

Psychological inoculation strategies to fight climate disinformation across 12 countries

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17 **Abstract**

18 Decades after the scientific debate about the anthropogenic causes of climate change has been
19 settled, climate disinformation messages are still challenging the scientific evidence in public
20 discourse. Here, we present a comprehensive theoretical framework of (anti)science belief
21 formation and updating to account for the different psychological factors that influence
22 acceptance or rejection of scientific messages. We will experimentally investigate, across
23 twelve countries (N=6816), the effectiveness of six inoculation strategies targeting the factors
24 identified in the framework – scientific consensus, trust in scientists, transparent
25 communication, moralization of climate action, accuracy, and positive emotions – to fight real-
26 world disinformation about climate science and climate mitigation actions. We expect the
27 inoculations to significantly protect participants’ climate change beliefs, affect towards climate
28 mitigation actions, actual pro-environmental behavior, and truth discernment capacity against
29 climate disinformation. Our findings will provide behavioral scientists and stakeholders with
30 new theory- and evidence-based strategies to fight climate disinformation in a warming world.

31

32 **Introduction**

33 The sixth report of the Intergovernmental Panel on Climate Change (IPCC)
34 unequivocally declared that climate change is real, and that humans are driving it^[1-2]. Whereas
35 97-99% of climate scientists agree about the human causation of climate change^[3-5], one third
36 of the global population doubts or denies its anthropogenic roots^[6-8]. This can be traced back
37 to half a century of disinformation by the climate change countermovement, comprised of fossil
38 fuel corporations and their front groups, scientists-for-hire, and lobbied politicians, who have
39 contested climate science and are now delaying necessary climate mitigation actions^[9-17]. This
40 multi-million dollar public relations effort^[18-21] operates mainly via popular communication
41 avenues^[3; 22-23] such as traditional^[24-26] and social media^[27-29], to shape climate discourse and
42 political decision-making^[17; 28]. Their claims take up legitimate concerns that people express –
43 such as high costs or uncertain efficacy of climate action – but qualify as disinformation
44 because concerns are intentionally distorted and amplified into misleading claims^[31-32] like bad
45 faith questioning of the scientific consensus^[33], overemphasizing the socio-financial burden of
46 climate mitigation policies^[14; 34], and scaremongering citizens into inaction through climate
47 doomism^[14]. Unfortunately, climate disinformation can be more persuasive than scientifically
48 accurate information^[35-38; see also 39].

49 People process scientific messages not as neutral information processors, but rather by
50 weighing them against their prior convictions^[40-45], against desired outcomes^[46-49], against
51 affective associations^[50-51], and through the lens of their sociocultural and ideological
52 contexts^[52-55] (see reviews^[56-60]). When these psychological factors are misaligned with
53 scientific information about climate change, antiscience beliefs fester^[39; 61] and become
54 resistant to correction^[57]. Two recent reviews offer distinct yet complementary perspectives on
55 how (dis)information and (anti)science beliefs hinge on different communicational bases and

56 psychological drivers. Phillip-Muller and colleagues^[61] identified the different
57 communicational bases upon which (anti)science beliefs can build: the sources of scientific
58 messages, the scientific messages themselves, recipients of the scientific messages, and the
59 recipients' epistemic style. In parallel, Ecker and colleagues^[57] grouped the psychological
60 drivers influencing (dis)information belief formation and revision into cognitive and socio-
61 affective drivers, depending on the psychological pathways they act upon to facilitate or hinder
62 belief formation and updating. Overall, both analyses affirmed that people's capacity and
63 motivation to process information and disinformation – (dis)information henceforth – is
64 conditional to the (mis)alignment of scientific information about climate change with specific
65 communicational and/or psychological factors^[57; 61].

66 Here we adapt these factors to construct a comprehensive framework of (anti)science
67 belief formation and updating (Table 1). In this framework, the processing of scientific
68 (dis)information is mapped onto its core communicational bases^[61]: sources, messages, and
69 recipients. These communicational bases are the entry points^[62] where different psychological
70 factors can influence (anti)science belief formation and updating through cognitive or socio-
71 affective pathways^[57].

72

73 Table 1 – Comprehensive framework of (anti)science belief formation and updating.

			CORE COMMUNICATIONAL BASES		
			Sources of scientific messages	Scientific messages itself	Recipients of scientific messages
PSYCHOLOGICAL DRIVERS	Cognitive pathway	Driver	Consideration of scientific sources	Match/mismatch with prior beliefs	(Lack of) analytical thinking and/or deliberation
		Proposed intervention	Scientific consensus inoculation	Transparent communication inoculation	Accuracy inoculation
	Socio-affective pathway	Driver	Trust in scientific sources	Match/mismatch with moral convictions	Emotional state during message processing
		Proposed intervention	Trust inoculation	Moralization inoculation	Positive emotion inoculation

74 Note: The interplay between the communicational bases and psychological drivers of (anti)science belief
75 formation and updating, and the theory-based psychological inoculations designed to address each entry point.
76 Dashed table borders between cognitive and socio-affective pathways signal that the pathway boundaries are
77 permeable, and that the effects of most intervention meant to address one pathway will very likely spill out to the
78 other pathway of scientific (dis)information processing. For example, we consider the transparent communication
79 inoculation to be acting on the cognitive driver “match/mismatch with prior beliefs”; however, its effects can spill
80 over towards the socio-affective driver “trust in scientific sources” [63; 64].

81 Such a framework allows both the systematic mapping of the different entry points of
82 scientific (dis)information, and the targeted, theory-based design of a comprehensive set of
83 psychological intervention strategies using cognitive and socio-affective pathways to protect
84 people from being influenced by disinformation. Among possible interventions, psychological
85 inoculations have been identified as one of the most promising approaches to fight climate
86 disinformation^[22; 65]. They consist of preemptive warnings about incoming disinformation
87 coupled with psychological resources^[66] – counterarguments^[38] and/or rhetorical techniques^{[67-}

88 ^{69]} – to resist disinformation^[70]. We now review how each factor identified in the framework
89 can engender acceptance or rejection of scientific messages, and propose a set of theory-based
90 psychological inoculations targeting them, with the aim of fighting scientific disinformation
91 about climate change.

92 The first entry point to (anti)science belief formation and updating are the sources of
93 scientific messages about climate change. At the cognitive pathway level, it has been shown
94 that the perception that the scientific community agrees about anthropogenic climate change
95 provides diagnostic information that people can use to strengthen their acceptance of climate
96 science. According to the gateway belief model^[71], accurate information about the scientific
97 consensus makes people more accepting of climate science and of climate actions^[72]. Since the
98 infamous “Luntz memo”^[73] coached Republican politicians to question the scientific consensus
99 about climate change, countermovement actors have been painting the scientific community as
100 divided and biased about the reality of climate change^[17; 33]. The result of this strategy has been
101 that people neglect current scientific sources, perceiving the scientific consensus to be
102 magnitudinally lower than the actual consensus (false consensus effect^[57; 71]), climate science
103 to be unsettled, and climate action therefore not necessary^[58]. To protect against disinformation
104 at the source basis via the cognitive pathway, people can then be psychologically inoculated
105 with arguments explaining the scientific consensus^[38]. At the socio-affective pathway level,
106 trust in the sources of scientific messages is essential for increasing information processing and
107 climate policy support^[74-82]. People update their beliefs when scientific messages are delivered
108 by trusted sources^[75; 83-85], whereas people who distrust mainstream and scientific information
109 sources are more susceptible to misinformation and to holding wrong beliefs^[86-88]. Moreover,
110 trust in climate stakeholders moderates the association between believing in climate change
111 and supporting mitigation policies like carbon taxes: people who distrust political climate
112 stakeholders oppose mitigation policies^[89-91], whereas people who trust them support

mitigation policies^[77-78; 89; 91; see also 92]. Scientists themselves are the most trusted sources for scientific information^[80; 93-94], and trust in science and scientists predicts support for climate mitigation behaviors more strongly than trust in other climate stakeholders^[95-96; see also 74]. To protect against disinformation at the source basis via the socio-affective pathway, emphasizing the trustworthiness of scientists can make this trust more salient^[82], potentially curbing disinformation uptake^[97]. Two non-peer-reviewed, preregistered studies support this idea, as preemptively making trust in key stakeholders of the energy transition salient protected support for renewable energy from multiple negative persuasive attacks^[98].

The second entry point to (anti)science belief formation and updating is the scientific message itself. People process scientific (dis)information based on the (un)intuitiveness of the messages^[39; 57; 99] and the (mis)alignment with their own worldviews, moral values, and political ideologies^[100-104]. At the cognitive pathway level, when people detect a conflict between their prior beliefs and incoming scientific messages^[43], they resist scientific information by generating counterarguments^[105-109]. Unaddressed counterarguments can cement policy opposition^[110-111; cf. 112], especially when people's legitimate concerns – such as the costs of climate actions^[113] – are turned into exaggerated counterarguments to stifle climate policies^[14; 33]. To protect against disinformation at the message basis via the cognitive pathway, counterarguing can be addressed by transparently communicating the pros and cons of debated policies^[63-64; 114-116]. Transparently addressing concerns while highlighting positive outcomes was recently found to increase COVID-19 vaccination intentions and trust in the source of the transparent communication, more than messages ignoring vaccination concerns; the elicited changes were moreover resistant to a subsequent conspiracy message attacking the vaccine^[63]. Turning to the socio-affective pathway level, scientific messages are resisted they are misaligned with people's moral values^[117-118]. Multiple studies show that when people's moral convictions are questioned by scientific messages, “moral convictions have the power to bend

138 people's factual beliefs, trust in authorities, and evaluations of procedures¹¹⁹ (pp. 87) (see¹²⁰⁻
139 ¹²⁴), which may result in rejection of scientific evidence. To protect against disinformation at
140 the message basis via the socio-affective pathway, one can link the importance of climate action
141 to a diversity of worldviews and moral orientations by framing scientific messages in moral
142 terms (e.g.¹²⁵⁻¹²⁸). Linking climate action to morality can moreover increase the likelihood
143 that people will take action¹²⁹: emblematically, climate activist Greta Thunberg cited moral
144 conviction as her primary driver for the climate strike movement¹¹⁸.

145 The third entry point to (anti)science belief formation and updating are the message
146 recipients. People who rely on intuitive thinking are more likely to believe and share
147 misinformation¹³⁰⁻¹³², whereas people who rely on reflective, deliberate thinking tend to hold
148 more accurate beliefs^{133-136; see review 43}. According to this research, most people are accurate in
149 determining the truthfulness of information when making judgments deliberately^{135; see also 111;}
150 ¹³⁷. However, they are easily distracted away from deliberation, thus engaging with
151 (dis)information without actively considering their factual basis¹³⁸. To protect against
152 disinformation at the recipient basis via the cognitive pathway, people can be directed to
153 thinking deliberately by prompting them to evaluate incoming information by their factual
154 accuracy¹³⁹⁻¹⁴⁰. Untested in the climate domain (but see a similar intervention¹⁴¹), accuracy
155 prompts robustly decreased the influence of misinformation on political belief and fake news
156 sharing¹³⁵ in the lab, in the field¹³⁶, and across countries (according to a non-peer-reviewed
157 preprint¹⁴²). Turning to the socio-affective level, the processing of scientific (dis)information
158 is furthermore influenced by the emotional state of the recipient¹⁴³. Emotions are a filter that
159 guides people towards relevant and valued information in a noisy environment¹⁴⁴⁻¹⁴⁶, their
160 motivational properties direct and support individuals' behavior¹⁴⁷. On the one hand,
161 correlational evidence suggests that emotion-laden misinformation spreads more widely in
162 social networks¹⁴⁸, and that people tend to believe misinformation more when it contains

emotional content^[149-150]. On the other hand, emotions have been found to foster belief updating and climate-related behavior^[50; 145; 151-153]. Positive emotions motivate discounting of counterattitudinal information^[40] and have been suggested as an antidote to overcome a lack of motivation to parse misinformation^[154]. Moreover, multiple recent reviews^[145; 147; 155-156] argue that the anticipation and experience of positive emotions elicited by acting pro-environmentally^[145; 155-159] increases pro-environmental behavioral intentions as well as actual behavior^[159-162]. To protect against disinformation at the recipient basis via the socio-affective pathway, the saliency of experienced positive emotions in the context of climate action can be increased, which should increase resistance to disinformation as well as likelihood to act pro-environmentally.

In summary, here we integrate previous analyses into a comprehensive framework of the communicational and psychological factors influencing (anti)science belief formation and updating. Based on this integrated, theory-driven perspective, we introduce a set of broad-spectrum psychological inoculations to protect against climate disinformation that will act on each of the identified entry points and pathways:

- a scientific consensus inoculation explaining that among climate scientists there is virtually no disagreement that humans are causing climate change;
- a trust inoculation making salient the trustworthiness of IPCC scientists in terms of climate change science and mitigation actions;
- a transparent communication inoculation transparently addressing the pros and cons of climate mitigation action;
- a moralization inoculation creating a stronger link between climate mitigation actions and the diversity of moral convictions;
- an accuracy inoculation reorienting participants towards judging incoming information by their factual accuracy;

- a positive emotions inoculation eliciting positive emotions towards climate mitigation actions.

We will investigate the effectiveness of these six broad-spectrum psychological inoculation strategies to protect against climate disinformation in a multi-country, multi-intervention study, against a sequence of twenty real climate disinformation spread by members of the climate change countermovement on the social media Twitter. We will assess the protective effect of the inoculations on participants' climate change beliefs^[163], appraisal of climate mitigation action, and truth discernment capacity, i.e., their capacity to correctly distinguish between true and false information^[165]. We will moreover investigate if the protective effects of psychological inoculations extend to actual pro-environmental behavior^[164]. Concretely, participants will be presented with twenty real climate disinformation statements that were selected based on an initial validation study (N=504, available at: https://osf.io/m58zx/?view_only=95fd430f4b7e4ee99c9c8b472e31d6b3). Participants will see multiple disinformation statements to assess if psychological inoculations are capable of protecting not against not only one but multiple occurrences of climate disinformation (which mirrors the preponderance of climate disinformation in certain epistemic communities^[29]). After each disinformation, participants will rate their current affect towards climate actions (we will measure affect towards, rather than political support for, climate mitigation actions because affective reactions predate and motivate policy appraisals and climate-friendly behavior^[50-51; 145]). After having viewed all twenty disinformation statements, participants will moreover report their perceptions concerning the reality, causes, and consequences of climate change ^[163], perform a version of a validated pro-environmental behavior task with actual environmental consequences^[164], and a truth discernment task with true and false climate statements. Compared to a passive disinformation control condition where participants are only confronted with the disinformation, we expect the inoculations to significantly protect

213 participants' affect towards climate action [H_{1A-B}], with a treatment effect bigger than for the
214 “standard approach” of fact-checking political topics^[166]. We moreover expect the protective
215 effect to extend to people's climate change beliefs [H₂], performance in the pro-environmental
216 behavior task [H₃], and truth discernment capacity [H₄]. We will collect responses from twelve
217 countries across the globe, seven of which non-WEIRD, to be able to make stronger claims
218 about the generalizability of the six psychological inoculations^[57; 60; 167-168]. We will
219 furthermore investigate treatment heterogeneity^[169] by assessing the effectiveness of the
220 inoculations depending on their thematic match with climate disinformation statements (e.g.,
221 testing if the scientific consensus inoculation protects especially well against disinformation
222 that targets the scientific consensus), and depending on participants' tendency for
223 intuitive/deliberative thinking. Not only has this tendency previously been shown to directly
224 influence belief in (anti)scientific topics^[43] and to moderate accuracy prompting^[136], but it may
225 moreover underlie people's overall tendency to rely on the socio-affective (for intuitive
226 thinkers) or the cognitive (for deliberative thinkers) pathways to enact belief updating and
227 revision^[43; 57]. We hypothesize this tendency to be a moderator depending on its match with
228 the inoculation pathway: cognitive-based inoculation will be more effective for people with a
229 tendency for deliberate thinking, whereas socio-affective-based inoculation will be more
230 effective for people with a tendency for intuitive thinking [H_{secondary 1}]. The aim of the study is
231 to introduce interventions that can comprehensively address the communicational bases and
232 the main psychological drivers of (anti)science belief formation and updating in order to
233 provide new interventions in the fight against climate disinformation.

Methods

Ethics information

The study has been approved by the ethical commission of the University of Geneva, Switzerland. Participants will explicitly express their consent to the study at the beginning of the survey; they will be compensated for their time.

Design

The study will follow a mixed design. Participants will be randomly assigned to one of eight different between-participants conditions: pure control (no inoculation, no disinformation), passive disinformation control (disinformation without inoculation), scientific consensus inoculation, trust in scientists inoculation, transparent communication inoculation, moralization of climate action inoculation, accuracy inoculation, and positive emotion inoculation. We chose a passive disinformation control condition over an active or positive control in order to better mimic real-life information environments, where climate disinformation is most frequently encountered passively and in multiple occurrences. Participants and experimenters will be blind to the name and aim of the condition that participants are randomized into (double blind). The experiment will contain twenty within-participants repeated measures of affect towards climate mitigation actions, assessed after each of the twenty climate disinformation statements.

Procedure: Participants will access the survey through an anonymous link made available by the panel provider, and will provide their explicit consent to the study. After consenting, participants will report their demographics (gender, age, education, and political orientation: single-item, 10-point scale: 1=[Extreme liberalism/left] to 10=[Extreme conservatism/right]), complete a baseline measure of affect towards climate action, and

complete the Cognitive Reflection Task, Version 2 (CRT-2^[170]), in random order. A two-strikes-out attention check ([Please select “3” to make sure you are paying attention]) will be presented; failing it will trigger a warning with a 10-seconds time penalty. Inattentive participants will receive the attention check for a second time, and participants found inattentive again afterwards will be screened out of the survey. Attentive participants will then be randomly allocated to one of the eight conditions and receive the assigned intervention or, for participants in the passive disinformation control condition, will directly be forwarded to the following section of the experiment. Participants in the pure control condition will receive neither the interventions nor the climate disinformation statements. All interventions will be presented sequentially in four screens, with a 5-20s time lock (depending on the content length of each screen) that will not allow participants to manually proceed to the next screen until the time has elapsed. A manipulation check measuring participants’ motivation to resist persuasion^[171] will follow. Afterwards, participants will receive twenty real climate disinformation statements in form of anonymous tweets, in randomized order with a 2s time lock, and report their affect towards actions to mitigate climate change after each disinformation statement. Following the disinformation provision, participants will complete the climate change perceptions scale^[163], a modified version of the WEPT task^[164; 179], and the truth discernment task, all described in full detail below. Finally, we will probe participant’s understanding of the experimental aims with an open-ended question to account for potential demand effects. The survey will end with an extended debriefing that will contain a reminder of the scientific consensus behind climate change with a link to the latest IPCC report. Survey duration will be about 25 minutes.

The six inoculations: The inoculations have been adapted to the same presentation format, as textual stimuli divided into two paragraphs. All inoculations will contain an opening paragraph referring to the IPCC assessment of anthropogenic climate change: “[In their latest assessment,

282 the Intergovernmental Panel on Climate Change (IPCC) has declared that anthropogenic
283 climate change is happening, and urgent action is needed to prevent irreversible negative
284 effects on the planet and society.]” followed by a preemptive warning of incoming threatening
285 information^[38]: “[However, some politically-motivated groups use misleading tactics to try to
286 convince the public that there is a lot of disagreement among scientists and that climate action
287 is useless or harmful to society]“. The second paragraph contains the inoculation itself (see
288 Table 2), introduced by the sentence: “[When confronted with such misleading information
289 about the science of climate change and the actions to mitigate it,...]”. To minimize any
290 differences between experimental conditions other than the theory-derived experimental
291 variations, we created a reference text and maintained the thematic information as similar as
292 possible across inoculations operating at the same communication basis, but varying the
293 salience of aspects that make the different psychological drivers salient. Both the scientific
294 consensus inoculation and the trust inoculation will operate by changing the perception of the
295 source of scientific messages about climate change, either by stressing the consensus about
296 anthropogenic climate change within the scientific community^[38] or by making the
297 trustworthiness of IPCC scientists salient^[98]. Both the transparent information inoculation and
298 the moralization inoculation will operate by emphasizing specific aspects of the presented
299 climate mitigation actions. For the transparent communication inoculation, a transparent
300 discussion of the societal costs of climate action including pros and cons of climate action will
301 precede the disinformation, for the moralization inoculation, the importance of climate action
302 will be framed using moralizing words taken from the Moral Foundation Dictionary^[172] to
303 increase its link with people’s moral convictions^[173-174]. Finally, both the accuracy inoculation
304 and the positive emotion inoculation operate by changing the internal state of the recipient. In
305 the accuracy inoculation, we reframed the original accuracy prompt^[136] into a passive
306 psychological inoculation^[184] where participants will be prompted to consider accuracy when

evaluating the information, whereas in the positive emotion inoculation, participants will be prompted to consider positive emotions related to acting in a climate-friendly way. The complete text for all interventions can be found in Table 2, with cross-condition differences highlighted in red.

Table 2 – Text of the six inoculations.

Cognitive Inoculation	Socio-Affective Inoculation
Scientific consensus Inoculation	Trust in scientists inoculation
When confronted with such misleading information about the science of climate change and the actions to mitigate it, remember that the IPCC, the most comprehensive review on the scientific agreement behind climate change and climate action, found that among thousands of climate scientists with the highest degrees of expertise “there is virtually no disagreement that humans are causing climate change”. Studies have shown that the consensus about anthropogenic climate change among expert scientists ranges from 97% to 99%. IPCC scientists from all cultural backgrounds and nations stated in the report that “It is unequivocal that human influence has warmed the atmosphere, ocean and land” and they are in agreement that urgent climate action is needed for a better planet and society.	When confronted with such misleading information about the science of climate change and the actions to mitigate it, remember that the IPCC is the most authoritative scientific body in the world assessing the knowledge about climate change and climate action and that the majority of citizens of multiple countries trust scientists. Climate scientists have the highest degrees of expertise and are committed to open and transparent review by other scientists and governments around the world, and value rigorous and balanced scientific information above all else. IPCC scientists come from all cultural backgrounds and nations, to reflect a diverse range of views and expertise in their work and to ensure an objective and complete assessment of the scientific evidence about climate change, to recommend actions and policies for a better planet and society.
Transparent communication Inoculation	Moralization of climate action Inoculation
When confronted with such misleading information about the science of climate change and the actions to mitigate it, remember that the IPCC scientists are open about the fact that climate actions will require substantial funding and a significant overhaul of our way of life to keep our planet livable. They also disclosed that there is some uncertainty about if and how these climate actions may reduce our quality of life, but they still concluded with confidence that limiting irreversible climate-induced risks with climate action is less risky than not acting at all. Acting is hard, they admit, but it is through these scientifically supported actions that we can protect our planet, reduce inequality, and generate	When confronted with such misleading information about the science of climate change and the actions to mitigate it, remember that the IPCC scientists provide valuable and authoritative advice about actions that our communities and nations must take to responsibly keep our planet livable for us and for future generations. As citizens of this earth, we have a moral responsibility to protect our homeland and our community from climate-induced risks and harms, and to stop defiling our pristine natural environment. Through these scientifically supported actions, we can protect our planet, create a more just and fair society with decent living conditions for everyone, and generate sustainable

sustainable growth.	growth beneficial for us, our nations , the world, and generations to come .
Accuracy Inoculation	Positive emotion Inoculation
When confronted with such misleading information about the science of climate change and the actions to mitigate it, remember that it is important to be able to accurately recognize these misinformation to avoid being influenced by them. One good strategy to distinguish between good and bad information is to ask yourself: “do I think this information is accurately describing the state of the science of climate change? Is this information not at all accurate, not very accurate, somewhat accurate, or very accurate?” . When you evaluate the information you see on any media about climate change, think about this accuracy question to get in the right frame of mind.	When confronted with such misleading information about the science of climate change and the actions to mitigate it, remember that climate actions are vital actions that will keep our planet livable for the next generation. Actions such as eating delicious and healthy meals with a lower carbon footprint or taking a bike ride instead of getting stuck in traffic are scientifically supported ways to make you happier and more fulfilled in your daily life. When you evaluate the information you see on any media about climate change, imagine the positive changes you can create with climate action, and think about how good you will feel when doing so.

312

313 Disinformation provision: The disinformation provision section of the experiment consists of
314 twenty different actual disinformation statements collected from Twitter and pre-validated in a
315 pilot study (see Table 4). We followed a two-step procedure for the selection of the climate
316 disinformation statements. First, we created a list of the available Twitter handles of members
317 of the climate change countermovement by reviewing academic and journalistic resources that
318 identified actors that have been spreading disinformation about climate change science and
319 policies^[11; 13-16] (<https://www.desmog.com/climate-disinformation-database/>). We furthermore
320 augmented this list with all the Twitter active members of the “World climate declaration”
321 (<https://clintel.org/world-climate-declaration/>), a document with 500 signatories – at the time
322 of data collection – that misinforms the public about anthropogenic climate change. Through
323 academic access to the Twitter API, we collected all the tweets by these users, first from
324 account creation until April 2022, and a second time from the 31st of October to the 20th of
325 November 2022, the week leading to and the two weeks of the UNFCCC Conference Of the
326 Parties 27. Second, we randomly selected and manually coded 20000 of their tweets according
327 to climate relatedness (1 = [not at all related to climate change] to 4 = [absolutely related to

climate change)), disinformation (1 = [not at all disinformation about climate change] to 4 = [absolutely disinformation about climate change]) and delay (1 = [not at all a delay argument about climate change policies] to 4 = [absolutely a delay argument about climate change policies]) status, following the coding schema and instructions by Coan and colleagues^[33] and Lamb and colleagues^[14]. From a final pool of n = 1033 tweets identified as climate related and disinformation/delay, we identified N = 79 tweets that were understandable without requiring background information and not including country-specific aspects. These seventy-nine tweets were pretested with a representative sample of N = 504 British participants on the data collection platform Prolific (<https://www.prolific.co/>), in terms of their impact on affect towards climate action and twelve further variables – e.g., perceived political slant – that may affect processing of disinformation about political topics^[175] (the full list of disinformation, with a description of the pre-testing design and all validation materials and data, can be found at: https://osf.io/m58zx/?view_only=95fd430f4b7e4ee99c9c8b472e31d6b3). Among these eighty statements, we selected N = 20 disinformation statements (see Table 3) that deviated the least from the mean ratings across all fifteen different validation measures, evenly divided between ten disinformation statements about climate science and ten disinformation statements to delay climate action (according to coding criteria developed in previous research ^[14; 33]). During the experiment, participants will be presented with all twenty selected climate disinformation statements in randomized order. Each statement will be presented as an anonymous tweet, with the default user image, no identifying information, and no engagement metrics. After each disinformation, participants will rate their affect towards climate actions on a visual analogue scale.

Table 3 – The twenty climate disinformation statements and their coding

Coding	Disinformation tweet
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Science_1	As more wind and solar are added they raise electricity prices and destabilize electric grids. Because they are part-time unreliable weather dependent sources. We want full-time electricity. Not part-time like third world countries. All for silly expensive net zero. CA pays more.
Science_2	The current exceptional warming and cooling your seeing is due to the location of the Jet Stream. It's become very wavy due to the lack of Solar Energy going into the Oceans and nothing to do with Man Made CO2
Science_3	Today's 'global warming' is estimated to be an otherwise unmeasurable 0.4°C (0.72°F) over the 1979-2000 average... despite 50% of all manmade emissions. No 2022 weather event was unprecedented or can be blamed on CO2 emissions.
Science_4	This is a portrait of climate fraud, posturing as the saviours of the world. They are a breed of crooks, getting rich by ripping off gullible western nations. The UN led climate hoax has been running since 1988. They want us to believe a pack of lies about earth's climate.
Science_5	Too often, academic reports on climate use highly skewed data that seem to have been carefully selected to support aggressive environmental regulations. One recent and much-cited Lancet report appears deliberately deceptive.
Science_6	The climate hoax devised by the UN, supported by rich elitists is endorsed by our treacherous leaders is an attack on freedoms & rights. Climate cultism is a form of global self hatred. It aims to punish western nations by transferring huge reparations to the developing world.
Science_7	Top NASA Climate Modeler Admits Predictions Are “Mathematically Impossible”
Science_8	Lots of links of studies of the Medieval Warm Period that climate science deniers (alarmists) want to pretend did not exist. Because there is no explanation for natural warming during this time. Studies point out temp was warmer back then, than now.

Science_9	According to global warming theory the poles should warm significantly if carbon dioxide is driving temperatures Just the opposite is occurring in the southern hemisphere.
Science_10	The evidence for manmade climate change is so thin they cannot debate it. They hide behind the lie of consensus. There is no room for consensus in science. The basis is a provable hypothesis. There is not a single peer reviewed study that proves manmade CO2 is causing warming.
Action_1	At Climate Summit, Elites Chow Down on Gourmet Meats While Telling Us to Eat Bugs
Action_2	FACT CHECK Results of the Biden administration's extreme climate agenda cutting emissions by 44% by 2030. Annual Jobs Lost: 1.2 MILLION. Lost Economic Growth: \$7.7 TRILLION. Increase in Electric Bills: 23% Increase in Gas Prices: 2\$ PER YEAR
Action_3	The war on 'fossil fuels' is absurd considering the vast fields of coal/oil/gas everywhere on earth. The mantle is brimming over with it. A United Nations bid for control, cash & power has led to an energy crisis that looms as the biggest self-inflicted disaster in human history.
Action_4	Death and privation caused by the lack of affordable energy caused by Green Energy policies will not affect the Elites at all. They want us to eat bugs, do a lot less as they carry on with their lives just as they are doing now. Climate scamsters. They should lead by example.
Action_5	You are lying. Fossil fuels gave us cheap energy for decades so billions live longer healthier happier lives. Many technologies like carbon capture, filters fuel additives etc reduces emissions. Banning fossil fuels is creating fuel poverty and harming people
Action_6	Energy literacy starts with the knowledge that renewable energy is only intermittent electricity generated from unreliable breezes and sunshine, as wind turbines and solar panels cannot manufacture anything for the 8 billion on this planet.

Action_7	Imagine sacrificing 500 high-paying coal jobs, ranging up to \$60,000/yr, for the climate hoax. Even if you believe in the hoax, global emissions are up 5% from pre-pandemic levels -- 90% because of China. Emissions from a single mine are insignificant.
Action_8	Europe's transition to renewable energy and net zero carbon is not working, except to make life hard on average European citizens.
Action_9	Willfully-blind ignorance about the consequences of [the rush to green policies] – deep recessions, broken societies and millions more going hungry – doesn't make them any less immoral. The road to hell is paved with good intentions. Bingo.
Action_10	Solar and wind are far more expensive than established reliable stable secure electricity from pure hydro coal gas nuclear. That's why your shift to unreliable, unstable, expensive solar and wind; is devastating families; and exporting manufacturing jobs

Note: In order to avoid climate change countermovement actors from understanding the net persuasive appeal of each disinformation statement, identifying numbers of each statement will differ from the identifying numbers in the data once collected. Correct matching will only be known to authors.

Affect towards climate mitigation actions: We will measure participants' affect towards actions to mitigate climate change with a visual analogue scale adapted from previous research^[98; 176] ([In general, what kind of feelings do you have when you think about actions to mitigate climate change?] 0 = [Very negative], 50 = [Neutral]; 100 = [Very positive]. Scale anchored at 50).

Climate change beliefs: We will assess participants' beliefs about climate change with the climate change perception scale^[163], a validated scale that encompasses different dimensions of the appraisal of climate science and the consequences of climate change. While the published scale is composed of five different subscales and related factors, the authors note that the climate change perception scale allows for the selection of subscales of interest^[163]. We will therefore focus on the three subscales measuring participants' belief in the reality of climate change, the causes of climate change, and the consequences of climate change. Climate change

beliefs will be collected with nine items (Reality subscale: [I believe that climate change is real]; [Climate change is NOT occurring] (reverse scored); [I do NOT believe that climate change is real] (reverse scored). Causes subscale [Human activities are a major cause of climate change]; [Climate change is mostly caused by human activity]; [The main causes of climate change are human activities]; Consequences subscale [Overall, climate change will bring more negative than positive consequences to the world.]; [Climate change will bring about serious negative consequences]; [The consequences of climate change will be very serious]; 1 = [strongly disagree], 7 = [strongly agree]. Items per each subscale will be mean-scored if Cronbach's $\alpha > .70$, otherwise we will use only the first item as representative of the subscale^[163]).

The pro-environmental behavior task: We will use a shortened version^[179] of the Working for Environmental Protection Task (WEPT^[164; 179]), a validated, multi-trial web-based procedure to measure actual pro-environmental behavior. In this task, participants can voluntarily choose to exert effort by screening numerical stimuli for the occurrence of target numbers beginning with an even digit and ending with an odd digit (e.g., "23"). In this version of the WEPT task, participants will be able to complete up to eight different numerical screenings of 60 numbers per page. Participants' willingness to engage in the screening task will be prompted before each new page with a yes/no question: participants who will answer positively will be directed to screening the numbers; participants who will answer negatively will be directed to the following section of the study. In the instructions, we will explicitly explain to participants that each screening page they accurately complete will result in an actual tree being planted by an environmental organization, the Eden Reforestation Project (<https://www.edenprojects.org/>), with whom we partnered to plant trees. In other words, participants will be able to create actual environmental benefits (measured in terms of trees planted by the environmental organization) at an actual behavioral cost (personal time)^[164; 179]. They will be able to track their tree-planting

progress, from zero to up to eight trees, with an image presented between the pages of the numerical screenings. We will measure their pro-environmental behavior in terms of the number of pages that each participant completes while correctly screening more than 90% of the target numbers^[164; 179].

Truth discernment task: Inspired by a preprint presenting a measure of domain-general news veracity discernment^[165], we developed a climate-specific truth discernment task in which participants have to categorize 20 statements mentioning climate-related topics as either false or real statements ([Please categorize the following statements as either “False Statement” or “Real Statement”]; Binary choice: [Real]; [False], item and response order randomized). These 20 statements are equally divided between true and false headlines and between supporting or opposing climate science and action. All statements were generated interacting with an AI tool (ChatGPT **Version 4**, by OpenAI). Over 300 true and false statements mentioning climate change or climate mitigation actions were initially created. The statements were then fact-checked and condensed into a longlist out of which 10 true and 10 false statements were selected to be included in the truth discernment task. The final statements are presented in Table 4 (the full list of generated statement is available in the OSF repository).

Table 4 – Truth discrimination task generated climate headlines.

Coding	Climate-relevant news headline
True_Supporting_1	Earth's average temperature continues to rise, setting new record highs each decade.
True_Supporting_2	Human activities, such as burning fossil fuels, are the main cause of climate change.
True_Supporting_3	Climate change is leading to more intense and frequent natural disasters.
True_Supporting_4	The transportation sector is a significant contributor to greenhouse gas emissions.
True_Supporting_5	Rising seas could displace hundreds of millions of people by the end of the century.

True_Delaying_1	Projections of Regional Impacts of Climate Change are Subject to Uncertainty.
True_Delaying_2	Transportation Sector Transition to Electric Vehicles Can Cost Billions in Infrastructure Upgrades.
True_Delaying_3	Brazil Missing Paris Agreement Targets with Deforestation and Agricultural Expansion Driving Up Emissions.
True_Delaying_4	China's continued construction of coal-fired power plants threatens progress on climate goals.
True_Delaying_5	Developing Countries Require \$40 Billion Annually to Mitigate Climate Change.
False_Supporting_1	Climate change will cause the extinction of up to 75% of all species on Earth.
False_Supporting_2	Global temperatures may rise by up to 20°C by the end of the century, potentially resulting in widespread drought and famine due to climate change.
False_Supporting_3	The Earth may enter a period of 'runaway warming' that cannot be stopped, which could lead to the collapse of civilization due to climate change.
False_Supporting_4	Germany Leads the Way in Renewable Energy, with Nearly 65% of Electricity Generated from Renewables.
False_Supporting_5	Climate Catastrophe: Entire Cities to be Submerged by Rising Seas Within Decades.
False_Delaying_1	Extreme Weather: Natural variability, not human activity, is the main driver of extreme weather events.
False_Delaying_2	The Climate Challenge Can Be Addressed Through Innovation and Technology Advancements in Fossil Fuels.
False_Delaying_3	Carbon Dioxide is Not a Pollutant, but a Benefit to the Environment.
False_Delaying_4	Catastrophic Consequences of Global Warming are Inevitable and Unavoidable.
False_Delaying_5	Renewable Energy is Costly and Inefficient, and Should Not be Subsidized.

Note: “True/False” refers to true or false statements; “Support/Delaying” refers to statements supporting or opposing climate science and action.

Tendency for intuitive versus reflective thinking (CRT-2): We will assess participants’ tendency for intuitive versus deliberate/reflective thinking using the version 2^[170] of the

Cognitive Reflection Task^[177]. This task comprises 4 open-ended, verbal problems that have an intuitive, but incorrect, answer, and require reflection in order to correctly answer ([If you're running a race and you pass the person in second place, what place are you in?] (intuitive answer: first, correct answer: second); [A farmer had 15 sheep and all but 8 died. How many are left?] (intuitive answer: seven, correct answer: eight); [Emily's father has three daughters. The first two are named April and May. What is the third daughter's name?] (intuitive answer: June, correct answer: Emily); [How many cubic feet of dirt are there in a hole that is 3' deep x 3' wide x 3' long?] (intuitive answer: 27, correct answer: none). We will use the CRT-2 instead of the traditional version because it shares less variance with numerical skills^[170]. Numeracy skills vary across countries^[178] and could therefore confound the original measure of tendency for intuitive thinking. We will compute the CRT-2 score as the number of correct answers given, ranging from 0 to 4, where lower scores represent an increasing tendency for intuitive thinking, whereas higher scores represent an increasing tendency to reflective thinking.

Manipulation check: Following the psychological inoculations literature^[178], we will measure motivation to resist persuasion as a theoretically and experimentally validated manipulation check^[181] with the 4-items motivational threat measure proposed by Banas and Richards^[171] ([Indicate your level of agreement with the following statements]: 1 = [Strongly disagree], 7 = [Strongly agree]; [I want to defend my current attitudes from attack]; [I feel motivated to think about why I hold the beliefs I do about climate change]; [I feel motivated to resist persuasive messages about climate change]; [I want to counterargue conspiracy theories about climate change]. Items will be mean scored if Cronbach's $\alpha > .70$, otherwise we will compare them separately). We expect motivation to resist persuasion to increase for participants receiving the different inoculations, compared to participants in the passive disinformation control condition.

Demand effects check: We will probe participants' understanding of the aim of the experiment by asking them "[Could you please describe what you think the aim of the experiment

was?]]. Two coders will then rate participants' belief in the experimental objective with a multiple-choice question ([To what degree do you think the participant believed we were testing interventions to fight climate disinformation?] 0 = [They seemed very convinced we were not testing interventions to fight climate disinformation]; 1 = [They seemed somewhat convinced we were not testing interventions to fight climate disinformation]; 2 = [They seemed unsure if we were not testing interventions to fight climate disinformation]; 3 = [They seemed somewhat convinced we were testing interventions to fight climate disinformation]; 4 = [They seemed very convinced we were testing interventions to fight climate disinformation]; ratings will be averaged, and differences in scoring will be discussed and resolved).

Sampling plan

We will collect the sample with quota for gender and age from the panel provider Market Science Institute. The sample will comprise of participants from twelve countries, $n = 568$ participants per country, for a total of $N = 6816$ participants. We identified the required sample size a-priori, with G*Power (Version 3.0^[182]), in order to have 95% power to detect a difference between any intervention condition and the passive disinformation control condition of $\delta = 0.20$ in a one-tailed t-test with $\alpha = .005$, for all main hypotheses separately. We selected the smallest effect size of interest (SESOI) from the lower bound of the confidence interval of the meta-analytically identified effect size^[183] of fact-checking interventions on political topics^[166], as we reasoned that a new disinformation intervention would be of interest if and only if it has an effect that is larger than already available interventions such as fact-checks. Incidentally, a recent paper showed that the effects of more established psychological inoculations on sharing intentions of manipulative content is $\delta = 0.20$ ^[184], increasing our confidence in the practical interest of this SESOI.

Countries: We will recruit participants based in the USA, Canada, UK, Ireland, Australia, New Zealand, Singapore, Philippines, India, Pakistan, Nigeria, and South Africa (see Fig. 1) to generalize our findings on the effectiveness of the six psychological inoculations across the globe and in non-WEIRD contexts. We settled on twelve countries to provide the minimum number of countries to provide a reasonably accurate statistical estimation for country-level variation in our dependent variables as a random effect in multilevel models^[190] rather than conducting cross-country comparisons. The twelve countries were furthermore chosen pragmatically for English being the main or one of the official languages, to maintain the climate disinformation statements in their original language and therefore maintain the highest ecological validity.

[Insert Figure 1 here]

Data inclusion: Participants will be removed from the survey and replaced with new respondents when they i) do not consent to the study, ii) do not finish the study, or iii) fail the two-strikes-out attention check. All incomplete responses and complete responses where participants did not consent to the study anymore at the end of the survey will be removed; all other responses will be included in the data analyses.

Analysis plan

Data will be analyzed with the most recent version of R available at time of data collection completion, with packages lme4^[186], lmerTest^[187], TOSTER^[188], and emmeans^[189]. Unless specified, we will test the hypotheses with multilevel models.

Manipulation check: We will analyze the differences between the passive disinformation control condition and the six inoculation conditions in terms of the motivation to resist persuasion^[171] with a set of six independent sample, one-tailed t-tests. We expect all

inoculated participants to report significantly more motivation to resist messages countering climate science and climate mitigation action than participants in the passive disinformation control condition. Should any of the contrasts between the passive disinformation control condition and the inoculations be not significant, we will first visually inspect the distribution of the responses, to visually identify ceiling or flooring effects for motivation to resist persuasion. If there is no strong evidence that such effects are present, we will then test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than the smallest effect size we are planning to detect ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the result as suggestive evidence that the inoculation of interest elicits smaller than predicted changes in motivation to resist persuasion, and that those changes are practically meaningless. Should any of the equivalence testing be significant and the effects of the inoculation of interest on affect towards climate mitigation actions or WEPT performance practically meaningless as well (see “primary hypotheses” section below), we will conclude that the inoculation of interest does not provide practically meaningful protection against climate disinformation and that the manipulation check suggests the inoculation of interest furthermore does not offer the persuasion resistance characteristic of psychological inoculations. Should any of the equivalence testing be significant but the inoculation of interest significantly protects affect towards climate mitigation actions or WEPT performance, we will conclude that the inoculation of interest provides significant protection against climate disinformation but potentially not through the persuasion resistance characteristic of psychological inoculations. Should any of the manipulation checks be significant but the effects of the inoculation of interest on affect towards climate mitigation actions or WEPT performance practically meaningless, we will conclude that the inoculation of interest offers

the persuasion resistance characteristic of psychological inoculations, but that such protection does not transfer to practically meaningful protection against climate disinformation.

Primary hypotheses: Gender, age, and political orientation will be added as a covariates in all models. All random effects of multilevel models will be weighed separately with Akaike Information Criterion (AIC) model comparison, and the random effect structures within 2 AIC of the best model will be used in each analysis.

We will analyze changes in affect towards climate mitigation actions during the disinformation provision as the dependent variable with a multilevel model. We will specify three random effects: intercept for participant; intercept for country, to account for the variance associated with each country^[185; 190]; we will also include a random intercept for the internal numbering of the climate disinformation statements, to proactively account for any variance associated with each particular climate disinformation statement^[185], as some differences across validation measures remained after the selection of the set of disinformation stimuli. Unless otherwise specified, we will specify as fixed effects: condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast), trial (continuous variable, from 1 to 20), and the two-way interactions of trial with condition.

We will analyze performance in the modified version of the pro-environmental behavior task as the dependent variable with a multilevel model. Unless otherwise specified, we will specify condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast) as the fixed effect.

To test whether inoculated participants have more positive affect towards climate mitigation action than participants in the control condition after receiving twenty climate disinformation, we will first compare affect toward climate action at the end of the intervention (i.e., after the twentieth disinformation statement) of the participants in the passive

disinformation control condition with the participants in each inoculation condition separately, with a one-tailed independent-sample t-test with α corrected to .005. Should any of the contrasts be not significant, we will first visually inspect the affect curve of the twenty measurements of affect across the processing of the twenty climate disinformation statements, to visually identify ceiling or flooring effects for the intervention conditions. We will then test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing (RQ1, see Design Table).

To test whether inoculated participants have more positive affect towards climate mitigation action than participants in the passive disinformation control condition after each one of the twenty climate disinformation statements, we will analyze changes in affect towards climate mitigation actions during the disinformation provision with a multilevel model (RQ1, see Design Table). We will specify three random effects: intercept for participant; intercept for the internal numbering of the climate disinformation statements, to account for the variance associated with each disinformation statement^[185]; intercept for country (factor, alphabetically coded), to account for the variance associated with each country^[190]. We will specify as fixed effects: condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast), trial (continuous variable, from 1 to 20), and the two-way interactions of trial with condition to test whether inoculated participants had more positive affect towards climate mitigation action than participants in the passive disinformation control condition after each climate disinformation.

To test whether inoculated participants reported believing more in the reality, causes, and consequences of climate change than participants in the passive disinformation control condition after receiving twenty climate disinformation statements, we will analyze the climate change perception subscales with three multilevel models (RQ3, see Design Table). We will

specify two random effects: intercept for participant; and intercept for country (factor, alphabetically coded), to account for the variance associated with each country^[185]. We will specify condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast) as the only fixed effect besides the covariates. Should any of the contrasts be not significant, we will plot the WEPT performance data to visually identify ceiling or flooring effects; if such effects are absent, we will test whether the difference between the control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the contrasts between the passive disinformation control condition and the inoculations be not significant, we will first visually inspect the raincloud distribution of the responses of each climate change perception subscale^[163], to visually identify ceiling or flooring effects. Upon visual confirmation of a normal distribution, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the result as suggestive evidence that the inoculation of interest does not offer better protection than traditional fact-checking. Should any of the equivalence testing be significant at $p < .005$, we will interpret the result as confirmatory evidence that the inoculation of interest does not offer better protection than traditional fact-checking.

To test whether inoculated participants completed more pages in the WEPT task than participants in the passive disinformation control condition after receiving twenty climate disinformation statements, we will analyze the performance in the modified version of the WEPT Task with a multilevel model, with the number of completed pages as the dependent variable (RQ2, see Design Table). We will specify two random effects: intercept for participant; and intercept for country (factor, alphabetically coded), to account for the variance associated with each country^[185]. We will specify condition (factor, seven levels, dummy coded

with 0 = passive disinformation control condition as the reference contrast) as the only fixed effect besides the covariates. Should any of the contrasts be not significant, we will plot the WEPT performance data to visually identify ceiling or flooring effects; if such effects are absent, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing.

To test whether inoculated participants have higher news veracity discernment^[165] than participants in the passive disinformation control condition after receiving twenty climate disinformation statements, we will analyze the performance in the truth discernment task with a multilevel model (RQ4, see Design Table). We will calculate news veracity discernment as the sum of correct identification of true and false climate-related statements^[165]. We will specify two random effects: intercept for participant; and intercept for country (factor, alphabetically coded), to account for the variance associated with each country^[185]. We will specify condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast) as the only fixed effect besides the covariates. Should any of the contrasts be not significant, we will plot the WEPT performance data to visually identify ceiling or flooring effects; if such effects are absent, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the contrasts between the passive disinformation control condition and the inoculations be not significant, we will first visually inspect the raincloud distribution of news veracity discernment, to visually identify ceiling or flooring effects. Upon visual confirmation of a normal distribution, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at $p < .005$, we will

interpret the result as confirmatory evidence that the inoculation of interest does not offer better protection than traditional fact-checking. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the result as suggestive evidence that the inoculation of interest does not offer better protection than traditional fact-checking. We will furthermore calculate the real news detection and the false news detection scores^[165], to investigate as to whether some inoculation might have influence only one of the two underlying factors of the general news veracity discernment score.

Secondary hypothesis: For this analysis, we will limit our sample to those participants who will have received one of the six inoculations ($n=5112$). We will analyze affect towards climate action mitigation during the disinformation provision with the multilevel model used for Hypothesis H_{1A}. We will add the CRT-2 score (continuous, range from 0 to 4) as a fixed predictor; we will substitute the “condition” variable with a “drivers” factor (2 levels: socio-affective; cognitive), each containing the corresponding psychological inoculations (socio-affective: trust inoculation, moralization inoculation, positive emotion inoculation; cognitive: scientific consensus inoculation, transparent communication inoculation, accuracy inoculation); and we will add the two-way interactions of driver with the CRT-2 score, the two-way interactions of trial with the CRT-2 score, and the three-way interaction between driver, trial, and the CRT-2 score. For the two-way interaction between the CRT-2 score and condition, if found to significantly influence affect towards climate mitigation actions, we will compute Johnson-Neyman intervals^[192] to investigate after which CRT-2 values the difference between socio-affective and cognitive inoculations is statistically significant.

Control analyses: For the H_{control A-D} analyses, we will limit our sample to those participants who participated in the pure control and passive disinformation control conditions ($n=1704$). We will test if consecutively presenting the twenty real climate disinformation statements decrease participants A) affect towards climate mitigation action; B) beliefs in

climate change; C) participants' performance in the modified version of the Work for Environmental Protection Task (WEPT^[164]); and D) truth discernment. We will compare affect toward climate action, belief in climate change, WEPT performance, and truth discernment at the end of the intervention (i.e., after the twentieth disinformation statement) of the participants in the passive disinformation control condition with the participants in the pure control condition, separately, with a one-tailed independent-sample t-test with α corrected to .005. For hypothesis H_{Control 1A-bis}, we will conduct an additional one-tailed, paired-sample t-test within the passive disinformation control condition, with affect towards climate mitigation action as the dependent variable. Should any of the contrasts be not significant, we will first visually inspect the dependent variables, to visually identify ceiling or flooring effects for the intervention conditions. After confirming the lack of ceiling/flooring effects, we will test whether the difference between the passive disinformation control condition and the pure control condition is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the result as suggestive evidence that, if the twenty real climate disinformation statements have a detrimental effect on any of our dependent variables of interest, it is lower than $\delta = 0.20$.

In order to account for potential demand effects, we will introduce the “demand effects check” measure as a control variable for H_{1A-B}. Should our participants be influenced by demand effects, we would expect that the variable will moderate the effectiveness of the psychological inoculations, such that participants who receive a psychological inoculation and have understood the experimental aim will report more positive affect towards climate action overall. We will add the “demand effects check” score (continuous, range from 0 to 4) as a fixed predictor as a main effect and a two-way interaction with condition. We will conduct a second multilevel model within the passive disinformation control condition, in order to assess whether demand effects might influence the disinformation provision. We will specify three

random effects: intercept for participant; intercept for the internal numbering of the climate disinformation statements, to account for the variance associated with each disinformation statement^[185]; intercept for country (factor, alphabetically coded), to account for the variance associated with each country^[185]. We will specify as fixed effects: “demand effects check” (continuous, range from 0 to 4), trial (continuous variable, from 1 to 20), and the two-way interactions of trial with demand effects check.

Finally, although the six psychological inoculations presented here are conceptualized as broad-spectrum inoculations^[184], it is possible that the content of specific climate disinformation statements matches the thematic content of specific psychological inoculations more closely than others, and that this thematic match increases the protective effect of the psychological inoculation. To address this possibility, we manually coded whether specific climate disinformation statements are thematic matches with one of the different psychological inoculations (see Table SM-1 in the Supplementary Information). To compare the effectiveness of the psychological inoculation between matching and unmatching climate disinformation statements, we will analyze changes in affect towards climate mitigation actions during the disinformation provision with four additional multilevel models, one for each psychological inoculation where we could identify at least one thematic match. We will specify four random effects: a slope per trial, an intercept per participant, an intercept per climate disinformation statement, and an intercept per country. We will specify as fixed effects: condition (factor, two levels, specific psychological inoculation and passive disinformation control), trial (continuous variable, from 1 to 20), and the interaction between “thematic match” (factor, two levels, matching and not matching) and condition. If a thematic match between climate disinformation statements and specific psychological inoculations does indeed increase the protective effects of the inoculation, we would expect the interaction to be significant, and the simple slopes to highlight a significant difference between thematically

matching vs thematically non-matching climate disinformation statements in the inoculation condition, so that the difference in affect would be smaller for climate disinformation statements that are thematic matches of the psychological inoculation.

Data availability

We commit to sharing all data should the Stage 2 manuscript be accepted. As noted on Table 3, in order to avoid climate change countermovement actors from understanding the net persuasive appeal of each disinformation statement, identifying numbers of each statement will differ from the identifying numbers in the data once collected. This modification will nevertheless still allow complete reproducibility of the analyses and results. Correct matching will only be known to authors and will not be shared.

Code availability

We commit to sharing the preprocessing and analysis code should the Stage 2 manuscript be accepted.

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1131 **Author contributions**

1132 **T.S.:** Conceptualization; Methodology; Software; Formal Analysis; Investigation; Resources;
1133 Data Curation; Writing – Original Draft; Visualization; Project administration.

1134 **U.H.:** Conceptualization; Methodology; Resources; Writing – Review & Editing; Supervision;
1135 Funding acquisition.

1136 **E.T.:** Conceptualization; Writing – Review & Editing; Supervision; Funding acquisition.

1137 **T.B.:** Conceptualization; Methodology; Resources; Writing – Review & Editing; Supervision;
1138 Funding acquisition; Project administration.

1139 **Competing interests**

1140 The authors declare no competing interests. The funders have/had no role in study design, data
1141 collection and analysis, decision to publish, or preparation of the manuscript.

1142 **Figures & Figure captions**

1143 Figure 1: Visual representation of the country distribution of data collection. Red color represents the countries
1144 where we will collect samples of $n = 568$ participants each.

1146 **Table 4. Design Table**

Question	Hypothesis	Sampling plan	Analysis plan	Interpretation given to different outcomes
RQ ₁ : Do the six inoculations protect participants affect towards climate action against twenty real climate disinformation statements?	H_{1A}: Compared to participants in the passive disinformation control condition, participants who have received one of the inoculations will express more positive affect towards climate action after receiving all the twenty climate disinformation statements. H_{1B}: Compared to participants in the passive disinformation control condition, participants who have received one of the inoculations will express more positive affect towards climate action after each trial presenting a single climate disinformation statement.	We identified the required sample of N = 5964 (i.e., sample without the pure control condition), a-priori, with G*Power (Version 3.0), in order to have 95% power to detect a difference between any intervention condition and the control condition of $\delta = 0.20$ in a one-tailed t-test with $\alpha = .005$, for both main hypotheses. We selected the smallest effect size of interest from the lower bound of the confidence interval of the meta-analytically identified effect size of fact-checking interventions on political topics ^[166] ; we reasoned that a new misinformation intervention would be practically interesting if and only if it has an effect that is larger than already available	Hypothesis H_{1A}: We will compare affect toward climate action at the end of the intervention (i.e., after the twentieth disinformation statement) of the participants in the passive disinformation control condition with the participants in each inoculation condition, separately, with a one-tailed independent-sample t-test with α corrected to .005. Hypothesis H_{1B}: We will analyze affect toward climate action during the disinformation provision with a multilevel model. We will specify three random effects: intercept for participant; intercept for the internal numbering of the climate disinformation statements, to account for the variance associated with each disinformation statement^[185];	Hypothesis H_{1A}: Should any of the contrasts between the control condition and the inoculations be not significant, we will first visually inspect the affect curve of the twenty measurements of affect across the processing of the twenty climate disinformation statements, to visually identify ceiling or flooring effects for the intervention conditions. After confirming the lack of ceiling/flooring effects, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the result as

		benchmark interventions such as fact-checks.	intercept for country (factor, alphabetically coded), to account for the variance associated with each country^[185]. We will specify as fixed effects: condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast), trial (continuous variable, from 1 to 20), and the two-way interactions of trial with condition to test hypothesis H_{1B}.	suggestive evidence that the inoculation of interest does not offer better protection than traditional fact-checking. Should any of the equivalence testing be significant at $p < .005$, we will interpret the result as confirmatory evidence that the inoculation of interest does not offer better protection than traditional fact-checking. Should H_{1A} not be supported, we will test if, for the inoculations with at least one thematically matching climate disinformation statement (see Table SM-1 in Supplementary Information), there are significant differences between the passive disinformation control condition and the specific psychological inoculation only within matching climate disinformation statements. This comparison will be carried out with the multilevel models described in the final analysis of the Analysis plan section, expecting the interaction between condition and thematic matching to be significant, and for the simple slopes to show a significant difference between the specific
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				psychological inoculation and the passive disinformation control condition only against matching climate disinformation statements (interaction simple slope α corrected to .125; see the Analysis plan section pp. 34-35). Hypothesis H_{1B}: Should the trial main effect not be significant, we will first visually inspect the affect curve of the twenty measurements of affect across the processing of the twenty climate disinformation statements, to visually identify ceiling or flooring effects for the effects of the climate disinformation statements. Should the interaction between trial and condition be not significant but the hypothesis H_{1A} confirmed, we will conduct an additional one-tailed independent sample t-test between the passive disinformation control condition and the inoculation of interest, with the affect towards climate action after the first climate disinformation statement as the dependent variable. Should this t-test be significant, we will conclude that the inoculation of interest influences affect
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				towards climate action only immediately, and not after each single climate disinformation statement. Should the equivalence test for hypothesis H_{1A} be significant, we will conclude that our data provides “suggestive evidence that the inoculation does not offer a better protection than traditional fact-checking”.
RQ₂: Do the six inoculations protect participants’ belief in A) the reality of climate change, B) the causes of climate change, and C) the consequences of climate change^[163], after twenty real climate disinformation statements?	H₂: Compared to participants in the passive disinformation control condition, participants who have received one of the inoculations will report higher belief in the reality of climate change (H_{2A}), the causes of climate change (H_{2B}), and the consequences of climate change (H_{2C}) after receiving all the twenty climate disinformation statements.	We identified the required sample of N = 5964 (i.e., sample without the pure control condition), a-priori, with G*Power, in order to have 95% power to detect an overall difference between any intervention condition and the control condition of $\delta = 0.20$ in a one-tailed t-test with $\alpha = .005$, for hypothesis H₂. We selected the smallest effect size of interest from the lower bound of the confidence interval of the meta-analytically identified effect size of fact-checking interventions on political topics^[166]; we reasoned that a new misinformation intervention would be practically interesting if and	We will analyze the climate change beliefs ^[163] with a multilevel model per each subscale. We will specify two random effects: intercept for participant; and intercept for country (factor, alphabetically coded), to account for the variance associated with each country^[185]. We will specify condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast) as the only fixed effect besides the covariates.	Should any of the contrasts between the passive disinformation control condition and the inoculations be not significant, we will first visually inspect the raincloud distribution of the responses of each climate change perception subscale^[163], to visually identify ceiling or flooring effects. Upon visual confirmation of a normal distribution, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the

		only if it has an effect that is larger than already available benchmark interventions such as fact-checks.		result as suggestive evidence that the inoculation of interest does not offer better protection than traditional fact-checking. Should any of the equivalence testing be significant at $p < .005$, we will interpret the result as confirmatory evidence that the inoculation of interest does not offer better protection than traditional fact-checking.
RQ ₃ : Do the six inoculations protect participants' performance in the modified version of the Work for Environmental Protection Task (WEPT ^[164; 179]) after twenty real climate disinformation statements?	H ₃ : Compared to participants in the passive disinformation control condition, participants who have received one of the inoculations will have correctly completed more pages in the WEPT pro-environmental behavior task after receiving all the twenty climate disinformation statements, resulting in more pro-environmental donations	We identified the required sample of $N = 5964$ (i.e., sample without the pure control condition), a-priori, with G*Power, in order to have 95% power to detect an overall difference between any intervention condition and the passive disinformation control condition of $\delta = 0.20$ in a one-tailed t-test with $\alpha = .005$, for hypothesis H ₂ . We selected the smallest effect size of interest from the lower bound of the confidence interval of the meta-analytically identified effect size of fact-checking interventions on political topics ^[166] ; we reasoned that a new misinformation intervention would be practically interesting	We will analyze the performance in the shortened version of the WEPT with a multilevel model, with the number of correctly completed pages as the dependent variable. We will specify two random effects: intercept for participant; and intercept for country (factor, alphabetically coded), to account for the variance associated with each country ^[185] . We will specify condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast) as the only fixed effect besides the covariates.	Should any of the contrasts between the passive disinformation control condition and the inoculations be not significant, we will first visually inspect the raincloud distribution of the WEPT responses, to visually identify ceiling or flooring effects for the WEPT performance. Upon visual confirmation of a normal distribution, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at

		if and only if it has an effect that is larger than already available benchmark interventions such as fact-checks.		.005<p<.05, we will interpret the result as suggestive evidence that the inoculation of interest does not offer better protection than traditional fact-checking. Should any of the equivalence testing be significant at p<.005, we will interpret the result as confirmatory evidence that the inoculation of interest does not offer better protection than traditional fact-checking.
RQ4: Do the six inoculations increase participants' news veracity discernment ^[165] ?	H4: Compared to participants in the passive disinformation control condition, participants who have received one of the inoculations will have higher news veracity discernment.	We identified the required sample of N = 5964 (i.e., sample without the pure control condition), a-priori, with G*Power, in order to have 95% power to detect an overall difference between any intervention condition and the passive disinformation control condition of $\delta = 0.20$ in a one-tailed t-test with $\alpha = .005$, for hypothesis H ₂ . We selected the smallest effect size of interest from the lower bound of the confidence interval of the meta-analytically identified effect size of fact-checking interventions on political topics ^[166] ; we reasoned that a new misinformation intervention	We will analyze the performance in the truth discernment task with a multilevel model. We will calculate news veracity discernment as the sum of correct identification of true and false climate-related statements ^[165] . We will specify two random effects: intercept for participant; and intercept for country (factor, alphabetically coded), to account for the variance associated with each country ^[185] . We will specify condition (factor, seven levels, dummy coded with 0 = passive disinformation control condition as the reference contrast) as the only fixed effect besides the	Should any of the contrasts between the passive disinformation control condition and the inoculations be not significant, we will first visually inspect the raincloud distribution of news veracity discernment, to visually identify ceiling or flooring effects. Upon visual confirmation of a normal distribution, we will test whether the difference between the passive disinformation control condition and the inoculation of interest is smaller than our smallest effect size of interest ($\delta = 0.20$) with equivalence testing. Should any of the equivalence testing be significant at p<.005, we will interpret the result as

		would be practically interesting if and only if it has an effect that is larger than already available benchmark interventions such as fact-checks.	covariates.	confirmatory evidence that the inoculation of interest does not offer better protection than traditional fact-checking. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the result as suggestive evidence that the inoculation of interest does not offer better protection than traditional fact-checking. We will furthermore calculate the real news detection and the false news detection scores ^[165] , to investigate as to whether some inoculation might have influence only one of the two underlying factors of the general news veracity discernment score.
RQ ₅ : Is the effectiveness of the inoculations moderated by people's baseline tendency for intuitive vs reflective thinking?	H _{secondary 1} : Participants' CRT-2 score will positively moderate the inoculations' effectiveness, depending on whether the inoculations target climate change disinformation through the cognitive or socio-affective pathway (see Figure 1). For inoculations working primarily through the cognitive pathway,	Power analyses conducted with R package InteractionPower ^[191] suggest that, with N=5112, we will hold more than 95% power ($\alpha = .01$) to detect an overall interaction effect of $\delta = 0.12$ size and 92% power to detect an overall interaction effect of $\delta = 0.11$ size. As Pennycook and Rand ^[136] identified a moderating effect of CRT scores on	For this analysis, we will limit our sample to those participants who will have received one of the six inoculations (n=5112). We will analyze affect towards climate action mitigation during the disinformation provision with the multilevel model used for Hypothesis H _{1A} . We will add the CRT-2 score (continuous, range from 0 to 4)	Should the relationship between CRT-2 and the psychological driver factor be non-significant, we will conduct a separate analysis looking at the interaction between CRT-2 scores and each psychological inoculation, to identify if CRT-2 influences inoculations differently within each driver. This will be done by

	we expect that a higher CRT-2 score will be related to an increased effect of the inoculation. For inoculations working primarily through the socio-affective pathway, we expect that a lower CRT-2 score will be related to an increased effect of the inoculation	accuracy prompting of $\delta > 1$, we feel confident this secondary analysis is adequately powered.	as a fixed predictor; we will substitute the “condition” variable with a “psychological drivers” factor (2 levels: socio-affective; cognitive), each containing the corresponding psychological inoculations (socio-affective: trust inoculation, moralization inoculation, positive emotion inoculation; cognitive: scientific consensus inoculation, transparent communication inoculation, accuracy inoculation); and we will add the two-way interactions of psychological driver with the CRT-2 score, the two-way interactions of trial with the CRT-2 score, and the three-way interaction between driver, trial, and the CRT-2 score. For the two-way interaction between the CRT-2 score and condition, if found to significantly influence affect towards climate mitigation actions, we will compute Johnson-Neyman intervals^[192] to investigate after which CRT-2 values the difference between socio-affective and cognitive inoculations is statistically	reintroducing the “condition” factor from previous analyses, and adding the two-way interaction between CRT-2 and condition, and the three-way interaction between CRT-2, condition, and trial. Should this relationship also be not significant, we will conclude that the tendency for intuitive thinking does not seem to affect climate disinformation processing, nor the effectiveness of the inoculations, or, if it does, its effects are likely lower than the smallest effect size we were able to detect.
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			significant.	
RQ _{Control 1} : does consecutively presenting the twenty real climate disinformation statements decrease participants A) affect towards climate mitigation action; B) beliefs in climate change; C) participants' performance in the modified version of the Work for Environmental Protection Task (WEPT ^[162]); and D) truth discernment?	H _{Control 1} : Compared to participants in the pure control condition, participants in the passive disinformation control condition will report more negative affect towards climate mitigation action (H _{Control 1A}), believing less in anthropogenic climate change (H _{Control 1B}), complete less pages of the WEPT task (H _{Control 1C}), and have a worse truth discernment (H _{Control 1D}). We furthermore expect participants in the passive control condition to report more negative feelings about climate mitigation actions at the end of the disinformation provision, compared to their baseline affect (H _{Control 1A-bis}).	As for our main hypotheses, we identified the required sample of $n = 852$ for the pure control condition, a-priori, with G*Power, in order to have 95% power to detect an overall difference with the passive disinformation control condition of $\delta = 0.20$ in a one-tailed t-test with $\alpha = .005$, for hypothesis H _{Control 1} . For hypothesis H _{Control 1A-bis} , sensitivity analysis shows we will achieve 95% power to detect an effect as small as $\delta_z = 0.14$ ($\alpha = .005$) and $\delta_z = 0.12$ ($\alpha = .01$).	Hypothesis H _{Control 1A-D} : We will compare affect toward climate action, belief in climate change, WEPT performance, and truth discernment at the end of the intervention (i.e., after the twentieth disinformation statement) of the participants in the passive disinformation control condition with the participants in the pure control condition, separately, with a one-tailed independent-sample t-test with α corrected to .005. For hypothesis H _{Control 1A-bis} , we will conduct an additional one-tailed, paired-sample t-test within the passive disinformation control condition, with affect towards climate mitigation action as the dependent variable.	Hypothesis H _{Control 1A-D} : Should any of the contrasts be not significant, we will first visually inspect the dependent variables, to visually identify ceiling or flooring effects for the intervention conditions. After confirming the lack of ceiling/flooring effects, we will test whether the difference between the passive disinformation control condition and the pure control condition is smaller than our smallest effect size of interest with equivalence testing. Should any of the equivalence testing be significant at $.005 < p < .05$, we will interpret the result as suggestive evidence that, if the twenty real climate disinformation statements have a detrimental effect on any of our dependent variables of interest, it is lower than $\delta = 0.20$.

1147 Exclusion criteria: Participants who i) do not consent to the study, ii) do not finish the study, or iii) fail the two-strikes-out attention check, will be removed from the survey
1148 and replaced with new respondents. All incomplete responses and complete responses where participants did not consent to the study anymore at the end of the survey will be
1149 removed; all other responses will be included in the data analyses.

Supplementary Materials for Registered Report “Psychological inoculation strategies to fight climate disinformation across 12 countries”

Table SM-1 – Summary of psychological inoculations potential thematic match with climate disinformation statements and truth discernment items.

Inoculation	Matching climate disinformation statement(s)
Scientific consensus	Science_8; Science_10
Trust in scientists	Science_4; Science_5; Science_6
Transparent communication	Action_8; Action_10
Moralization of climate action	Action_4; Action_5; Action_9
Accuracy	
Positive emotion	
