)	2.00 (1.20)	4.30 (1.90)	1.80 (1.10)	3.70 (1.70)	2.00 (1.30)	3.90 (1.50)	1.70 (1.10)
Perceived credibility	3.93 (1.48)	2.73 (1.56)	3.88 (1.61)	2.98 (1.65)	3.53 (1.26)	2.68 (1.54)	3.85 (1.57)	2.47 (1.57)
Intention to share	2.37 (1.79)	1.74 (1.46)	2.51 (1.95)	2.12 (1.70)	1.72 (1.53)	1.83 (1.26)	1.97 (1.56)	1.89 (1.68)

Note: N = 296. The number above the bracket indicates the mean while the number within the bracket indicates the standard deviation. For example, 4.65 (1.44) represents mean = 4.65 and standard deviation = 1.44.

Manipulation check results. A one-way ANOVA revealed significant differences across the three inoculation messages in terms of the perceived story-like content of the message ($F(3, 292) = 48.78$, $p < .001$). Participants perceived negative narrative inoculation ($M = 5.67$; $SD = 1.09$) or positive narrative inoculation ($M = 5.45$; $SD = 1.13$) as reading significantly more like a story compared with the didactic inoculation message ($M = 4.20$; $SD = 1.63$). In addition, there were no significant differences regarding the perceived story-like content of the message between negative narrative inoculation and positive narrative inoculation according to Sidak post hoc comparisons ($p = .987$).

The results of a one-way ANOVA indicated significant differences in the perception of three types of inoculation messages emphasizing negative outcomes from individuals failing to identify misinformation ($F(3, 292) = 58.28$, $p < .001$). Sidak post hoc comparisons revealed that the participants who were exposed to negative narrative inoculation ($M = 5.15$; $SD = 2.03$) perceived the message to emphasize someone who failed to identify misinformation significantly more than those exposed to positive narrative inoculation messages ($M = 2.14$; $SD = 1.66$). Additionally, participants perceived the didactic inoculation to significantly emphasize someone failing to identify misinformation more than the positive narrative inoculation ($M = 4.69$; $SD = 1.72$). There were no differences observed between negative narrative inoculation and didactic inoculation regarding the perception of negative outcomes.

Similarly, the results of a one-way ANOVA indicated significant differences in participants' perception of the three types of inoculation messages emphasizing positive outcomes for individuals who successfully identified misinformation ($F(3, 292) = 48.71$, $p < .001$). Sidak post hoc comparisons revealed that participants exposed to positive narrative inoculation ($M = 6.36$; $SD = 1.41$) perceived the message to significantly emphasize someone who successfully identified misinformation more than those exposed to negative narrative inoculation ($M = 4.54$; $SD = 2.00$). Furthermore, participants exposed to positive narrative inoculation perceived the message to significantly emphasize the positive outcome compared with those exposed to didactic inoculation ($M = 4.17$; $SD = 1.85$). However, there were no significant differences between negative narrative inoculation and didactic inoculation in terms of the perceived positive outcome.

Data analysis & robustness check. First of all, one-way ANOVAs were conducted to test the effects of different types of inoculation messages on perceived threat ($F(3, 292) = 3.59$, $p = .01$, $\eta_p^2 = .04$), counterarguing ($F(3, 292) = .08$, $p = .97$, $\eta_p^2 = .001$), belief in misinformation ($F(3, 292) = .49$, $p = .69$, $\eta_p^2 = .005$), perceived credibility ($F(3, 292) = .78$, $p = .51$, $\eta_p^2 = .008$), and intention to share ($F(3, 292) = 1.10$, $p = .35$, $\eta_p^2 = .01$). Results indicated that different types of inoculation messages had a significant effect only on perceived threat, with no significant differences observed for other variables of interest. However, Sidak post hoc comparisons revealed that exposure to didactic inoculation ($M = 5.58$; $SD = 1.21$) significantly induced higher level of threat compared with positive narrative inoculation ($M = 4.92$; $SD = 1.53$; $p = .05$) but other pairs of comparisons did not have significant differences. To ensure that the null results are not due to the study's relatively small sample size, a Bayesian one-way ANOVA assessing the effects of conditions on perceived threat ($F(3, 292) = 3.59$, $p = .01$) indicated that the null hypothesis could be rejected, but the Bayes Factor (testing model vs. null model: $B_{10} = 0.06$) provided very strong evidence in favor of H0. Furthermore, Bayesian ANOVAs examining the effects of conditions on counterarguing ($F(3, 292) = .08$, $p = .97$, $B_{10} < .001$), belief in misinformation ($F(3, 292) = .49$, $p = .69$, $B_{10} = .001$), perceived credibility ($F(3, 292) = .78$, $p = .51$, $B_{10} = .001$), and intention to share ($F(3, 292) = 1.10$, $p = .35$, $B_{10} = .002$) also failed to reject the null hypothesis, with Bayes Factor values providing very strong evidence in its favor.

Next, two-way ANOVAs were conducted to test the effects of different types of inoculation messages and prior attitude to climate change on variables of interest. The two-way ANOVA results showed that there was a significant main effect of types of inoculation messages on perceived threat ($F(3, 288) = 3.49$, $p = .04$, $\eta_p^2 = .03$). Sidak post hoc comparisons revealed that exposure to didactic inoculation significantly resulted in higher level of threat compared with positive narrative inoculation. However, there were no significant main effects of types of inoculation messages on counterarguing ($F(3, 288) = .13$, $p = .94$, $\eta_p^2 = .001$), belief in misinformation ($F(3, 288) = .72$, $p = .54$, $\eta_p^2 = .007$), perceived credibility ($F(3, 288) = .60$, $p = .60$, $\eta_p^2 = .006$), and intention to share ($F(3, 288) = 1.36$, $p = .26$, $\eta_p^2 = .01$). Furthermore, two-way ANOVA results showed that there was a significant main effect of prior attitude on perceived threat ($F(1, 288) = 24.70$, $p < .001$, $\eta_p^2 = .08$), counterarguing ($F(1, 288) = 52.64$, $p < .001$, $\eta_p^2 = .16$), belief in misinformation ($F(1, 288) = 168.04$, $p < .001$, $\eta_p^2 = .37$), and perceived credibility ($F(1, 288) = 33.28$, $p < .001$, $\eta_p^2 = .10$). Those who had high concern about climate change perceived significantly more threat, counterargue against misinformation more, believed in climate misinformation less, and perceived misinformation less credible compared with those who had low concern about climate change. However,

ANOVA results revealed that there was no significant main effect of prior attitude on intention to share ($F(1, 288) = 1.36$, $p = .26$, $\eta_p^2 = .01$).

To further ensure the data analysis is robust, a series of 2 prior attitude (low climate concern vs. high climate concern) × 4 (negative narrative inoculation, positive narrative inoculation, didactic inoculation, misinformation only) ANCOVAs controlling for age, gender, race (dummy coded), education, income, political ideology was conducted to examine the main effects of prior attitude towards climate change and inoculation message format on the variables of interest. The ANCOVA results mirrored the patterns observed in the one-way and two-way ANOVAs reported above. The final ANCOVA results are presented below.

H1 proposed that (a) negative and (b) positive narrative inoculation would induce higher levels of threat compared with didactic inoculation. However, a significant difference was observed in perceived threat among participants exposed to different types of inoculation messages through the two-way ANCOVA results ($F(3, 282) = 2.76$, $p = .04$, $\eta_p^2 = .03$). Sidak post hoc comparisons revealed that participants exposed to didactic inoculation ($M = 5.58$; $SD = 1.21$) perceived a significantly higher level of threat compared with those exposed to positive narrative inoculation ($M = 4.92$; $SD = 1.53$; $p = .03$). However, there was no significant difference in perceived threat level between didactic inoculation and negative narrative inoculation ($M = 4.95$; $SD = 1.60$; $p = .06$). In addition, Sidak post hoc comparisons indicated that participants exposed to negative narrative inoculation or positive narrative inoculation did not perceive a significant difference in the level of threat ($p = 1.00$). Therefore, H1 was not supported.

H2 proposed that (a) negative and (b) positive narrative inoculation will induce higher levels of counterarguing compared with didactic inoculation. The two-way ANCOVA results indicated that there were no significant differences in counterarguing against misinformation among participants exposed to different types of inoculation messages ($F(3, 282) = .26$, $p = .86$, $\eta_p^2 = .003$). Therefore, H2 was not supported.

H3 proposed that compared with those exposed to didactic inoculation, individuals exposed to negative or positive narrative inoculation would (a) have a lower level of belief in misinformation, (b) perceive misinformation as less credible, and (c) have lower intent to share misinformation. Results showed that there was no difference in belief in misinformation ($F(3, 282) = 1.24$, $p = .30$, $\eta_p^2 = .01$), perceived credibility of misinformation ($F(3, 282) = .78$, $p = .50$, $\eta_p^2 = .01$), and intention to share misinformation ($F(3, 282) = 1.69$, $p = .17$, $\eta_p^2 = .02$) across the three types of inoculation messages (see Table 3). Therefore, H3 was not supported.

H4 proposed that individuals who are more concerned about climate change would be more likely to (a) perceive a threat, (b) counterargue against misinformation, (c) have less belief in misinformation, (d) perceive misinformation as less credible, and (e) express a lower intent to share misinformation compared with those who are less concerned about climate change. Two-way ANCOVAs results showed that there was no difference between the high climate concern group and the low climate concern group regarding intent to share misinformation ($F(1, 282) = .66$, $p = .42$, $\eta_p^2 = .002$). However, there was a main effect of prior attitude towards climate change on perceived threat ($F(1, 282) = 12.69$, $p < .001$, $\eta_p^2 = .04$). Those who had high concern about climate change perceived significantly more threat ($M = 5.44$; $SD = 1.35$) compared with those who had low concern about climate change ($M = 4.56$; $SD = 1.53$). There was also a main effect of prior attitude towards climate change on counterarguing

Table 3. Variables of interest as a function of inoculation message condition.

	Negative narrative inoculation	*Positive narrative inoculation*	*Didactic inoculation*	*Misinformation only*	
Perceived threat	4.92ab (1.53)	4.95b (1.60)	5.58a (1.21)	5.01ab (1.48)	$F(3, 282) = 2.76$, $p = .04$, $\eta_p^2 = .03$
Counterarguing	5.06a (1.70)	5.08a (1.79)	5.19a (1.68)	5.10a (1.76)	$F(3, 282) = .26$, $p = .86$, $\eta_p^2 = .003$
Belief in misinformation	2.79a (1.62)	2.72a (1.84)	2.50a (1.61)	2.55a (1.64)	$F(3, 282) = 1.24$, $p = .30$, $\eta_p^2 = .01$
Perceived credibility	3.20a (1.63)	3.30a (1.68)	2.94a (1.50)	3.00a (1.70)	$F(3, 282) = .78$, $p = .50$, $\eta_p^2 = .01$
Intention to share	1.99a (1.62)	2.25a (1.79)	1.80a (1.34)	1.92a (1.62)	$F(3, 282) = 1.69$, $p = .17$, $\eta_p^2 = .02$

Note: N = 296; lower-case subscripts reflect significant differences within rows. Without a shared subscript indicates a significant difference at $p < .05$; adjustment for multiple comparisons: Sidak. Age, gender, race (dummy coded), education, income, and political ideology were controlled. In addition, a series of one-way ANOVA without controlling for age, gender, race (dummy coded), education, income, political ideology, and prior attitude towards climate change issue were also conducted. Results showed that the significance of testing did not change, and the findings remain the same.

($F(1, 282) = 13.63$, $p < .001$, $\eta_p^2 = .08$). Those who had high concern about climate change counterargue against misinformation more ($M = 5.61$; $SD = 1.52$) than those who had low concern about climate change ($M = 4.21$; $SD = 1.69$). In addition, there was a significant main effect of prior attitude towards climate change on belief in misinformation ($F(1, 282) = 52.59$, $p < .001$, $\eta_p^2 = .18$). Those who had high concern about climate change believed in misinformation less ($M = 1.88$; $SD = 1.16$) compared with those who had low concern about climate change ($M = 3.99$; $SD = 1.61$). There was a main effect of prior attitude towards climate change on the perceived credibility of misinformation ($F(1, 282) = 6.77$, $p = .01$, $\eta_p^2 = .02$). Those who had high concern about climate change perceived misinformation as less credible ($M = 2.72$; $SD = 1.58$) than those who had low concern about climate change ($M = 3.81$; $SD = 1.48$). Therefore, H4e was not supported and H4a-H4d were supported (see Table 4).

5 ▪ Discussion

Inoculation has proven to be a powerful tool in building immunity to misinformation, particularly when used preemptively before individuals are exposed to false information [Compton, 2021; Vraga et al., 2022]. Its effectiveness has been demonstrated in various contexts, including public health campaigns and combating contested science and conspiracy theories [Cook et al., 2017]. Despite its success in these areas, surprisingly this study revealed that all three types of inoculation messages had no significant effects on various measures of resistance to misinformation, such as counterarguing against misinformation, belief in misinformation, perceived credibility of misinformation, and intention to share misinformation. While these findings may not be encouraging for the field of inoculation research, recent studies have also struggled to establish the effectiveness of inoculation messages in dealing with misinformation [Harjani et al., 2023; Schmid-Petri & Bürger, 2022].

Table 4. Variables of interest as a function of prior attitude towards climate change.

	Low climate concern group	*High climate concern group*	
Perceived threat	4.56a (1.53)	5.44b (1.35)	$F(1, 282) = 12.69$, $p < .001$, $\eta_p^2 = .04$
Counterarguing	4.21a (1.69)	5.61b (1.52)	$F(1, 282) = 13.63$, $p < .001$, $\eta_p^2 = .08$
Belief in misinformation	3.99a (1.61)	1.88b (1.16)	$F(1, 282) = 52.59$, $p < .001$, $\eta_p^2 = .18$
Perceived credibility	3.81a (1.48)	2.72b (1.58)	$F(1, 282) = 6.77$, $p = .01$, $\eta_p^2 = .02$
Intention to share	2.15a (1.72)	1.90a (1.52)	$F(1, 282) = .66$, $p = .42$, $\eta_p^2 = .002$

Note: N = 296; lower-case subscripts reflect significant differences within rows; without a shared subscript indicates a significant difference at $p < .05$. Adjustment for multiple comparisons: Sidak. Prior attitude towards climate change issue were categorized into two groups: low climate concern group (score 1 through 4) and high climate concern group (score above 4 to 7). Control for age, gender, race (dummy coded), education, income, and political ideology, two-way ANCOVAs were conducted to test the effects of prior attitude towards climate change and message format condition on variable of interest. No interaction effects were detected. The results of the main effect of prior issue attitude on variable of interest were presented in the table.

Our findings suggest that inoculation may not be effective in preventing individuals from believing and sharing misinformation about climate change. Although our null findings regarding the effects of inoculation messages do not align with prior research demonstrating that inoculation against the fake expert technique effectively reduces the acceptance of misinformation across the political spectrum [Cook et al., 2017; Maertens et al., 2020; van der Linden et al., 2017], the relatively low effect sizes observed in some studies warrant further investigation and consolidation [Schmid-Petri & Bürger, 2022]. While our findings are somewhat unexpected, recent studies have also encountered challenges in establishing the effectiveness of inoculation messages against misinformation [Harjani et al., 2023; Schmid-Petri & Bürger, 2022; Spampatti et al., 2024]. For instance, Schmid-Petri and Bürger [2022] replicated Cook et al.'s [2017] study but failed to reproduce the inoculation effects, finding instead that inoculation had only minimal impact on climate-related attitudes. Their findings reinforced the critical role of pre-existing worldviews in shaping attitudes toward climate change. Spampatti et al. [2024] conducted a cross-national experiment across 12 countries and found that six inoculation strategies had no significant effect on shielding individuals from climate misinformation. Their findings indicated no impact of inoculation on climate change beliefs, the evaluation of climate mitigation efforts, or the ability to discern truth. Similarly, Harjani et al. [2023] found that gamified inoculation was ineffective in the Indian context, highlighting a significant gap in inoculation research, which has predominantly been conducted in WEIRD (Western, Educated, Industrialized, Rich, Democratic) countries. This raises important questions about whether inoculation can be effective in developing countries with distinct media consumption patterns.

Researchers have suggested that the lack of significant inoculation effects may be due to the true effect size being smaller than anticipated [Spampatti et al., 2024]. Given the relatively small sample size in our study, this could be a potential explanation for the null findings regarding the effects of the inoculation message. Additionally, a recent meta-analysis found

that for polarized scientific issues like climate change, fact-checking had no significant effect on correcting misbeliefs about scientific evidence, highlighting the crucial role of preexisting attitudes in how people process misinformation [Chan & Albarracín, 2023]. While our study did not find significant inoculation effects, it does provide insight into a key moderating factor — preexisting issue attitudes — that may influence the effectiveness of inoculation strategies. Our null findings contribute to this ongoing discussion by reaffirming the importance of pre-existing attitudes in shaping responses to climate change issues. As climate change becomes an increasingly contentious topic — arguably more polarizing now than when earlier studies tested inoculation effects [e.g., Cook et al., 2017; Maertens et al., 2020; van der Linden et al., 2017] — it remains valuable to reassess these effects in contemporary contexts. Given that climate change is becoming an increasingly polarized issue in the United States, prior attitudes towards the issue may play a more significant role in shaping reactions to climate change misinformation, irrespective of whether individuals were exposed to inoculation messages or not. In this case, inoculation messages may not be strong enough for those who are not concerned about climate change, such as those who do not believe that climate change is important and do not think any action is needed to address it.

The lack of persuasion observed in the inoculation messages can be attributed to the firmly established attitudes of the participants towards the issue of climate change [Druckman & McGrath, 2019; Ma et al., 2019]. Our findings showed that their pre-existing beliefs regarding climate change served as a barrier to the effectiveness of the inoculation messages. This observation suggests the presence of a floor effect, indicating that participants in the study generally held a very low level of resistance to climate change misinformation. Consequently, the inoculation was ineffective in conferring resistance to climate change misinformation. To address these limitations and advance the field, future research should emphasize the selection of issues that have not already solidified in the minds of individuals. By focusing on topics where pre-existing attitudes are not as firmly established, future research can explore the potential of inoculation against the misinformation attack more effectively.

The results revealed that participants who were less concerned about climate change were significantly less likely to counterargue against misinformation and more likely to believe in misinformation and perceive it as credible compared with those who were more concerned about climate change. The findings showed us prior issue attitude has a strong impact on resistance to future misinformation attacks. This suggests that there is a need to examine whether prior attitude moderates any effects of inoculation treatment on conferring resistance. It also highlights why classic inoculation research prefers issues that are not typically attacked to avoid biased processing [McGuire, 1964]. However, since controversial issues are often accompanied by misinformation, research is needed to develop effective inoculation messages for contested topics [Compton, 2020].

Although the three types of inoculation messages used in the study did not have significant effects on the majority of variables related to resistance to misinformation, the didactic inoculation did have a significant effect on the perceived threat of being misinformed. It is worth noting that threat was conceptualized traditionally as “the recognition of impending challenges to attitudes, which triggers a perception of the vulnerability of attitudes to potential change” [Compton & Pfau, 2005, p. 100]. Threat is a prerequisite for generating counterarguments in the process of inoculation, which means without threat resistance will not be able to generate [McGuire, 1964]. Results showed that didactic inoculation

significantly induced more perceived threat than exposure to positive narrative inoculation. Furthermore, individuals exposed to didactic inoculation perceived a similar level of threat compared with those exposed to negative narrative inoculation. This is contrary to the prediction that narrative inoculation, which involves emotionally evocative language, could induce a higher level of threat [Green, 2006; McQueen et al., 2011]. The results suggest that cognitive (didactic) inoculation [Pfau et al., 2001], which relies on logical arguments and facts, may be more effective in inducing perceived threat than narrative inoculation.

One potential explanation for the unexpected outcome of narrative inoculation's effectiveness could be attributed to individuals perceiving that others are more susceptible to being deceived by misinformation techniques, particularly when they have been exposed to narratives illustrating how others were deceived by fake experts. Previous research has demonstrated that individuals tend to believe that others are more vulnerable to falling for fake news compared to themselves [Yang & Tian, 2021]. This perception of others' susceptibility to misinformation can, in turn, lead to a reduction in individuals' perceived threat of misinformation. Despite the prevalence of misinformation and the potential dangers it poses, individuals may develop a sense of overconfidence in their own ability to discern between true and false information. This overconfidence can arise from a cognitive bias that allows individuals to believe they are less susceptible to misinformation than others, thus diminishing their perceived threat of misinformation attacks.

There are several limitations in this study that need to be addressed. First, this study only tested inoculation messages aimed at combating one type of misinformation technique: fake experts. Misinformation is a complex phenomenon, and there are many different strategies and techniques that are used to spread false information, including impersonation, emotional language usage, spreading conspiracy theories, and trolling [Basol et al., 2020]. By only focusing on one type of misinformation technique, the current study runs the risk of case-category confounding [Jackson, 1992], where the results are specific to that misinformation and may not generalize to other types of misinformation. Therefore, future research should investigate the effectiveness of inoculation messages against various types of misinformation techniques to provide a more comprehensive understanding of this approach's effectiveness.

Furthermore, the present study lacks an examination of the long-term effectiveness of inoculation. McGuire [1964] suggests that the ideal timeframe between inoculation and persuasive attack should be two to seven days. A meta-analysis by Banas and Rains [2010] reveals that most studies adopt a delay ranging from one to thirteen days. The current research primarily focused on assessing the immediate resistance to misinformation attacks and did not assess whether the effects of inoculation would endure over time. Nonetheless, some studies have explored the longevity of inoculation effects. For instance, Maertens et al. [2021] found evidence of long-term effects in their research. Additionally, research has suggested that the decay of inoculation effects might occur at a slower pace when using narrative approaches [Niederdeppe et al., 2015]. This is because narratives tend to be more memorable than didactic forms of inoculation, as exemplars within narratives are more accessible and retrievable [Busselle & Shrum, 2003]. Future studies should incorporate longitudinal designs which would involve tracking individuals' attitudes and behaviors over an extended period after their exposure to inoculation.

Lastly, the current study relies on Amazon MTurk through a Cloud Research panel to collect data. While MTurk is a convenient and cost-effective platform for conducting research, there are concerns about data quality. The data quality from MTurk is less than ideal, and research has found that MTurk participants not only skim questions instead of reading them, but some even become professional survey takers for a living [Smith et al., 2016] thus potentially skewing the sample of a study. To address these concerns, the current study required MTurk participants to meet certain criteria, such as having a high approval rating and checking their IP addresses. However, future research could consider adopting additional measures to ensure data quality, such as using VPN blockers to prevent participants from using multiple accounts or bots to complete surveys.

Despite these limitations, the current study holds important implications for the theoretical and practical understanding of inoculation as a strategy to combat misinformation. One significant finding of this study is that narrative inoculation may not directly promote accurate information or diminish the impact of false claims, and that preexisting attitudes towards climate change significantly influence the inoculation process. Understanding how prior attitudes towards climate change interact with other components of inoculation, such as perceived threat and efficacy, can help optimize the persuasive impact of inoculation interventions. Our study suggests a closer examination of inoculation theory and its practical application in message design, particularly in combating misinformation on contested environmental issues.

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How to cite

Zhang, B. and Schmierbach, M. (2025). 'Comparing the efficacy of narrative and didactic inoculation in combating climate change misinformation: impact on misbeliefs and intention to share misinformation'. *JCOM* 24(04), A02. https://doi.org/10.22323/JCOM.1502.

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