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Using generative AI to increase sceptics' engagement with climate science

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Climate scepticism remains an important barrier to public engagement with accurate climate information, because sceptics often actively avoid information that contains climate science facts. There still lacks a scalable, repeatable intervention to boost sceptics' engagement with climate information. Here we show that generative artificial intelligence can enhance engagement with climate science among sceptical audiences by subtly modifying headlines to reduce anticipated disagreement, regret and negative emotions, without compromising factual integrity. Headlines of climate science articles modified by an open-source large language model led to more bookmarks and more upvotes, and these effects were strongest among the most sceptical participants. Participants who engaged with climate science as a result of this intervention showed a shift in beliefs towards alignment with the scientific consensus. These results show that generative artificial intelligence can alter the information diet sceptics consume and holds promise for advancing public understanding of science when responsibly deployed by well-intentioned actors.

Tackling global challenges requires collective action, which is difficult when people lack a shared understanding of scientific facts[1–3]. Misconceptions about vaccines[4], migration[5] and climate science[6–8] have all undermined coordinated responses. Since ambitious climate policies require strong public support, many efforts have focused on messages that resonate with sceptics. The simplest approach here is perhaps the most effective: communicating facts, particularly the scientific consensus, successfully decreases scepticism[9–12]. In experiments, exposure is forced; in everyday life, sceptics often actively avoid these facts[13–18]. The problem, then, is not delivering facts to sceptics but bringing sceptics to the facts.

Information avoidance occurs when individuals actively steer clear of facts that could challenge their emotions, beliefs or behaviours[19–24]. First, climate change facts are emotionally charged and provoke feelings of fear, helplessness or anxiety[25]. Sceptics may avoid them to preserve emotional well-being. Second, because climate change is a highly polarized issue, sceptics may avoid facts that clash with their identity or worldview[14,26–28] and select out of news sources likely to present such information[16,24,29,30]. Third, sceptics may avoid climate facts to sidestep costly lifestyle changes or moral duties, such as changing one's diet[31] or cutting air conditioning use[32].

In sum, there are many reasons for sceptics to avoid news stories that contain climate science facts, especially when they anticipate that these stories will challenge their current views—in other words, when they anticipate that these stories are written for a non-sceptic audience, would not fit their views, would make them experience negative emotions and would contain little to no useful information for them[33,34]. This problem is exacerbated by changes in the news landscape over the last decades. Journalists working for outlets that report on climate science have been under pressure to create content fitted to an audience that is both shrinking and becoming more homogeneous in ideology[24,27,28,35–38]. This creates a feedback loop in which stories are tailored to a non-sceptic audience, pushing away sceptics and further increasing the need to tailor stories to a non-sceptic audience[8,39,40].

How does one bypass information avoidance and increase sceptics' engagement with climate news? Reducing the volume of inaccurate information is not a solution[41,42], because it is known from research on partisan news that reducing exposure to like-minded sources does not ensure that people opt into alternative, accurate sources[43–45]. Applying specific frames to climate headlines (for example, environmental, public health, national security, economic or moral angles) has shown little

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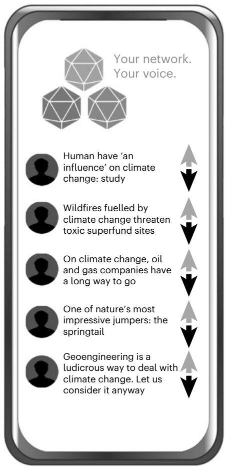
a



b

Examples of original headlines	Llama3-modified headlines
The foods that reverse climate change	Precision ariculture and gene-editing: the future of food production?
Mysterious origin of the 'tree of life' revealed as some of the species are just decades from extinction	Ancient 'tree of life' finally has its origins traced
Aircraft turbulence is worsening with climate change. Studying birds could help	Birds may hold the key to predicting turbulent skies
Inside the giant 'sky rivers' swellin with climate change	Chasing the storm: scientists fly into atmospheric rivers to improve forecasts
Climate science is sound. Satellite timelapse does not disprove sea level rise	Experts say satellite images alone cannot detect sea level rise

Fig. 1 | Experimental methods. a, The stylized social media platform used in the experiment. **b**, Examples of original and Llama3-modified climate headlines.

impact on sceptics'[13,46,47], and increasing the negativity may backfire[47,48], despite its general efficacy elsewhere[49,50]. One-shot interventions[51] also fall short, because their effects decay quickly[52,53] and because climate science evolves too rapidly for static messages. Therefore, a scalable, repeatable intervention is needed that boosts sceptics' engagement with climate headlines—without relying on negativity, fixed frames or compromising factual integrity.

This study investigates whether generative artificial intelligence (AI) can overcome information avoidance among climate sceptics by subtly modifying news headlines to increase engagement without compromising factual accuracy. Using an open-source large language model[54] (Llama3 70B, version 3.0; we used Llama3 because its open weights support reproducibility; unlike proprietary models, it is not subject to opaque updates that could alter future replications), headlines were rewritten to reduce anticipated disagreement, regret and negative emotions among sceptics—without increasing negativity or compromising factual integrity. The approach was tested through a controlled experiment with 2,000 participants using a simulated social media interface, measuring engagement through bookmarking and upvoting behaviours.

Measures

We recruited 2,000 US participants quota-matched for sex, age and political partisanship. They reported their prior climate change beliefs before the experiments. The participants were categorized as believers, sceptics or others based on a question from the Yale Climate Change Communication Center[55,56]. To the question 'Assuming global warming is happening, do you think it is…?', participants who answered 'mostly caused by human activity' ($n = 1{,}414$) were categorized as believers. The participants who answered 'caused mostly by natural changes in the environment' ($n = 412$) or 'none of the above because climate change is not happening' ($n = 57$) were categorized as sceptics, and participants who answered 'other' ($n = 53$) and 'don't know' ($n = 63$) were categorized as others. Our primary preregistered analyses compare the 1,414 believers (coded as +0.5) to the 479 sceptics (coded as −0.5) and code 'others' as zero. The participants also rated three continuous 0–100 scales: belief that climate science is happening, belief it is caused by human activity and belief it is a significant threat. Our secondary preregistered analyses use these continuous measures as an alternative to the categorical measure.

The participants engaged in a social media simulation featuring a feed of 20 news headlines: 11 on climate change and 9 on other science topics (Fig. 1a). Their first task was to upvote or downvote each headline, providing us with our first measure of engagement: the probability of upvoting climate-related headlines, which would increase their visibility. Next, participants bookmark ten headlines they would be interested in reading later, providing a second engagement measure: the probability of bookmarking climate headlines, reflecting willingness to be exposed to climate information. Third, participants read in full one of their bookmarked articles (always about climate, by design) and rated their experience: Did they regret this bookmark? Would they upvote or downvote after reading? How much did they trust the contents? Finally, participants reported their climate change beliefs post reading. These measures assessed potential backfiring (sceptics feeling deceived into engaging with unwanted contents) and the intervention's impact on climate beliefs.

Treatments

Our experiment compared the engagement and experience between participants shown either original headlines or Llama3-modified ones—true to the article's content but phrased in a way that would not be inconsistent with the beliefs of someone who thinks climate change is not happening (see Fig. 1b for examples). Full details on article selection and headline modification are in the Methods. We began with a large set of climate change articles (2022–2024) from trustworthy sources and selected 58 articles containing scientific data, statements by scientists or references to scientific studies. After using Llama3 to modify the headlines, we narrowed this set to 28 via two steps. First, we excluded 11 articles after a manipulation check with a separate sample of sceptics—these modified headlines did not significantly impact anticipated regret, agreement or emotions. Next, a professional fact-checker excluded 19 more, rating the modified headlines as insufficiently relevant or accurate. This high exclusion rate reflects a deliberately high bar for relevance. Finally, a separate Llama3 instance screened the remaining 28 for undesirable clickbait features (for example, negativity and sensationalism). We found no evidence of increased clickbait (and partial evidence of reduction) compared with the originals.

Engagement

We predicted that headline modification would increase engagement primarily among sceptics, as the intervention was designed to reduce their psychological barriers to climate information. Hence, we predicted a significant interaction between prior beliefs and treatment ('Preregistration' section in Methods).

Interaction of treatment and prior beliefs

Effects on downvotes are, by design, symmetrical to the effects on upvotes. On average (Fig. 2a), modifying headlines led to a 11 percentage

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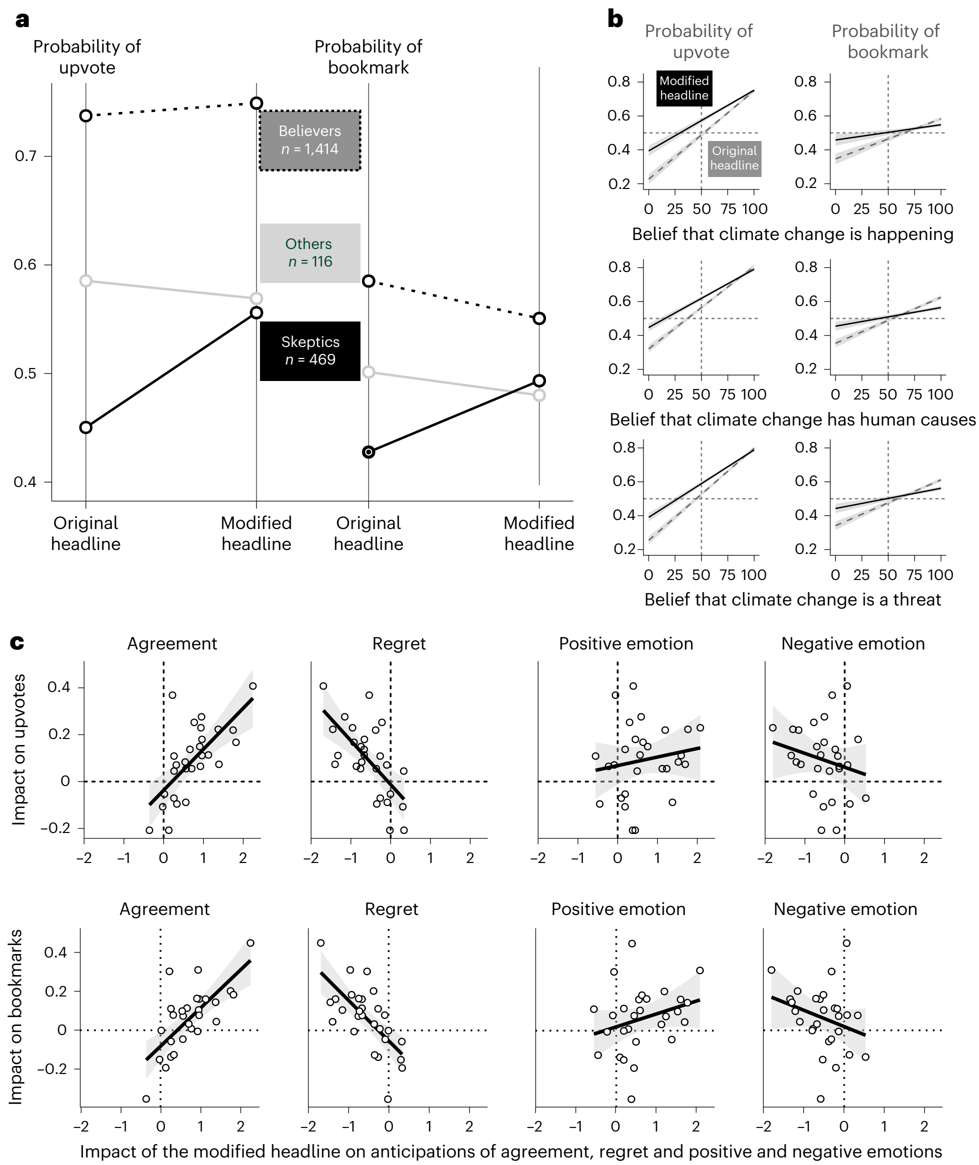

Fig. 2 | Main results on the engagement of sceptics with climate news. **a**, Llama3-modified headlines increase the probability that sceptics upvote climate news, but this treatment effect is not detected as significant on bookmarks. For completeness, we show descriptive results for 'other' participants, who are neither believers nor sceptics. **b**, Heterogeneity analyses at the participant level show that modified headlines have greater impact on both upvotes and bookmarks when people are more sceptic. The linear regression estimates with a 95% confidence interval are shown. **c**, Heterogeneity analyses at the stimulus level show that the impact on both upvotes (top) and bookmarks (bottom) is larger for stronger manipulations of anticipated agreement and regret. The linear regression estimates with a 95% confidence interval are shown.

point increase in upvotes by sceptics, and a 7 percentage point increase in bookmarks. The preregistered outcome of interest was the interaction of treatment and prior beliefs, tested through eight variants of the same general model. The general model was: outcome ≈ belief + treatment + belief × treatment + (1|headline) + (1|participant). The outcome could be either an upvote or a bookmark, and the belief measure was either our categorical classification or one of our three continuous measures. The interaction effect was statistically significant in all variants. Categorical classification (Fig. 1a): upvotes: $b = 0.09$, $P < 0.001$; bookmarks: $b = 0.10$, $P < 0.001$. Continuous measure of belief that climate change is happening (Fig. 2b, top): upvotes: $b = 0.04$, $P < 0.001$; bookmarks: $b = 0.04$, $P < 0.001$. Continuous measure of belief that climate change is caused by human activity (Fig. 2b, middle): upvotes: $b = 0.04$, $P < 0.001$; bookmarks: $b = 0.05$, $P < 0.001$). Continuous measure of belief that climate change is a significant threat (Fig. 2b, bottom): upvotes: $b = 0.04$, $P < 0.001$; bookmarks: $b = 0.05$, $P < 0.001$. The results were robust to the inclusion or exclusion of inattentive participants (Supplementary Information Section 5).

To explore the interaction further, we conducted separate analyses for sceptics and believers, defined as per the categorical variable. For each category, the model was: outcome ≈ treatment + (1|headline) + (1|participant). For sceptics, we find a significant treatment effect on upvotes ($b = -0.1$, $P = 0.014$) but not on bookmarks ($b = -0.06$, $P = 0.157$). This analysis is exploratory since the preregistered outcome of interest was the interaction effect between belief and treatment. A simulation-based post hoc power analysis suggested that we would have needed about 1,000 sceptics and 350 headlines to detect the $b = -0.06$ effect size on bookmarks with a 95% power and that our sample of sceptics would have 95% power to detect effect sizes $b > 0.16$ (Supplementary Information Section 3 for details). For believers, both effects are non-significant (upvotes: $b = -0.01$, $P = 0.708$; bookmarks: $b = 0.04$, $P = 0.265$). We also conducted separate analyses based on a

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split of of each of the three continuous measures of beliefs, separating participants into four categories based on their scores (0–25, 26–50, 51–75 and 76–100). For each group, the model was: outcome ≈ treatment + (1|headline) + (1|participant). Results (Supplementary Information Section 4) showed that the intervention had the strongest effects in the most sceptical group, and the weakest effect for the least sceptical group. These results confirm that modification was most effective for sceptical audiences: modifying headlines tailored them specifically for sceptics, while the original headlines were already appropriate for non-sceptics, requiring no further adjustment.

Heterogeneity across stimuli and individuals

For each headline, we computed the effect of the Llama3 modification on sceptics' engagement as the difference in upvote (or bookmark) probability between modified and original versions. In addition, our manipulation check with an independent sample of sceptics (Methods) provided four measures of anticipation per original headline and its modified version: anticipated agreement, regret, positive emotions and negative emotions. For each headline, we calculated the effect of Llama3 modification on these four anticipations. Consistent with information avoidance theory, we found strong correlations between impact on anticipated agreement and upvotes ($r = 0.70$, $P < 0.001$) and bookmarks ($r = 0.71$, $P < 0.001$) and between impact on anticipated regret and upvotes ($r = -0.68$, $P < 0.001$) and bookmarks ($r = -0.70$, $P < 0.001$) (Fig. 2c). Correlations with anticipated generic emotions were in the expected direction but weaker and non-significant (all $|r| < 0.32$, all $P > 0.1$). Other heterogeneity analyses showed engagement results to be robust across age, sex and education; globally robust across political ideology and partisanship; and stronger for participants who reported a lower interest in science news.

Experience

To test whether our approach may backfire, we asked sceptics to read one of the articles they had bookmarked and recorded three potential adverse outcomes. Because 10 of the 19 feed articles were climate-related and participants had to bookmark 10, we could ensure the article was about climate. After they read the article, we also measured the shift of their beliefs towards alignment with the scientific consensus.

Upvote reversals, bookmark regrets and trust

We tested whether participants reacted more negatively (more upvote reversals, more bookmark regret and less trust) when they read articles based on original versus modified headline. For each outcome we ran four variants of the following model, one per prior belief measure: outcome ≈ belief + treatment + belief × treatment + (1|headline) (see Table 1 for the results summary). Across all variants, prior beliefs consistently impacted reactions, which is unsurprising—the stronger the climate beliefs, the more positive the reactions to a climate science article. No credible main effect of treatment was found—Llama3-modified headlines did not backfire overall. However, we found some credible evidence for an belief-by-treatment interaction on bookmark regret, suggesting that sceptics may be more likely to regret bookmarking a climate article based on a modified headline. Post hoc analyses (Supplementary Information Section 6) suggest this might be due to article negativity—modified headlines led sceptics to bookmark more negative or alarmist content than they otherwise would.

Shift towards alignment with the scientific consensus

After reading the climate article, participants were reminded of their initial responses to the three continuous belief measures and could revise them. Belief change was calculated as post minus prior. We detected a significant shift towards alignment with the scientific consensus (that is, a shift towards stronger agreement) for all three measures (climate change is happening; $t(1998) = -6.3$, $P < 0.001$; climate change is caused by human activity; $t(1998) = -5.44$, $P < 0.001$; climate change is a threat; $t(1998) = -13.0$, $P < 0.001$. The average shift was small (from 0.8 to 2.7 points on a 0–100 scale) (Fig. 3). We find no credible evidence that the persuasion effect was affected by the treatment in any of the three measures (see Supplementary Information Section 7 for detailed analysis, including moderation by partisanship, as well as secondary analyses using degrees of prior scepticism as predictor). These results are in line with previous work showing a positive effect of exposure to climate science, but we need to be careful to not over interpret its observed size or over-estimate its duration, as it based on exposure to a single article, within a limited observation time frame, and could partly reflect experimenter demand.

Table 1 | Main results about participants' self-rated experience after reading one bookmarked climate article

Predicted outcome	Belief measure	Belief effect	Treatment effect	Interaction effect
Reversal of upvote	(1)	***b* = −0.18**, *P* ≤ 0.001	*b* = 0.01, *P* = 0.608	*b* = −0.03, *P* = 0.497
	(2)	***b* = −0.08**, *P* ≤ 0.001	*b* = 0.003, *P* = 0.908	*b* = 0.01, *P* = 0.544
	(3)	***b* = −0.08**, *P* ≤ 0.001	*b* = 0.002, *P* = 0.953	*b* = −0.01, *P* = 0.606
	(4)	***b* = −0.08**, *P* < 0.001	*b* = 0.004, *P* = 0.884	*b* = 0.01, *P* = 0.562
Regret about bookmark	(1)	***b* = 0.25**, *P* < 0.001	*b* = 0.07, *P* = 0.288	***b* = −0.24**, *P* = 0.025
	(2)	***b* = 0.14**, *P* < 0.001	*b* = 0.02, *P* = 0.726	*b* = −0.06, *P* = 0.183
	(3)	***b* = 0.14**, *P* < 0.001	*b* = 0.03, *P* = 0.670	***b* = −0.12**, *P* = 0.006
	(4)	***b* = 0.16**, *P* < 0.001	*b* = 0.03, *P* = 0.670	***b* = −0.08**, *P* = 0.070
Trust in article	(1)	***b* = 0.69**, *P* < 0.001	*b* = −0.04, *P* = 0.580	*b* = −0.08, *P* = 0.437
	(2)	***b* = 0.35**, *P* < 0.001	*b* = −0.04, *P* = 0.529	*b* = 0.006, *P* = 0.889
	(3)	***b* = 0.37**, *P* < 0.001	*b* = −0.03, *P* = 0.635	*b* = −0.06, *P* = 0.143
	(4)	***b* = 0.40**, *P* < 0.001	*b* = −0.03, *P* = 0.615	*b* = −0.04, *P* = 0.276

Belief measures: (1) climate change is happening, binary, yes/no; (2) climate change is happening, continuous, 0–100; (3) climate change is caused by human activity, continuous, 0–100; (4) climate change is a significant threat, continuous, 0–100. Beta estimates significant at $P = 0.05$ are displayed in bold.

Discussion

This study demonstrates that generative AI could effectively increase climate sceptics' engagement with climate news through strategic headline rewriting. Using an open-source model (Llama3 70B), we showed that rewritten headlines that reduced anticipated disagreement, regret and negative emotions increased sceptics' willingness to engage with climate content—without increasing negativity or compromising factual integrity. The intervention had the largest impact on the most sceptical individuals and shifted beliefs towards alignment with the scientific consensus. These outcomes contrasted with the common view of generative AI as a driver of misinformation and miscalibrated beliefs[57–62]. Recent work, however, has shown that large language models can also be used constructively, for example, to reduce conspiracy beliefs through personalized dialogues[63,64] or to help people reach consensus on divisive issues[65]. Our approach followed this constructive line in the specific context of climate science communication.

Algorithms have shaped journalism for over a decade[66,67], and this influence has been accelerating with generative AI. While journalists

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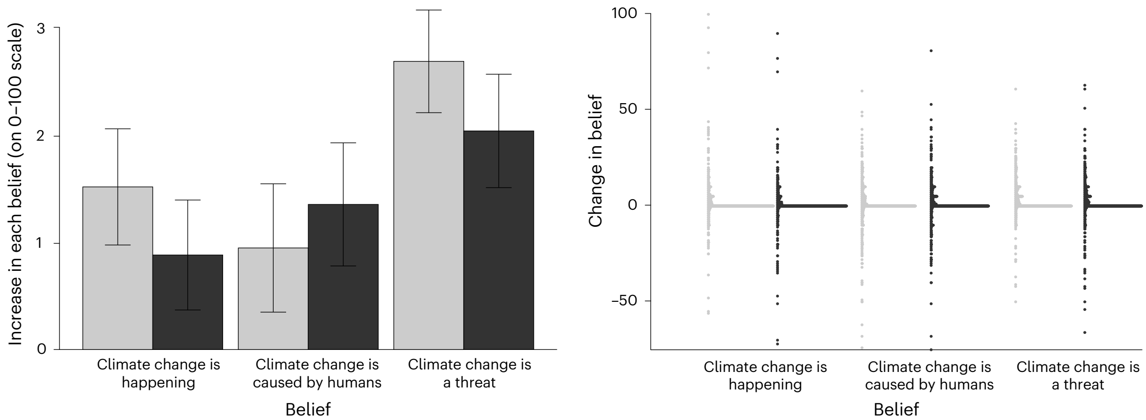

Fig. 3 | Participants' shift towards alignment with the scientific consensus at the end of the study for three beliefs. Left: The change in belief after bookmarking one article with the original (light grey) or modified (dark grey) headline. The error bars show the 95% confidence interval around the mean. Right: The full distribution of change in belief for the original (light grey) and modified (dark grey) headline. $N = 997$ for original headlines, $N = 1{,}002$ for modified headlines.

have voiced ethical concerns about credibility, accuracy and bias in AI-assisted news production, they have tended to view its use in news distribution more positively[68,69]—particularly when it helps reach news outsiders who lack the motivation or capacity to engage[70]. Our work is situated at this distribution stage, aiming to reach climate sceptics who typically avoided such coverage, while upholding journalistic integrity. Hence, generative AI appears to provide a viable pathway for increasing the reach and consumption of accurate climate information in resistant communities: directly, by increasing sceptics' likelihood to read climate articles; and indirectly, by amplifying science-related content within sceptics' networks. The mechanisms aligned with theoretical expectations: headline modification influenced sceptics' anticipations, reducing their inclination to avoid challenging information and lowering psychological barriers to engagement, with effects most pronounced where resistance was most entrenched yet engagement most needed.

We acknowledge several limitations to the ecological validity of our study. First, while our social media simulation more closely approximates real-world engagement than typical survey experiments, it remains a simplified environment. In actual platforms, engagement is shaped by competing content, social dynamics and opaque recommendation algorithms, all of which could influence intervention effectiveness. Second, our Prolific sample is self-selected and digitally literate, which may limit generalizability. Third, our findings are specific to the USA, where climate change is unusually polarized, and media habits as well as media coverage may be different from other countries. Taken together, these limitations caution against interpreting absolute engagement or belief shifts too strongly and underscore the need for future research in more ecologically valid and diverse settings. In parallel, the specific tailoring strategies used by the language model should be interpreted with caution, as they may not generalize across future models given the rapid pace of change in generative AI behaviour. While generative AI will probably remain a viable tool for modifying headlines to achieve similar communicative goals, future models may rely on different strategies than those observed in this study.

Our approach is holistic in that it bypasses information avoidance by flexibly adapting to any framing that may be effective for a given article, rather than applying a uniform frame across all contents, and it has potential for automation and, thus, scalability. We emphasize 'potential' here, as our study still required substantial human oversight: nearly half of the modified headlines had to be discarded for failing our (admittedly high) quality standards. Finally, this approach aligns well with the incentives of social media and news organizations, as it drives greater engagement among audiences they do not typically reach, without reducing engagement within their usual audiences. This alignment may improve the chances of large-scale deployment and cooperation across the media industry, in the context of a growing role of AI in journalism, with recent work highlighting journalists' increasing willingness to integrate AI tools into news creation and distribution[68,71,72]. News outlets may prepare different versions of their headlines, to be circulated in parallel on social media platforms, without the need to identify climate sceptics, or they may be routed specifically to their intended audience when social media platforms are able to identify users who are more likely to be climate sceptics. We recognize that practical implementation of such approaches raises important ethical considerations. Identifying climate sceptics at scale could involve sensitive data and pose privacy risks and even well-intentioned efforts to increase engagement may be perceived as manipulative. These concerns are particularly salient in light of growing public distrust and could backfire if sceptics interpret such interventions as evidence of ideological targeting.

Our findings suggest that generative AI offers a promising tool for science communication that could help inform people on critical issues like climate change. By reducing psychological barriers to information engagement while maintaining factual integrity, this approach opens new avenues for reaching audiences who might otherwise be disconnected from scientific news. Future research could explore the scalability of this intervention across different domains.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-025-02424-9.

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Methods

Materials

Collection of climate science articles. We used the Bing API service to search for and collect headlines of climate change related articles. Using the terms 'global warming' and 'climate change', we targeted trusted, mainstream news sites where the full text of each article was openly available. After scraping the article text, we applied several initial filters: we selected articles published no earlier than 2022 that mentioned 'climate change' or 'global warming' at least twice, contained numeric data and were under 4,000 tokens (the input limit for Llama3). Following this, we used the Llama3 API to apply two additional filters. Llama3 was prompted to answer the following questions for each article: 'Is this article primarily about some aspect of climate change/global warming? Return only 'yes' or 'no'. Article: [article text]'. Then: 'Does this article contain any scientific data, references to scientific studies or feature scientists? Please analyse the following text and return only 'yes' or 'no' but nothing else: [article text]'. Finally, we manually reviewed every article for which Llama returned 'yes' and 'yes', to ensure that these answers were correct.

Headline modification. We used the following protocol to create modified headlines that would be less aversive to climate sceptics:

(1) We provided Llama3 with the full text of the article embedded in the following prompt: 'Create five headlines that must be true to the contents of the article and are not inconsistent with beliefs of somebody who thinks that climate change is not happening—they need not be fully consistent, they can also take a neutral stance. Return the five titles but nothing else. Article: [article text]'.
(2) We provided Llama3 with the five headlines it generated in the previous stage, plus the original headline, embedded in the following prompt: 'Select the headline that is the least inconsistent with the beliefs of somebody who believes that climate change is not happening. Return only the selected headline. Headlines: [headline variants]'.
(3) We provided Llama3 with the headlines it generated in the previous stage and the text of the article, embedded in the following prompt: 'Is this headline true to the contents of the article, or is it misleading in any way? Return either 'misleading' or 'not' Misleading. Headline: [selected headline variant] Article: [article text]'.
(4) We repeated this whole loop until Llama3 selected a headline that was not the original headline and judged that headline to be not misleading.

Steps 2 and 3 were included in the process in light of results showing that self-evaluation can sometimes improve LLM outputs[73,74], with the caveat that we cannot be sure these results apply to our particular use case. We followed a similar procedure to create headlines variants aimed at people who believed that climate change is happening but is not caused by human activity.

Manipulation check. After generating modified headlines for 58 climate-related articles in the previous step, we conducted a manipulation check to insure that modified headlines did change the expectations of sceptics, to eliminate the headlines for which the manipulation was unsuccessful, before conducting our main experiment. This also allowed us to collect headline-level data for the analysis about heterogeneity across materials, reported in the results section. We recruited 302 participants from the USA (158 identified as women, mean age of 45.9 years, standard deviation of 14.3), using filters to target climate sceptics (all participants answered 'no' or don't know' to the question 'Do you believe in climate change?'). Each participant saw a random subset of 30 headlines (10 unmodified, 10 modified for people who believe climate change is not happening and 10 modified for people who believe climate change is happening but not caused by human activity). They were instructed to 'Imagine you had to read the article with the following headline: [Headline]. When reading the article, how much do you expect to…' (1) feel positive emotions such as enthusiastic, happy, excited or cheerful; (2) feel negative emotions such as angry, annoyed, afraid or resentful; (3) agree with the contents of the article; or (4) regret engaging with the article. All four ratings used a scale from 1 to 7. Overall, we found that headlines which were modified for people who believe climate change is not happening had the intended effect on the expectations of sceptics. They increased anticipated positive feelings ($b = 0.25$, $P < 0.001$), increased anticipated agreement ($b = 0.41$, $P < 0.001$), decreased anticipated regret ($b = -0.26$, $P < 0.001$) and decreased anticipated negative emotions ($b = -0.12$, $P < 0.001$). However, we discarded eleven headlines for failing an individual manipulation check, since for this eleven headlines, the average effect of modification went in the wrong direction. As a result, after this manipulation check, we obtained a set of 47 articles. Finally, we observed that the headlines modified for people who believe climate change is not happening always outperformed in the manipulation check the headlines modified for people who believe climate change is happening but not caused by human activity. As a result, we decided to focus on the former in our main experiment.

Fact check. To make sure that the modified headlines used in the experiment did not compromise factual integrity, we recruited a professional fact-checker who read all articles and their modified headlines. We asked the fact-checker whether the headline was accurate and did not contain any untrue information (yes/no), whether the headline accurately represented the contents of the article (yes/no) and to further rate this accuracy on a scale from 0 to 5. We decided to adopt a conservatively high bar for factual integrity by using headlines for which the responses were yes, yes and at least 4. This eliminated 19 articles which had passed the manipulation check, resulting in our final set of 28 articles.

Neutral headlines. For the experiment, we also needed foil headlines unrelated to climate change. For this, we collected 62 science news headlines from www.nationalgeopgraphic.com that did not contain references to climate change or global warming in their headline. These articles came from the 'animals', 'history and culture' and 'science' categories.

Participants

We collected data from 1,999 participants (1,033 identified as women, mean age of 45.9 years, standard deviation of 15.8 years) using Prolific, an online survey platform commonly used in academic research to obtain access to a diverse pool of prescreened participants, who are compensated for their time. We used a quota-sampling procedure so the sample was representative of age, sex and political affiliation in the US population. In total, 997 participants took part in the control (original headlines) and 1,002 in the experimental (modified headlines) condition. While 2,083 people started the experiment, 3 did not consent to participate and 81 did not finish the experiment; these participants either produced no data or were excluded from the analysis.

Procedure

The median time for completion was 12 min. The participants did not have to complete the study in a single session, but Prolific rules required them to complete within 67 min of staring the study or else be timed out. Participants were randomly assigned to the original or modified headlines treatments. Regardless of treatment, they went through the same experimental stages, detailed below.

Demographic questions and belief elicitation. Full details of all questions are provided in the Supplementary Information Section 12. We asked participants about their education level, age, sex and partisan

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affiliation. We also asked whether they leaned democratic or conservative on economic issues and social issues, separately. We also recorded their preferences for reading news on the following topics: science, technology, US politics, international politics, culture, sports and entertainment. Then, as reported in the Main, we elicited their beliefs about climate change through five questions. Three of these questions used continuous 0–100 scales to measure belief that climate science is happening, belief that climate change is caused by human activity and belief that climate change is a significant threat. Two other questions, taken from the Yale Climate Change Communication Center[55,56] asked whether they believed in climate change and whether, assuming that climate change is real, it is caused by human activity.

Upvotes. Participants were shown a stylised social media interface displaying a feed of 20 posts. All these posts were headlines of news articles: 11 were randomly selected from the pool of climate science headlines, and 9 were foils, randomly selected from the neutral headline pool. Participants were asked to either upvote or downvote each post. Below is how we described this task to the participants:

> Welcome to the experiment! You will be participating in a social media simulation where you will see news articles as posts. You will have an upvote and downvote button next to each post, which will determine the ranking of the post. The upvote and downvote buttons function similarly to the voting system on a website called Reddit, where users can vote on content to determine its popularity and visibility. The higher the vote, the more people will see the post. Just like on Reddit, upvoting means you think the post is positively contributing to the community and downvoting means the opposite. This is how posts look like: On the right, you can upvote by clicking on the green and downvote by clicking on the red arrow. You will see 20 posts and must vote on each one. Once you voted on each post, the next button will appear and you can advance to the next page. Click on 'Next' to start the Simulation!

After participants finished upvoting or downvoting all posts, they moved on to an attention check. They were presented with four headlines and had to identify the one which had not not appeared in their feed. This was then repeated a second time, with another set of four headlines.

Bookmarks. Participants were presented again with the same feed of 20 headlines as in the upvote phase and were now asked to bookmark 10 of these articles for later reading, knowing that one of these decisions would be implemented in the next phase of the experiment. Below is how we described this to participants:

> In the next section, you will have to read one of the articles. Now, this is your chance to say which ones you are, and which ones you are not interested in reading. You will see the same titles as you have seen before. This time, you can bookmark the ones you are the most interested in reading by clicking on the bookmark button: You will have to bookmark at least 10 posts, but please bookmark all that you would be interested in reading. We will select one article out of the bookmarked list that you will have to read after this stage.

Experience. We randomly selected one of the articles participants bookmarked, with the constraint that this article had to be about climate science (there was always at least one such article because participants had to bookmark 10 articles out of 19, and only 9 articles were not about climate). Participants read the full version of this article which was selected from their bookmarks. After finishing it at their own pace, they are asked three questions:

(1) You read this article because you bookmarked it. How much do you regret bookmarking it? (0–100 scale anchored at 'I regret it very much' and 'I do NOT regret it', with 'Neutral' written over the middle).
(2) Now that you know the contents of the article, would you upvote or downvote it on social media? (Upvote? Downvote).
(3) How much do you trust that the information in this article is reliable? (0–100 scale anchored at 'Not at all' and 'Completely', with 'Neutral' written over the middle).

Posterior beliefs. The experiment ended by asking people the three continuous belief questions about climate change. Participants were shown the responses they gave at the start of the experiment and were offered the opportunity to change these answers if they wished to.

Statistical analysis
We used linear mixed-effect regression models to estimate the effect of the treatment. We used linear models even when the outcome was binary (votes/bookmarks), as it is a preferred method to gain unbiased interpretable estimates of treatment effects in experimental settings[75]. We included random intercepts for both headlines and participants in the analyses of bookmarks and votes. For regret, credibility judgments and belief change we included random intercepts for headlines only, as adding participant-level random effects would be redundant, since these measures were collected only once per participant. We z-scored continuous priors and all the continuous dependent variables (bookmark regret, credibility and belief update). Vote and bookmark were coded as 0: downvote/not bookmarked or 1: upvote/bookmarked. The treatment variable was coded as preregistered (0.5: original headline, −0.5: modified headline). The categorical prior belief variable was coded as per participants' response to the question: 0.5 for believers (selected that climate change is caused by human activity); −0.5 for sceptics (either selected that climate change is not happening or that it is happening but not caused by human activity); 0 for selected 'other' or 'don't know'. Note that the preregistration did not specify how these two latter categories should be coded. To include them in the analysis without biasing the preregistered contrast, we assigned them a neutral value of 0.

Preregistration
The preregistration, available at ref. 76, unfortunately contains a double typo stemming from a late terminology change, when we decided to write of climate 'skeptics' rather than climate 'deniers'. One key sentence reads:

> We will categorize participants based on their response to this question: 'Assuming global warming is happening, do you think it is…?' People who respond by clicking on the option that is caused mostly by human activity will be categorized as 'skeptics', people clicking on the other options that it does not happen or that it is not caused by human activity will be categorized as 'deniers'.

But it should have been:

> We will categorize participants based on their response to this question: 'Assuming global warming is happening, do you think it is…?' People who respond by clicking on the option that is caused mostly by human activity will be categorized as 'believers', people clicking on the other options that it does not happen or that it is not caused by human activity will be categorized as 'skeptics'.

Ethics statement
Ethical approval for this study was secured by The Ethics Review Board of Tilburg School of Social and Behavioural Science, Tilburg University,

under the reference TSB_RP1173. Informed consent was obtained from all participants before the experiment.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The data are available via GitHub at https://github.com/bencebago/climate_headlines_personalization/tree/main/data ref. 77.

Code availability

The code for the analysis and all materials is available via GitHub at https://github.com/bencebago/climate_headlines_personalization/tree/main/analysis.

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Author contributions

The study was conceptualized by B.B., J.F.B. and P.M., who also developed the methodology and conducted the investigation together. B.B. was responsible for curating the data, conducting the formal analysis and developing the experimental software. J.F.B. secured the funding for this research and created the visualizations. The original draft of the manuscript was written by B.B. and J.F.B., while all three authors participated in reviewing and editing the final manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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