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Climate Change Disinformation and How to Combat It

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Abstract

Climate change presents a challenge at multiple levels: It challenges our cognitive abilities because the effect of the accumulation of emissions is difficult to understand. Climate change also challenges many people's worldview because any climate mitigation regime will have economic and political implications that are incompatible with libertarian ideals of unregulated free markets. These political implications have created an environment of rhetorical adversity in which disinformation abounds, thus compounding the challenges for climate communicators. The existing literature on how to communicate climate change and dispel misinformation converges on several conclusions: First, providing information about climate change, in particular explanations of why it occurs, can enhance people's acceptance of science. Second, highlighting the scientific consensus can be an effective means to counter misinformation and raise public acceptance. Third, culturally aligned messages and messengers are more likely to be successful. Finally, climate misinformation is best defanged, through a process known as inoculation, before it is encountered, although debunking techniques can also be successful.

1. CLIMATE CHANGE: PHYSICAL SCIENCE VERSUS SOCIAL COGNITION

Misinformation: information that turns out to be false

1.1. A Century of Emerging Consensus

More than 160 years ago, on 10 June 1859, John Tyndall reported to the Royal Society the results of an experiment that he had conducted, which showed that "carbonic acid," despite being a perfectly colorless and invisible gas, was able to absorb heat radiation. Unlike the atmosphere, carbonic acid was nearly opaque to radiant heat. We now refer to carbonic acid as CO_2, and, following on the heels of Tyndall's discovery, scientists recognized before the end of the nineteenth century that industrial CO_2 emissions were bound to alter Earth's climate (4).

During the last 30 years, the evidence that humans are altering the climate has become unequivocal. There is near unanimity (around 97% or more) among domain experts that Earth's climate is being altered by emissions of CO_2 and other greenhouse gases, mainly from the burning of fossil fuels (3, 35, 36). The Intergovernmental Panel on Climate Change (IPCC) periodically summarizes the scientific consensus in their Assessment Reports (ARs). The latest report (AR5) has underscored the urgency of the problem and the need for mitigation policies (78).

The impacts of climate change on human health are now being felt. Climate change has measurably increased the capacity for the transmission of vector-borne and waterborne diseases, such as dengue fever and malaria (172). Warming has also been tied to an increase in the prevalence of mental health problems in the United States (128).

1.2. Decades of Public Hesitancy

Notwithstanding the pervasive scientific agreement and measurable adverse consequences of climate change, the public in many countries remain partially unconvinced that climate change presents a societal risk and is caused by fossil-fuel combustion. Meta-analyses of survey data between 2002 and 2017 have shown that public concern with climate change peaked in 2008 but then declined until 2011–2013 (5, 28), before showing a rebound since then (5). Although the relevance of those fluctuations in public opinion is unclear (47), there is no doubt that many Americans [around 36% (47)] are currently not worried about climate change and that a similar number or more do not accept its human origins (5, 66). One of the most extensive and long-standing surveys of the American public, by Yale University and George Mason University, has found that the share of people who accept that climate change is happening has been hovering around 70% between 2016 and 2020, although the share of people who are "extremely" or "very" sure that global warming is happening has risen from ~40% to more than 50% during the same period (98).

The American public also widely underestimates the extent of the scientific consensus. As of 2016, less than 70% of the public recognized that most scientists agree on climate change, although that share has increased from 50% in 2010 (65). In 2017, only 13% of Americans were aware that the scientific consensus is over 90% (99), although that share has risen to 21% in 2020 (98).

One pervasive aspect of US public opinion on climate change is its increasing polarization along party lines: Whereas Republican and Democrat voters differed little from each other in their level of concern in the 1990s, there has been a marked and increasing divergence since about 2000. By 2016, only 40% of Republicans worried about climate change, compared with 84% of Democrats (47). Similar gaps exist for other measures, such as acceptance of the scientific consensus and the human causes of climate change (66). Analysis of the factors that contribute to this polarization is crucial to mapping out the psychological, cognitive, and sociological landscape on which climate misinformation and potential countermeasures unfold. The political polarization of

climate change is particularly acute in the United States but also transcends national boundaries. It turns out to reflect two principal components: first, a pervasive and global association between right-wing political views and climate "skepticism" and, second, specific actions involving parts of the American political and economic leadership.

Skepticism: careful scrutiny of all evidence, central to the scientific ethos and method

Denial: motivated rejection of evidence in favor of political or personal views

1.3. Drivers of Climate Skepticism

Research has identified the main drivers of climate skepticism and denial. The most important variables are people's personal worldviews and elite cues.

1.3.1. The worldview challenge of climate mitigation. Dealing with climate change will require a transformation of the global economy. Although numerous instruments for climate mitigation exist, the required cuts to CO_2 emissions cannot be achieved without some new policies or regulations—from carbon taxes to explicit emission controls—that will transform a fossil fuel–based economy into one based on renewable sources of energy. Mitigation therefore presents a deep challenge to people whose personal identity and worldviews are tied up with free-market economics.

It is unsurprising, therefore, that countless surveys have shown a strong association between right-wing or libertarian worldviews and the rejection of climate science. This association is particularly strong in Anglophone countries (146), accounting for nearly 50% of the variance in Americans' attitudes toward climate change (105), whereas it is somewhat attenuated in other countries (113). Nonetheless, the association has been found in Australia (33), the United Kingdom (27), and 22 European countries and Israel (135), using a variety of different worldview measures. A recent meta-analysis confirmed the presence of the association across 56 nations around the world (75). Irrespective of how worldviews are measured (e.g., as free-market libertarianism or as political conservatism) and irrespective of what instrument is used to assess climate attitudes (e.g., endorsement of the science or policy support), the strong association between right-wing political attitudes and climate skepticism represents one of the most robust—and large, up to 50% of variance accounted for (105)—findings in the literature on people's acceptance of science.

1.3.2. Anti-elitism and conspiracism. The recent surge in populism around the world has also caught up with climate science. At the heart of populism is the Manichaean view of a binary conflict between the virtuous "people" and a corrupt "elite" (170). The "elite" are constructed differently in different contexts and often include established institutions such as mainstream media, the judiciary, and academics and experts (123). Climate denial has therefore become a pervasive attribute of many, though not all, populist movements (116) and many, though not all, far-right European parties and actors (54). More detailed empirical examinations of the underlying variables for the association between populism and climate denial have identified exclusionism (e.g., as reflected in opposition to multiculturalism) and social dominance orientation (i.e., endorsement of group-based hierarchies) as the main drivers in Sweden (85) and Brazil (84).

Populist rhetoric is frequently aligned with the rhetoric of conspiracy theories (9). Both "offer the same binary scheme to understand events and a state of affairs, based on a similar polarised worldview, discursively creating an external threat to the inner group" (9, p. 170). Conspiracy theories are thus often encountered in science denial (12, 89, 107), at least in part because they offer an escape from compelling scientific agreement when a consensus can be reinterpreted as reflecting a conspiracy among scientists in pursuit of some ulterior motive (33, 103). Accordingly, considerable evidence supports a link between climate denial and endorsement of conspiracies, at least in the United States (76, 105, 108, 157, 165).

The involvement of conspiracy theories in climate denial is problematic for at least two reasons: First, evidence shows that mere exposure to conspiracy theories about climate change (e.g., that scientists doctored the data) diminishes people's intentions to reduce their carbon footprint (42, 81, 158). Conspiratorial rhetoric may therefore have adverse consequences on political discourse, beyond the effects on the beholders of such views themselves. Second, conspiracy theories are notoriously difficult to debunk because of their "self-sealing" nature. Contrary evidence is often reinterpreted as confirmatory evidence (152).

1.3.3. The role of elite cues. Worldviews, populism, and conspiratorial rhetoric do not occur in a vacuum. Instead, these variables take effect in a political and rhetorical context that is shaped by the media and by political and cultural elites. This context may affect people's selection of sources that they consider reliable and believable (43), and people's opinions may be formed quite rationally on the basis of information from chosen sources (33).

Notwithstanding populist antielite rhetoric, empirical evidence indicates that elite cues are a major determinant of climate-related attitudes, even among conservatives. For example, in the late 1990s, at a time when some Democratic and Republican leaders were still aiming for bipartisan climate legislation, political affiliation had little discernible effect on their climate attitudes. In fact, highly educated conservatives were slightly more likely than their liberal counterparts to accept that scientists agreed on climate change (156). By 2010, the issue had become intensely polarized, and conservatives and liberals no longer shared a common ground (156). A longitudinal statistical analysis of data from 2001–2013 identified elite cues (e.g., votes in Congress, tone of press releases by members of Congress), amplified by the media, as the greatest determinant of public concern about climate change (28). These conclusions have been supported by another recent study that analyzed US media coverage and found that messages from Democratic elites—which nearly exclusively favored climate policies and endorsed climate science—increased during the 25 years from 1990 to 2015, whereas the number of messages from Republican elites decreased and more mixed messages were sent (125). The shift in media coverage may have had flow-on consequences, increasing the public's polarization (125).

The importance of elite cues has also been repeatedly established in experiments. In one study in Australia, participants were found to become more polarized when leaders took diverging positions, whereas their polarization lessened when leaders converged on a policy position (96). In an American study, participants being informed that "more Democrats and Republicans in Congress than ever before" accepted the facts of human-caused climate change significantly affected attitudes, including (marginally) for a subsample of conservatives (156).

1.3.4. Social cognition of climate change. In summary, as a first approximation, attitudes toward climate change are driven largely by motivated cognition that seeks to protect individuals against scientific evidence that is ideologically or economically threatening. Although elite cues can attenuate those processes or steer them in different directions, there is no doubt overall of the important role that worldviews play in the rejection of climate science. However, this rejection is not the only challenging aspect of the climate problem. Even in the absence of interference from worldviews or other forms of motivated cognition, climate change presents multiple challenges to human cognition.

2. CLIMATE CHANGE VERSUS HUMAN COGNITION

2.1. The Power of the Anecdote

In February 2015, US Senator James Inhofe (Republican from Oklahoma) famously brought a snowball to the floor of the US Senate in an apparent attempt to prove that global warming is a

hoax and to question the fact that 2014 had just clocked in as the hottest year on record. (The subsequent five years, 2015–2019, have all been hotter than 2014.) Although scientifically ludicrous, the snowball stunt was well aligned with the human tendency to be influenced by anecdotes, images, and personal experiences.

Disinformation: intentionally disseminated false information

Accordingly, much evidence indicates that people's acceptance of climate change is a function of perceived temperature on a specific day (115). Climate attitudes in a US county (90) or US state (10) can be linked to the prevailing local climate indices. Local temperatures also find expression in Twitter discourse about climate change (92); even opinion pieces about climate change in major American media have been found to be more likely to reflect the scientific consensus after particularly warm seasons, whereas skeptical opinions are more prevalent after cooler temperatures (41).

Effects on attitudes can also be observed in response to extreme events. In a quasi-naturalistic experiment, New Jersey residents' attitudes toward climate change were found to become considerably more proenvironment after Hurricane Sandy (143). A discernible effect of extreme events was also observed when survey data from 130,000 respondents were linked to local climatic events (95). The effect holds across 24 countries (20), including the United Kingdom (155).

Some qualifications do apply, however, to the effects of events on attitude. First, a recent study has argued that the effects of extreme events on climate attitudes and willingness to act are limited to individuals who attributed their extreme weather experience to climate change (129). Second, when the effects of climatic conditions are statistically compared with the role of worldviews, the latter are found to exert a considerably larger influence (120).

2.2. Stock and Flow Problems

Whereas people tend to put undue weight on anecdotes and events, they systematically underappreciate the implications of carbon emissions. The extent of global warming is determined by the concentration of CO_2 in the atmosphere (93), which has been built up by all emissions since the onset of industrialization. Current emissions increase that concentration, even though roughly half of CO_2 emissions are taken up by natural carbon sinks such as the oceans and terrestrial biomass. Reducing emissions will therefore not immediately reduce concentrations; it will merely slow the further accumulation of CO_2 in the atmosphere, just as the level of water in a bathtub will rise as long as the flow from the faucet exceeds the flow out through the drain. It is only when emissions cease completely, or nearly so, that carbon sinks will begin to draw CO_2 from the atmosphere (93, 147).

This relationship between emissions and atmospheric concentrations, known as a stock-and-flow problem, is difficult for most people to appreciate (149). Even highly skilled individuals (e.g., with a background in science, engineering, mathematics, or economics) erroneously believe that CO_2 concentrations can be kept from increasing by stabilizing—rather than eliminating—current CO_2 emissions (151). Formal training in system dynamics cuts the error rate in half, from 50% to 25%, but fails to eliminate it (150). This cognitive limitation conspires against recognition of the urgency and magnitude of the challenge: The mistaken belief that reducing emissions will immediately reduce warming leads people to believe, falsely, that there is still plenty of time, that we can wait and see how bad climate change will be before acting because the climate will respond quickly to policies designed to cut emissions.

People's overreliance on anecdotes, combined with their failure to understand the nature of stock-and-flow problems, provides a soft target for disinformation.

3. CLIMATE SCIENCE VERSUS DISINFORMATION

Opposition to climate science typically claims the mantle of "skepticism" and purports to defend "sound science" against the alleged "politicization" of mainstream climate science. This rhetoric

resembles the tobacco industry's campaigns to undermine the medical evidence about the health risks from smoking (137). Those claims do not withstand scrutiny. Several analyses of skeptical arguments have shown them to be flawed methodologically (8) as well as logically (32, 102). Contrarian argumentation is frequently incoherent, for example when it is simultaneously argued that (*a*) global temperature cannot be reliably measured and (*b*) it has been cooling for 10 years (102). Guides to detect flawed argumentation are available (32). Blind expert tests have also revealed contrarian interpretations of climate data to be misleading and unsuitable for policy advice (100, 111).

3.1. Organized Disinformation

Disinformation does not erupt spontaneously. It is actively disseminated. Recent research has identified the sources and mechanisms underlying the dissemination of disinformation.

3.1.1. Disinformation funding and lobbying. Research has clearly established that disinformation about climate change is disseminated in an organized manner through well-funded networks. One avenue is through the publication of environmentally skeptical books, which can be traced back to conservative think tanks (44, 79). More than 90% of such books published in the United States have been linked to think tanks (79), and a similar proportion has not undergone peer review (44).

Analysis of Internal Revenue Service data has revealed that the overall annual income of think tanks involved in climate disinformation reached $900 million between 2003 and 2010 (22), although how much of that money is spent specifically on climate disinformation is unknown. During the last 20 years, the network of think tanks and other actors promulgating scientific misinformation has also become increasingly integrated into American philanthropy (52). A content analysis of 16,000 documents produced by think tanks has revealed that the relative prevalence of statements casting doubt on mainstream science has increased between 1998 and 2013 (16).

At the political level, studies have estimated that between 2000 and 2016, more than $2 billion was spent on lobbying Congress concerning climate change legislation (23), money that was expended primarily on legislators who had an antienvironmental track record (59). To illustrate, the Lieberman–McCain Climate Stewardship Act of 2007 attracted lobbying expenditures of $443 million, and the Clean Energy and Security Act of 2009 attracted $716 million.

Archival historical work has revealed that the fossil fuel industry was aware of the anticipated consequences of climate change at least as early as 1965 (55). This knowledge was expressed inconsistently, however. In an analysis of Exxon's climate change communications between 1977 and 2014, more than 80% of internal documents and peer-reviewed articles acknowledged the reality of human-caused climate change, whereas only 12% of public-facing "advertorials" did (153).

3.1.2. Disinformation networks and impact. The effectiveness of organized disinformation can be examined by tracing the dissemination of content into mainstream media and the political sphere (see the sidebar titled Rhetorical Strategies of Disinformation). A recent computational content analysis of more than 40,000 documents from 164 skeptical organizations produced between 1993 and 2013 showed that the most central actors in this network—but not those at the periphery—had received funding from Exxon or Koch Family Foundations (KFF) (51). These funded actors were more likely to have produced and disseminated material to further polarize the climate change issue (50). Moreover, the similarity between skeptical content and reporting on climate change in three major US news outlets significantly increased over time, as did the similarity between skeptical content and the speech produced by US presidents (51). Documents

RHETORICAL STRATEGIES OF DISINFORMATION

The rhetorical strategies employed by climate disinformation have been curated by public relations professionals (45, 53).

- Undermine and question the scientific consensus (49).
- Highlight scientific uncertainty and demand certainty as a condition for climate action (57).
- Attack individual scientists to undermine their credibility (145).
- Undermine institutions generally, such as peer review (45).
- Project pseudoscientific alternatives through a network of blogs (48, 69, 103).

produced by actors with corporate funding found more echo in the media than did those by non-funded skeptical sources.

These computational analyses illustrate the links from corporate funders, through a network of think tanks and other organizations, to the media and even the president's rhetoric. Recent theoretical and modeling work has shown that even fairly subtle biases (173) and even just a few evidence-resistant agents (110) are sufficient to prevent a network of rational agents from accepting the best available scientific knowledge in the presence of disinformation.

3.2. Disinformation versus the Public

The demonstrated political success of climate disinformation (50, 51) is accompanied by discernible effects on public attitudes.

3.2.1. Media coverage and social media. A long-standing journalistic norm is the assumption that there are always two sides to an issue. Accordingly, US mainstream media and TV gave contrarian voices equal coverage with climate scientists for a long time (17, 18). Although the situation has gradually improved, with the media no longer presenting pervasive false balance (21), the few contrarian scientists continue to be given disproportionate representation in the media (133). In addition, even quality media coverage has ignored very basic facts about climate change (140). For example, *The New York Times* rarely mentions the mechanics of the basic greenhouse effect (140).

False-balance coverage constitutes one of the most insidious, albeit sometimes inadvertent, forms of climate misinformation. When people see two sides arguing a complicated scientific issue, they come away with the impression of an ongoing equally split scientific debate. False-balance media coverage demonstrably reduces the public's understanding of the strength of scientific evidence (94) and reduces the public's perception of the scientific consensus (34).

One way to present conflicting viewpoints without misleading is by presenting weight-of-evidence or weight-of-experts information. These approaches acknowledge multiple sides to a debate while also evaluating which side is supported by evidence and a scientific consensus (46). This approach fosters more accurate beliefs while also acknowledging contrarian viewpoints (30, 46).

Although mainstream media coverage has arguably improved during the last 10 years [with the exception of polarizing outlets such as Fox News (13, 62)], social media continue to misrepresent scientific knowledge about climate change. For example, the majority of YouTube videos about climate change espouse antiscientific viewpoints (1).

3.2.2. Effects of disinformation on people's attitudes. Misinformation demonstrably undermines the public's knowledge and acceptance of climate change. Just a handful of misleading

numbers often used by "skeptics" can lower acceptance of climate change (138). Misinformation can also cancel out the impact of accurate information. When people are presented with two conflicting pieces of information, the two can cancel each other out (34, 121, 162). In a comparison of different disinformation strategies, a petition that purports to show that 31,000 scientists disagree with the scientific consensus (virtually none of the signatories have relevant scientific credentials) has been identified as particularly damaging (162). The most frequently shared climate article on social media in 2016 featured this misleading petition (139).

With regard to social media, comments on blog posts have been shown to alter people's own attitudes and perceptions of others' attitudes (71, 101). Even very subtle cues, such as the number of times a YouTube video has been viewed, can affect people's perceptions of the salience of the climate issue (148).

3.3. Disinformation versus Scientists

The adverse effects of contrarian activities are not limited to the public at large. Several researchers have suggested that the constant barrage of public criticism and attacks on individual scientists (145) has induced the scientific community to exercise undue caution (56, 109) or to "err on the side of least drama" (25). Indeed, the language used in the IPCC assessment reports has been far more cautious than that used by climate change–denying think tanks (124). The mean confidence expressed by the IPCC in the findings reported in its latest report is "medium," and only a small share of the findings are reported with "very high" confidence (70).

Direct empirical evidence for the assertion that the scientific community has been unduly cautious in response to denial is difficult to assemble. However, interviews with researchers have revealed that some forms of contrarian activities, such as the use of freedom-of-information requests, have led to changes in how scientists communicate and have imposed an additional work burden that draws time away from research (114). At a theoretical level, agent-based simulations have shown how readily knowledge accumulation by a scientific community can be delayed or disrupted by bad-faith actors (110, 173).

4. COMMUNICATING CLIMATE CHANGE IN AN ADVERSARIAL ENVIRONMENT

The terrain for climate communication is treacherous and requires suitable rhetorical tools (see the sidebar titled Communicating in an Adversarial Environment). The implications of climate change challenge many people's worldviews and have created an adversarial political and rhetorical environment. The physics of climate change pose a challenge to cognition for everyone. To top it off, the stakes could hardly be higher and, as the consequences of climate change become increasingly apparent, the emotions could hardly be more fraught.

COMMUNICATING IN AN ADVERSARIAL ENVIRONMENT

Communicators must take care to select the right tools to operate in an adversarial environment.

- Acknowledge and use the nuances of emotion but avoid focusing on fear.
- Affirm the science through culturally appropriate messages and by highlighting the scientific consensus.
- Counter disinformation by inoculation or well-designed debunking.
- Focus on policies instead of climate attitudes.

4.1. Emotion, Visuals, and the Arts

Delaying climate mitigation will magnify adverse consequences and increase the difficulty of solving the climate problem. Many communicators have therefore used fear as a motivator, and attributes such as "terrifying" or "catastrophic" are commonplace in media reports about climate change (130).

Fear campaigns, however, are not without their critics. Fear is known to be motivating in situations where the threat is readily averted (175). Those circumstances do not hold in climate change where no quick-fix solutions exist (130). When no easy solution exists, fear appeals may be counterproductive because a frightening but unsolvable problem is often avoided or denied (64). In a recent review of the evidence relating to climate change, Hornsey & Fielding (73, p. 23) concluded that "unrealistic apocalyptic messaging runs the risk of diluting the integrity of all climate-related messages. But caution should be exercised in simply assuming that fear messages around the climate are leading to disengagement."

This nuanced view of emotions meshes well with other recent proposals to recognize emotions as essential components of motivation (61) rather than levers that can be pulled at will to achieve some desired result (29). One way in which people's emotions can be engaged constructively is through art. Unlike conventional means of communication, art uses novel metaphors and narratives, which demand the viewer's attention (142). Art can therefore challenge viewers in constructive ways that unidirectional communication cannot (26).

Even simple visuals can be effective. For example, maps of sea-level rise increase acceptance of sea-level rise specifically and climate change generally (167). When maps of sea-level rise are animated, they are particularly effective and can weaken the effects of contrarian counterframes, thus helping overcome politicization (15). When engagement is taken a step further by letting people make their own policy decisions in a realistic climate simulation, affective engagement and knowledge increase considerably (141).

However, use of visuals and art also requires care: First, some images (e.g., of floods) that are highly salient and illustrate the threat from climate change are also demotivating (131). Highlighting efficacy requires different visuals (e.g., solar panels) (131). Second, researchers need to avoid the anecdotal snowball trap and to illustrate the consequences of climate change with images that are scientifically legitimate—for example, showing retreating glaciers legitimately illustrates long-term trends, whereas a picture of a dying crop does not (112). Helpful guidelines for the construction of visuals have been proposed (171).

4.2. Affirming the Science

Calls to educate the public are traditionally made by stakeholders when public attitudes and beliefs diverge from scientific evidence on the assumption that additional information will redress the situation (39). This deficit model of science communication has been the target of trenchant critique by researchers who highlight the role of culture (i.e., people's worldviews and ideologies) in the processing of scientific information (87). On this cultural-cognition view, people are not lacking information but processing it differently and in a manner that is consistent with their culture. Hence, liberals who endorse climate science are not in possession of more knowledge than conservatives who reject it, but both groups weight information—i.e., the relative risks of unmitigated climate change versus the risks to economic activity from emission cuts—differently (87).

Although the literature has often dichotomized those two views, this approach is unhelpful in practice (164). Evidence supports (*a*) the success of providing additional information and (*b*) for doing so in a culturally appropriate manner.

4.2.1. Providing information. Numerous research findings demonstrate that people's knowledge about climate change matters. For example, specific knowledge about the causes of climate change was associated with an attenuation of the effect of conservative worldviews in an Australian sample (63). In experiments, providing a causal explanation of the greenhouse effect in 35 words has been shown to significantly increase acceptance of the science and orient toward mitigative action (138).

Similarly, asking participants to focus on mechanistic explanations can reduce polarization (80), and focusing on the absence of such explanations in contrarian argumentations can reduce the impact of those false arguments across the party divide (80). When conservative participants first acknowledge several general contributions of science, they subsequently report significantly stronger beliefs in climate science than do conservatives who were asked only about their beliefs (58). It appears that the need for consistency—e.g., to recognize the value of science regardless of domain—can overcome ideological reflexes.

Providing scientific information also raises people's recognition of the importance of climate policies, in particular among people who are skeptical of climate change (39). This result was obtained across party lines and in the United States as well as in Germany (39). Notably, interventions that avoid fear and guilt but highlight climate mitigation actions (e.g., reducing meat consumption) are particularly effective in stimulating proenvironmental intentions among people who reject the human causes of climate change (74).

In summary, the preponderance of evidence suggests that, in line with the deficit model, providing information can be helpful. Information is particularly valuable if it provides an explanation (or highlights the absence of an explanation in contrarian arguments). Although these effects transcend political partisanship, culturally appropriate messaging is known to be particularly effective.

4.2.2. Culturally appropriate messaging. Messages that are designed to align with an individual's cultural frame of reference are particularly easy to understand (83) and have greater impact. For example, when messages emphasize free-market solutions to climate change, acceptance of the science increases among conservatives (40). When stories are created that contain heroes and villains (e.g., the libertarian Cato Institute versus the egalitarian Club of Rome; both can be hero or villain depending on people's worldview), the extent of positive affect for the hero predicted outcome measures such as perceived risk from climate change or policy preferences. For example, people's affect for the Cato Institute predicted their endorsement of cap-and-trade policies when Cato was presented as a hero, whereas no such association existed when the Club of Rome was presented as hero—in that case, affect for the hero was associated with support for renewable energy (82).

There is little doubt that culturally consonant messages [and messengers (86)] are received more favorably than are their culturally misaligned counterparts. This approach has been labeled "jiu jitsu" persuasion (72), on the basis of the idea that rather than tackling people's expressed attitudes (such as climate denial) directly, communicators should understand the underlying roots of those expressed attitudes (e.g., a person's identity as a free-market adherent), yield to those values, and then align messages accordingly. A nuanced review of the roles of culture and values was provided by climate communication practitioner Adam Corner and colleagues (37).

4.2.3. Consensus messaging. One of the most popular climate disinformation strategies is to question the scientific consensus (49, 139). It is also the most damaging rhetorical tool (162), which is unsurprising because people's perceptions about scientific agreement are a key "gateway belief" to their acceptance of science and policy support (161, 166). The status of perceived consensus

as a gateway belief to acceptance of (climate) science has since been confirmed by a number of independent studies (14, 19, 122).

Numerous studies have leveraged the scientific consensus as a communication tool, and in many instances highlighting the 97% consensus has increased acceptance of climate science or increased policy support (38, 60, 91, 106, 160). The boost is particularly pronounced when videos rather than text are used to highlight the consensus (60). The evidence base includes at least one successful preregistered replication of the main initial findings (174).

The effects of perceived consensus persist longitudinally (using a cross-lagged design). Specifically, estimates of the scientific consensus were associated with acceptance of climate change six months later, with the reverse association being weaker (159). In an experimental context, consensus messaging has also had a relatively long-lasting effect (119).

There are, however, some reported exceptions to consensus messaging. For example, the message can produce reactance—that is, an oppositional response—among people who are predisposed to disbelieve climate change (33, 118). However, those effects tend to be limited to a subset of individuals.

4.3. Countering Disinformation

Much research effort has uncovered ways in which disinformation can be countered (for reviews, see 31, 53; see the sidebar titled Countering Disinformation). The take-home message from this research is that (*a*) corrections are frequently only partially effective, and the effects of misinformation linger even if people acknowledge a correction; and (*b*) inoculating people against misinformation by alerting them to how they are being misled before they encounter misinformation is a promising approach.

4.3.1. Inoculation or prebunking. Inoculation involves two elements: first, an explicit warning of an impending disinformation attempt and, second, a refutation of an anticipated argument that exposes its fallacy. To illustrate, one study applied inoculation to climate change by presenting participants with (*a*) a warning that political operatives often attempt to cast doubt on the scientific consensus and (*b*) a detailed explanation of the dissenting fake experts technique that is used to feign a lack of scientific consensus. Following this inoculation, people were resilient against the subsequent misinformation (the petition discussed in Section 3.2.2), and their responses to various climate-related items were indistinguishable from a control condition that received no misinformation. In another condition that was not inoculated, the misinformation had a discernible detrimental effect (34).

COUNTERING DISINFORMATION

The political and economic contexts in which climate disinformation is disseminated must be considered at all times. Precedents from other pseudoscientific disinformation campaigns, for example by the tobacco industry, are helpful to understand these contexts (67).

- Inoculation or "prebunking" is often helpful (34, 163).
- Inoculation can involve exposing the misleading strategies being used to disinform (34, 67, 163).
- Debunking can be successful, in particular if it uses culturally aligned messengers (7) and highlights reasoning errors in the disinformation (169).
- Debunking can often correct factual misperceptions but may not shift attitudes or policy preferences (136).

Several studies have demonstrated the efficacy of inoculation against climate change disinformation (163, 169). In one preregistered study, the inoculation effect was shown to be stable over a week-long delay (119).

An extension of the conventional inoculation approach involves interventions that encourage people to engage in critical thinking. For example, people's ability to differentiate climate disinformation from valid information increases significantly after people consider a set of guidelines about how to evaluate news online (117).

4.3.2. Debunking. The effects of corrections are nuanced and rarely straightforward. One pervasive finding in the literature is that people will remember, acknowledge, and believe a correction (104) but may continue to rely on the information they now know to be wrong in other ways (e.g., while drawing inferences about a situation). In the political domain, this tendency expresses itself when people recognize that a politician's statements are false without that realization affecting voting intentions or favorability judgments (154). Similarly, when climate-related misinformation issued by US President Donald Trump is corrected in an experiment, people are responsive—that is, they update their factual understanding irrespective of partisanship—but their policy attitudes toward climate change remain unaffected (136). Correction of specific pieces of misinformation can be achieved equally well with fact-based and logic-based corrections (169). Logic-based corrections that target reasoning flaws in disinformation have the advantage that they can be applied across domains of misinformation (144).

Debunking has been shown to be more effective when the ideology of messengers is consonant with that of the audience—in particular, a Republican messenger correcting misinformation from a Republican source (e.g., Senator Inhofe). In this instance, the response variable comprised items probing the perceived consensus, the human origins of climate change, and the seriousness of the problem: All three were affected by the correction, hinting at the possibility that attitudes may be shifted by an ideologically aligned messenger (7).

Although debunking is often successful (though see 168), there is limited evidence that this strategy is sufficient to shift people's attitudes toward climate change. The possibility of bypassing attitudes and debunking altogether has therefore attracted research attention.

4.4. Changing Views on Policies Not Attitudes

Attitudes are notoriously difficult to change, in particular if they are central to a person's identity (72). Fundamental beliefs about climate change are also not necessarily a barrier to mitigation: If the public endorses renewable energies and societies achieve emission cuts, then people's views on climate change are of no political consequence. Researchers have therefore increasingly focused on the communication of specific policies rather than climate change in general (132).

These endeavors have focused mainly on framing climate policies in different ways, for example by underscoring the health benefits that result from emission cuts rather than focusing on environmental benefits (134). Many, but not all, of those efforts have been successful. For example, underscoring health benefits was successful in one study (134) but failed to find support in another (11). A recent large-scale study in four high-income European countries found the effects of framing mitigation within a health frame to be significant (2). Unlike in previous studies, these researchers presented the health benefits as a "private good," that is as a direct positive consequence to the individual rather than as a societal benefit (2).

In another study, framing carbon emissions as "pollution" rather than referring to global warming was shown to increase policy support (126). This result relates well to an earlier finding that

simply calling a surcharge for an airline ticket a carbon offset, rather than a tax, more than doubled Republicans' willingness to pay the surcharge and raised it to equal that of Democrats (68).

Finally, a substantial effect of framing was observed in a study that presented the effects of emission cuts on the economy either as a loss or a foregone gain (77). Opponents of emission cuts usually paint a dire picture of the consequences by highlighting the expected economic "losses." Although substantial emission cuts are expected to impede economic growth, the economy is widely expected to continue growing albeit at a reduced pace. Thus, an identical economic impact can be described either as a loss relative to a business-as-usual future or as a foregone gain relative to the current size of the economy. The latter frame increased participants' support for more rigorous mitigation policies (77).

4.5. Long-Term Outlook: Benefits of Education

There are encouraging signs that education can have long-term effects. For example, analysis of the Longitudinal Study of American Youth has revealed an association between interest in science at age 12–14 and increased trust in climate scientists 20 years later (127). Other indicators, such as quantitative ability or science knowledge, did not exhibit a longitudinal association. Similar findings involving an instrument that measures "science curiosity" have been reported cross-sectionally with adults (88).

Misinformation can be a valuable educational tool if it forms the basis of detailed refutation, an approach known as "agnotology" (6). Much evidence indicates that refutational learning is a more effective way to acquire knowledge than are conventional techniques (97).

5. CONCLUSION

Communication by scientists and their allies by itself will not move climate mitigation forward. As sociologist Robert Brulle and colleagues (24) noted, "[T]he barriers to action on climate change are based in the distribution of social power in the economic, political, and cultural spheres. Introducing new messages or information into an otherwise unchanged socioeconomic system will accomplish little" (p. 185). But socioeconomic and political systems are not impervious to change. A Swedish school girl taught the world that lesson in 2019.

SUMMARY POINTS

1. Climate change challenges our cognitive abilities and the worldviews of many.
2. Because addressing climate change has serious economic and political implications, any communication takes place in an environment of adversity.
3. Providing information about climate change, in particular about the scientific consensus and explanations of why it occurs, can enhance people's acceptance of science.
4. Culturally aligned messages and messengers are more likely to be successful.
5. Through a process known as inoculation, climate misinformation can be rebutted or, ideally, defanged before it is encountered.

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