Anti-Climate Science

Computational Propaganda in the United States

A review of disinformation campaigns and collective intelligence interventions

ABSTRACT

This article reviews a thorough body of evidence suggesting that an extensive group of conservative political actors continues to engage in large-scale disinformation campaigns against climate science, using both traditional and digital media.

In reviewing these campaigns, this study identifies the two central tactics of their disinformation campaigns: (1) increasing susceptibility to social influence by increasing uncertainty toward climate science, and (2) exploiting uncertainty through positive framing techniques that reduce cognitive dissonance and co-opt progressive language. Furthermore, this study examines how these campaigns harness social media platforms and fake automated accounts (bots) to strengthen their impact. In terms of solutions, this study discusses a range of empirically-informed interventions against disinformation online, and it concludes that many promising interventions will emerge once disinformation is approached as a collective-level network problem concerning the structure of social networks, rather than as a purely individual-level problem concerning media literacy and cognitive bias. With a focus on social network dynamics, this article summarizes recent empirical findings in the study of collective intelligence that are especially promising for interventions against disinformation online, both in general and regarding climate science in particular.

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ABOUT THESE PAPERS

This case study series explores the social implications of computational propaganda. Each report outlines how tools and tactics, including bots, disinformation and political harassment, were used over social media in attempts to silence social and issue-focused groups prior to the 2018 US midterm elections.

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introduction

"The major problems in the world," wrote Gregory Bateson, "are the result of the difference between how nature works and the way people think" (1972; p. 469). Climate change is an issue where this gap is especially concerning. Despite remarkable consensus in the scientific community about the reality of climate change, a loud and primarily conservative group of political actors continues to challenge climate science through a range of disinformation tactics. A large body of literature illustrates that climate denial is linked to partisan biases and motivated reasoning, which together are exacerbated by disinformation campaigns. Crucially, these campaigns harness social media platforms and fake automated accounts (bots) on these platforms to strengthen their impact. This case study reviews evidence that disinformation campaigns against climate science are linked to a conservative issue public—i.e., an organized social network tasked with influencing what the public believes about a particular issue (in this case, climate change). In reviewing these campaigns, this study identifies two central tactics of disinformation: (1) increasing susceptibility to social influence by increasing uncertainty toward climate science, and (2) exploiting uncertainty through positive framing techniques that reduce cognitive dissonance and co-opt progressive language. This study reviews efforts to intervene against disinformation online, and it concludes that many promising interventions will emerge once disinformation is approached as a collective-level network problem rather than as a purely individual-level problem concerning media literacy and cognitive bias. With a focus on social network dynamics, this article reviews empirical findings in the study of collective intelligence that are especially promising for intervening against disinformation online, both in general and regarding climate science in particular.

Disinformation campaigns from the conservative climate change counter-movement

A growing body of literature has identified a persistent, well-funded, and continued disinformation[1] campaign against climate science, originating from right-wing corporations, think tanks, and legislative groups (McCright & Dunlap, 2010, 2011; Brulle, 2014). These disinformation efforts take advantage of a wide range of media, including books (Dunlap & Jacques, 2013), news articles (Antilla, 2005), and social media websites (Boussalis & Coan, 2016) that provide an outlet for the diffusion of climate denial arguments. Another primary dissemination tactic involves hacking the television ecosystem by securing airtime for fringe and controversial scientists who deny climate change (Elsasser & Dunlap, 2012). Disinformation campaigns against science communication have begun to harness social media platforms to rapidly spread false and deceptive information, aided by fake automated accounts called bots (Jameison, 2018). The rising threat of disinformation technologies underlies the recent meetings of the National Intelligence Council (2012) and the National Academy of the Sciences (2012, 2017), which focus on climate change communication and online disinformation as top issues for the global economy, national security, and the overall integrity of democracy.

Recent research has exposed an intricate network of dark money and right-wing organizations behind sustained disinformation campaigns against climate science. Using IRS data from 2003 to 2010, Brulle (2014) uncovers "the climate change counter-movement (CCCM)": a network of 91 organizations linked to receiving over $900 million, in total, from a range of funders—primarily ExxonMobil and Koch Enterprises.

1. In this paper, I use the term disinformation to refer to coordinated efforts to manufacture and disseminate media content of a false and/or deceptive nature. I reserve the term misinformation for content that may be unintentionally false or in error, but which may nevertheless arise from and diffuse within social networks, and may furthermore be co-opted for the purposes of propaganda.

As Brulle (2014) argues, the purpose of these organizations is to lobby against pro-climate change policies and to generate disbelief and skepticism toward climate science through the production and dissemination of counter-attitudinal materials. For example, over $125 million were given by secretive donors to think tanks tasked with lobbying against Obama's climate change bill when it was proposed (Goldenberg & Bengtsson, 2015). The anonymous money came from two obscure organizations–the Donors Trust and Donors Capital Fund–which have been referred to as the "Dark Money" of the right wing (Hickey, 2013). When channeled through these organizations, the funds cannot be traced to individual donors. To trace how the money was spent, *The Guardian* obtained annual tax filings made to the IRS by the Donor's Trust and Donor's Capital Fund and cross-checked grantees with organizations associated with the CCCM. In 2011, 42% of funding, or $35.7m, went to groups that explicitly promote climate denial and oppose environmental regulations, according to the tax filings (Goldenberg, 2013).

Due in part to the growing prevalence of climate-related disinformation, the National Intelligence Council (2012) and the National Academy of the Sciences have made recent calls for research into the structure, function, and effects of this disinformation (2012, 2017), as well as how it spreads in social networks online. A number of disinformation tactics have been explored in the literature to date (den Hove & Bettignies, 2002). This case study connects identifiable disinformation tactics in climate change denial with theories of cognitive bias and motivated reasoning with the aim of exposing possible network-based interventions for fighting the spread of climate-related disinformation. It examines two main propaganda techniques: (1) increasing uncertainty toward the findings of climate science and climate scientists; (2) using framing effects to rebrand fossil fuels and coal as having a positive impact on society and the planet. The latter includes a process I call "cultural co-opting," where categories and frames from a target community are co-opted to support an oppositional agenda. Here I focus on how the CCCM co-opts progressive language to support the right-wing agenda.

UNDERMINING CREDIBILITY AND CREATING UNCERTAINTY

Insofar as climate change has become identified as a primarily Democratic issue, it poses serious threats to right-wing rhetoric on policy agendas, especially given that climate discourse is armed with the authority of empirical data and consensus in the scientific community. Studies have shown that both liberals and conservatives are more receptive to arguments supporting climate change when the source of the message is nonpartisan and recognized as a credible scientific source (e.g., NASA) rather than as a left-leaning source (Jameison & Hardy, 2014; Hardy & Jameison, 2017; Bosetti et al., 2017). With evidence that scientific clarity and consensus can persuade individuals across party lines, it is no surprise that a dominant rhetorical tactic in climate-related disinformation is to undermine the credibility of climate science and climate scientists (Lewandowsky et al., 2015; van der Linden et al., 2015, 2017).

The strategies to undermine the credibility of climate science are multifarious. One dominant move in mainstream media draws from a classic rhetorical technique in propaganda, namely *ad hominem* (Jowett & O'Donnell, 2011). Pervasive in the mainstream media's coverage of the climate change debate are arguments suggesting that climate scientists cannot be trusted because (1) they have vested interests in convincing the public of climate change for reasons of careerism, and (2) because they are funded by liberal sources that push climate narratives with a partisan agenda (Anderegg et al., 2010; Bodenstein, 2010; Knight & Greenberg, 2011; Attari et al., 2016). The strategy here is to distance the findings of climate science that appear in rigorous, international, and peer-reviewed academic journals from the motives and incentives of the scientists themselves, where matters of credibility, trust, and moral evaluation are seen as key determiners for the validity of content (Anderegg et al.. 2010). These attacks overlook the fact that the anonymous peer review process is designed to guard precisely against these kinds of motives. The public is largely unfamiliar with the inner workings of the peer review process, so these rhetorical attacks can be

effective in swaying perceptions about the credibility of scientists on the basis of personality judgments and related valuations. Ultimately, statistical rigor, replicable experiments, and data availability facilitate collective mechanisms of validation that lend credibility to climate science results independent of the personal motives and viewpoints of the climate scientists themselves.

Another widespread technique is to cast doubt on scientific findings by disseminating alternative forms of data or alternative interpretations of data that conflict with the intended messages of climate scientists. A paradigmatic case of motivated reasoning is called "endpoint bias," where recent fluctuations in data are used to motivate interpretations of data instead of clear statistically significant trends over time (Jameison & Hardy, 2014; Hardy & Jameison, 2017). This has been documented in a number of sources with respect to a graph released by NASA depicting Arctic sea ice change, where a recent increase in Arctic sea ice has been shown to compel large numbers of conservatives to misinterpret the graph and infer that Arctic sea ice is not depleting and does not, as such, pose a social issue (Jameison & Hardy, 2014; Hardy & Jameison, 2017; Guilbeault et al., 2018b).

This is recognized as a classic case of motivated reasoning, which emerges when people are confronted with arguments that conflict with their existing values and beliefs. Countervailing information is said to cause "cognitive dissonance," the mental discomfort felt at sustaining and attempting to resolve contradictory ideas important to one's belief system (Festinger, 1957). Rather than endure this discomfort, research shows that people prefer to concoct skewed interpretations of facts that support their initial biases (Kunda, 1990; Kahan, 2013). Endpoint bias is one of several known cognitive biases and heuristics that lead to motivated reasoning about climate change. Several manufactured conservative websites have been uncovered containing similar tactics, where these sources reframe climate data to activate motivated reasoning that supports partisan biases (Hmielowski et al., 2013; Pennycook & Rand, 2018a).

The effort to undermine the certainty of climate science is especially concerning because it not only splits people on the basis of scientific literacy and partisanship, but also increases their susceptibility to social influence. Research in the area of collective intelligence shows that people are more influenced by the judgments of others when they are uncertain about their own beliefs on a given topic; this has been shown across a range of domains, including generic estimation tasks, the analysis of financial data, and recently, in the interpretation of climate data (Becker et al., 2017; Guilbeault et al., 2018). As a suggestive implication, Arendt (1951) observed that a recurring technique in totalitarian regimes is to instill uncertainty in media as a way of causing the people to be more susceptible to influence by the state's propaganda. It is in this sense that the effort to undermine the certainty of climate science serves as a catalyst for a suite of related tactics that take advantage of the increased susceptibility of audiences.

EXPLOITING UNCERTAINTY THROUGH FRAMING EFFECTS

Foundational research in behavioral economics indicates that increasing uncertainty systematically alters how people respond to information both in their beliefs and their actions (Tversky & Kahneman, 1981; Sluijs et al., 1998; Mussweiler & Strack, 2000; Kahneman, 2013). Uncertainty here refers to an individual's lack of confidence in their beliefs regarding a particular problem. When messages are framed[2] positively, amidst uncertainty, people have been shown to be more influenced by positive messages (Kuhn, 1997), with evidence from climate-related messages specifically (Morton et al., 2011). The theory is that increasing uncertainty inclines people to resolve cognitive dissonance by seeking arguments and framings that reinforce their existing beliefs, and messages that frame their initial beliefs in a positive light are highly appealing in terms of resolving this cognitive dissonance.

2. Following foundational social theory, framing here refers to rhetorical techniques of message presentation and design that are aimed at altering how people interpret the content of messages, with downstream effects on the choices they make based on the messages they receive (Goffman, 1986). It is beyond the scope of this piece to review the full breadth of framing techniques identified in communications research. In this piece, the act of framing messages "positively" refers to ways of communicating about issues that evoke positive affective responses, relating largely to the moral acceptability of the beliefs and actions argued for. More specifically, this section focuses on approaches to word choice and argument structure that present climate-denial and behaviors, such as oil consumption, as not only morally acceptable but even morally laudable.

Peabody Energy, America's biggest coal company and one of the largest treasuries of the CCCM according to the Center for Media and Democracy, has been exposed for funding two dozen conservative think tanks and litigation groups to cast doubt on climate science and climate-related regulations (Goldenberg & Bengtsson 2016). A key rhetorical maneuver in their campaigning, is to cloud poorly informed critiques of science with the claim that rising carbon emissions are actually beneficial for people and the environment. In 2013, Peabody wrote to the White House Council on Environmental Quality describing carbon dioxide as "a benign gas that is essential for all life," while also denying the dangers of global warming (Goldenberg & Bengtsson, 2016). As a coauthor of *The Guidance for Federal Departments and Agencies Consideration of Greenhouse Gas Emissions and the Effects of Climate Change*, the company maintained: "While the benefits of carbon dioxide are proven, the alleged risks of climate change are contrary to observed data, are based on admitted speculation, and lack adequate scientific basis" (Goldenberg & Bengtsson, 2016). A recent experiment showed how these kinds of framing techniques, along with others, were especially effective at strengthening conservatives' doubt in climate science and the climate change narrative (McCright et al.. 2015).

Another crucial disinformation tactic used by the CCCM is to exploit what I call "cultural co-opting" (similar to linguistic borrowing between different languages) where the terms of a target social group are borrowed and co-opted to undermine their rhetoric and reframe their meaning. This technique is readily seen in the hate speech memes produced in alt-right circles; for instance, the meme "My borders my choice" borrows and corrupts the phrase "My body my choice" from the progressive sexual diversity movement (ADL, 2018). The power of this particular cultural borrowing lies in co-opting the logic of personal freedom from the women's movement and suggesting that anti-immigration politics and border control are also an issue of personal freedom, so that fighting for progressive values implies support for the right-wing agenda; meanwhile, the phrase itself is deployed as an offense against the liberal movement because there are various reasons why anti-immigration politics are an affront to liberal models of personal freedom.

> "The allure of referring to coal as green is that it primes target audiences into viewing coal as compatible with a healthy natural environment.

In media campaigns against climate change from the CCCM, we observe a nearly identical tactic. Fred Palmer from the *Heartland Institute* (2017) made the following claim at the conservative movement's energy conference, in a talk entitled "The Future of Coal:" "Coal is green. It is not dirty, because of electrification. CO2 is a benign gas required for life on Earth and is not dirty … It's not dirty; it's green. It's electricity. Electricity is life. Coal is life." The allure of referring to coal as green is that it primes target audiences into viewing coal as compatible with a healthy natural environment and therefore compatible with the beliefs and priorities widely held in the progressive movement. It does so through what rhetoricians call an *enthymeme*, which is a fallacious argument that guides listeners to false conclusions by loading dubious assumptions into what appears to be a coherent logical structure. In this case, the logical structure is as follows:

1. Coal is green.
2. Coal is green because of electrification.
3. Electricity is life.

∴ Coal is life.

The problem with this logic is that the claims made are unclear and take advantage of the loose associations around the terms green and life. Electricity cannot be synonymous with life in any factual sense, especially insofar as life refers to natural environments and biological ecosystems. However, by evoking these loose associations within the semblance of a syllogism, Palmer creates the rhetorical opportunity to manipulate these associations to construct a transitive identity relation between coal and life. If coal is electricity and electricity is life, it follows that coal is life. Each identity relation in this transitive sequence is figurative, contentious, and incapable of the synonym needed for the transitive relation to hold, while the formal structure of the argument creates the false air of clarity and rigor.

This rhetorical moment is not a one-off. Donald Trump used the phrase "clean coal" at his rallies (Worland, 2017). The concern is that people might be inclined to adopt this reasoning because believing that coal is clean carries the fuzzy positive connotations of being green, which helps to alleviate the cognitive dissonance of supporting industrial developments and policies that are actively destroying the environment. Cultural co-opting from progressive rhetoric is a common disinformation tactic that aims to hijack progressive values so that this progressive language is nullified by appearing to be consistent with the right-wing agenda.

Disinformation is not only an individual-level psychological problem

Traditional perspectives in climate communications focus on how messages influence individuals as a result of their psychology. This approach has aimed to figure out how media can be used to inoculate people against disinformation, with specific applications to climate communications (Hart & Nisbet, 2012; McCright et al., 2015; van der Linden et al., 2017). A number of studies have attempted to educate people about the indicators of disinformation and fake news content to enhance their ability to detect it on their own (e.g., Cooper, 2011; Frenda et al., 2011; Ecker, 2014; Zhang et al., 2018). A recent experiment tested whether flagging images for their validity improved people's ability to distinguish true and fake images, finding no benefit of such nudging tactics (Shen et al., 2018). These results do not bode well for widespread efforts to tag false accounts and false users in online environments.

> "Political biases and scientific illiteracy prevent the public from accurately interpreting climate science results.

Research on motivated reasoning shows that spreading facts for the purposes of inoculation is not enough, because it matters how these facts are interpreted. Political biases and scientific illiteracy prevent the public from accurately interpreting climate science results, and these vulnerabilities are exploited via disinformation campaigns. Indeed, a range of mass-media campaigns designed to combat public misinterpretation of scientific claims have found systematic backfire effects, where messages actually amplify the biases they are intended to minimize; for example, this has been observed in a number of public health campaigns (Cappella et al., 2015; Chou et al., 2018) and in media messages to support climate science (Hart & Nisbet, 2011; Jamieson & Hardy, 2014). Circulating facts is often insufficient because this approach is unable to control the effects that communication in social networks, both online and offline, can have on the interpretation of media content. Peer networks have been shown to provide a medium not only for the spread of media content, but also for the collaborative evaluation of media content (Katz & Lazarsfeld, 1955; Watts & Dodds, 2007; Gough et al., 2017). This has been found to be especially true in the case of climate change (Pearce et al., 2014), where large social networks online are engaged in the regular exchange and discussion of climate-related beliefs (Leombruni, 2015). Recent research has begun to identify a range of ways in which communication among peers can generate "network effects" that activate and reinforce existing biases in the interpretation of media content—a problem that has become a central concern for the climate change debate.

An especially concerning network effect in the context of climate change arises in politically homogeneous social networks (often referred to as "echo chambers"; Jameison & Cappella, 2008), in which partisan bias is reinforced through regular interactions among likeminded peers (Sunstein, 2011; Jasny et al., 2015). Climate disinformation has been shown to systematically target online echo chambers (Carmichael et al., 2017), and researchers argue that echo chambers accelerate the spread of disinformation because people within these networks conform to a common narrative and encounter social incentives against publicly criticizing dominantly accepted beliefs (Del Vicario et al., 2016, 2015).

It is important to note that when people evaluate media content that is not linked to salient partisan biases, communication in echo chambers may not amplify bias (Dubois & Grant, 2018). Echo chambers are a problem in discussions around highly polarized topics such as climate change, as reviewed in the literature on "issue-based" polarization (Mason, 2014). For highly polarized issues, individuals have been shown to actively select

media content as well as discussion partners that (1) reinforce their existing biases and (2) increase the salience of their partisan identity (Knobloch-Westerwick & Kleinman, 2012; Horwitz & Nir, 2014). In extreme cases, politically homogeneous social networks (i.e., echo chambers) can organize and coordinate as an issue public to spread a particular partisan viewpoint on an issue (e.g., the CCCM) (Sunstein, 2011). When the competing arguments surrounding an issue become publicly associated with partisan identities, even minor forms of political signaling can activate bias in the interpretation of messages (Iyengar et al., 2012; Iyengar & Westwood, 2014; Bail et al., 2018; Guilbeault et al., 2018a). As a result, communication in echo chambers can reinforce and entrench biased interpretations of an issue through the lens of party membership, causing the members of echo chambers to become vulnerable to the spread of disinformation that appeals to their biases (Tucker et al., 2018).

Another way in which online networks can amplify the effects of disinformation is through the use of fake automated accounts (bots) to advance climate denial narratives (Gorwa & Guilbeault, 2018). Recent studies show that bots have been increasingly used to inject disinformation into online discussions of pertinent scientific topics, ranging from vaccines to climate science (Broniatowski et al., 2018; Jameison, 2018). The concern is that bots can "manufacture" alternative consensus against climate science by representing a fake grassroots movement (Guilbeault & Woolley, 2016; Woolley & Guilbeault, 2017), and a potential critical mass (Centola et al., 2018) that can influence people to adopt climate denial beliefs on the assumption that these beliefs constitute a credible social norm.

In the domain of bots, media literacy has been shown to similarly fail. One experiment showed that, even after a media literacy intervention, people were no better than chance at distinguishing human from bot accounts on Twitter (Edwards et al., 2014). Some researchers have argued that media literacy efforts fail online because human psychology operates differently in online environments, where our intuitions for how to assess credibility and trustworthiness are maladaptive and vulnerable to manipulation. For instance, online, the trustworthiness of a source has to be assessed on the basis of minimal cues (Walther, 1996). Offline, humans

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rely on body language and speech to determine authenticity and trust (Metzger & Flanagin, 2013). But online, users rely on profile pictures, emoticons, and other automated tools that create a much lower bar for bots.

Meanwhile, some researchers argue that media literacy in general is orthogonal to the problem of disinformation online. A recent randomized-controlled experiment tested whether Democrats and Republicans were more likely to believe fake news content if it aligned with their partisanship (Pennycook & Rand, 2018a). When examining only those subjects who showed evidence of actually examining the news content, they found that members of both parties were equally and surprisingly effective at distinguishing fake from true news. However, they found that when examining subjects who paid minimal attention to the stimuli, these subjects were highly susceptible to fake news that aligned with their partisanship. Psychological experiments have found that under low attention settings, minimal partisan cues (e.g., the identity of the source or party logos) can activate substantial partisan bias in the consumption of novel information and news content (e.g., Jameison & Hardy, 2014; Iyengar et al., 2014).

The problem of disinformation lies not in whether people are capable of identifying disinformation but in how much attention people allocate to the task of verifying information. This is especially problematic in online environments, which foster a culture of communication based on the rapid consumption and sharing of novel information by showing people news in limited headlines within message threads and by providing 'one-click' buttons that allow users to automatically spread news content. These interface features designed to expedite information diffusion in social networks are partly why false information has been found to spread further and faster in online environments (Vosoughi et al., 2018). A click-bait culture has arisen where news sources

and digital advertisers compete for users' attention by designing attention-grabbing headlines, and where users are incentivized to share the most eye-grabbing news links as rapidly as possible while they are relevant, which inclines them to only read headlines prior to sharing (Marwick, 2017).

Under such conditions, signals of social capital, such as the number of views, likes, or shares associated with an article, serve as deceptive indicators of the value of that information. In this sense, the vulnerabilities of human psychology online play into the arguably more important driver of disinformation, which is not lack of media literacy but rather the role of social media platforms and online social networks in accelerating the spread of disinformation. A number of researchers have turned toward the detection of biases linked to how social networks produce and spread climate-related disinformation and have identified a number of conditions for when collective intelligence breaks down, as well as when it can be harnessed to potentially resist the spread of disinformation.

Disinformation is a collective-level network problem

The spread of disinformation online has been described as a failure of collective intelligence. Ferguson (2017) explains how Google, Facebook, and Twitter were founded on the "False Prophecy" that, by allowing more people to share information in ever-growing social networks, a "collective intelligence effect" would emerge in the marketplace of ideas that would filter out truthful content from false content. In the words of Twitter co-founder Evan Williams, "I thought once everyone could speak freely and exchange information and ideas, the world is automatically going to be a better place" (Streitfeld, 2017). The same logic motivated Google's page-rank algorithm, which assumed that the most visited websites by the population were likely to represent the most valuable sources of information and so should be ranked the highest.

What is worse, the algorithms over at Google, Facebook, and Twitter have been shown to foster echo chambers by tailoring recommendations of content and friends to appeal to the ideological biases of users (Benkler et al., 2018; Noble, 2018), creating what has been called a "filter bubble" (Pariser, 2011). Such tailored algorithmic recommendations are more likely to be successful, which is desirable for a company in terms of advertising revenue and the value of the recommendation algorithm as a product. The selective-exposure effects of such filter bubbles have been identified as a driver of disinformation diffusion across a range of scientific topics, including climate change (Koteyko et al., 2015). The capacity for algorithms to spread disinformation and radicalization has thus become a core concern in science communication (National Academies of Sciences, Engineering, and Medicine, 2017). In one especially appalling case, a fake news story produced by trolls on 4chan was shared by Google News and subsequently linked via Facebook's crises responses page (Machovech, 2017). Indeed, in a number of cases, Google's recommendation algorithms have been shown to accidentally encourage radicalization among political groups by providing ideological links to biased user networks; when an ideological link is followed, a user will be recommended links that other more radical people have followed before and will be led down a rabbit hole to politically extreme websites filled with false content (Benkler et al., 2018; Tucker et al., 2018).

Another crucial reason why echo chambers are susceptible to disinformation is revealed by network studies on social diffusion (the spread of ideas, emotions, and behaviors in social networks). In studies of diffusion, there is a central distinction between "simple" and "complex" contagions (Guilbeault et al., 2018a). Simple contagions require only exposure to one other person for someone to adopt and spread the contagion throughout the network (e.g., information about who won the election), whereas complex contagions require exposure to multiple people for someone to adopt (e.g., an exercise routine). Centola (2018) explains how different types of network structures are better at spreading complex contagions as opposed to simple contagions, with major implications for the spread of disinformation online.

In studies of diffusion, it has been found that neutral fact-based information spreads as a simple contagion because it only takes one exposure to adopt the fact (e.g., the answer to who won the Super Bowl). Politicized information over Twitter and Facebook, however, has been found to spread as a complex contagion because the costs of sharing are higher (i.e., it may incite debate, so seeing evidence that several peers in your network agree will provide the support needed to share) (Guilbeault et al., 2017). This finding sheds light on why political information is more likely to spread through clustered networks in echo chambers. In echo chambers, there is a greater likelihood of encountering multiple peers who will support and reciprocally share the political content, which meets the multiple peer exposure criteria for disinformation. Even more concerning is the idea that political information is beginning to spread more like a simple contagion. As Centola (2018) explains, by designing a world that encourages the rapid sharing of information through automated buttons, media environments have encouraged the spread of "simple" as opposed to "complex" contagions. Simple contagions are more shallow and ideologically infused, making echo chambers an especially volatile incubator for false content. This argument is highly consistent with recent findings indicating that people are much more susceptible to disinformation if they invest minimal time in investigating media content and instead rely on the titles and abstracts of articles to determine their willingness to share the content (Pennycook & Rand, 2018a)

Altogether, research on the spread of information in social networks has major implications for the design of interventions to resist the spread of climate-related disinformation (and disinformation more broadly). These implications are discussed in the next section.

Intervention design: insights from collective intelligence research

Consensus among scientists, and growing consensus among the public, about the reality of climate change has been identified as one of the most reliable antidotes to disinformation on the topic (van der Linden et al., 2017). How consensus forms, and its social impact, has been studied thoroughly from a collective intelligence perspective. A large body of literature in the study of collective intelligence is based on the DeGroot model of consensus formation, in which the exchange of beliefs in social networks has been found to increase both individual and collective accuracy (Becker et al., 2017). Ever since it became clear that the public's interpretation of climate change was influenced by information exchange in online social networks, there has been speculation about how online spaces can be structured to enhance collective intelligence as a defense against climate-related disinformation (Malone & Klein, 2007). Recent work has begun to explore the use of formal models (e.g., DeGroot's) and online experiments to test how online social networks can be structured to activate social learning that improves people's capacity to accurately interpret climate-related information (Guilbeault et al., 2018a).

> "... media environments have encouraged the spread of 'simple' as opposed to 'complex' contagions.

As a potential countermeasure to online echo chambers, social media companies have begun to consider ways of redesigning platforms and their recommendation algorithms to increase exposure to content from other political viewpoints, as well as bipartisan interaction (Bail et al., 2018). As an initiative to combat fake news, Facebook is experimenting with updates to its recommendation algorithm, where each article is associated with recommended links to content from different political viewpoints; Google has reportedly experimented with intentionally neutralizing the political bias of its search engine; and Twitter recently reported that it is experimenting with features that promote alternative viewpoints to address disinformation and reduce echo chambers (Romm & Dwoskin, 2018). Longstanding research suggests that these interventions may further exacerbate the problem. For example, a recent study found that exposing people on Twitter to media content from members of their political outgroup actually increased partisan bias and polarization among Republicans (Bail et al., 2018). However, the presumed

failure of bipartisan communication differs with the findings of a large body of literature on collective intelligence, which show that exchanging diverse ideas in social networks can activate social learning that increases consensus and reduces bias (see Guilbeault et al., 2018b for review). Indeed, a number of bipartisan discussion groups have been found to increase political literacy and bipartisan consensus (e.g., Fishkin, 2009).

A recent paper provides causal insight into what drives partisan bias in the context of scientific information concerning climate change. Guilbeault et al. (2018a) explain how prior experiments on bipartisan communication had yet to separate the causal effects of two potential drivers of polarization: (1) exposure to opposing information, and (2) partisan priming and framing associated with information, such as group membership signaling and cultural symbols. In both face-to-face discussion groups or complex media environments like Twitter, people in bipartisan interaction are not only exposed to opposing views but also to various symbols of group opposition and party identification that have been shown to activate strong partisan bias. Indeed, prior experiments showed that partisan biases could be activated through the use of even minimal political cues, such as party logos (Iyengar & Westwood, 2014).

Using an experimental online social media platform, Guilbeault et al., (2018a) show that exchanging information in bipartisan networks without any partisan cues in the environment can eliminate political bias in the interpretation of climate information. The authors further show that introducing party logos or indicators of partisan group membership into the same conditions can disrupt social learning and maintain belief polarization.

Regarding the two disinformation tactics used against climate science, this study suggests that collective intelligence can both (1) increase the accuracy and consensus of people's judgments about climate change as discussed over social media, and (2) reduce motivated reasoning and the dynamics of cognitive dissonance that lead to biased interpretations of countervailing media content. Social media platforms could enhance the role of collective intelligence in filtering disinformation by minimizing the salience of political imagery and group membership signaling on their platforms. Furthermore, separate web forums or tools where people can discuss news content in anonymous social networks may allow social media websites to tap into the wisdom of the crowds within their user populations and thus enable them to better detect disinformation. There have been recent efforts to use crowdsourcing methods to detect fake news, where an anonymous panel of paid internet workers are asked individually to rate the validity of news content (Pennycook & Rand, 2018b). While a useful start, these approaches have yet to tap into the power of social networks for enhancing collective intelligence, where social networks have been shown to significantly increase accuracy across a range of estimation tasks. In this way, collective intelligence interventions provide a promising set of methods for combating the spread of misinformation online.

Collective intelligence approaches have the added advantage of allowing users to define bots and disinformation for themselves. These tools can be viewed as ways of simply strengthening the detection capabilities and general media literacy of users; and they have the complementary benefit of adapting to changes in the public's categorization of disinformation as various new forms of disinformation arise (whereas definitions encoded into legal policies, either via government or social media companies, will be updated more slowly).

conclusion

Using computational social science to combat disinformation online

As the scientific community advances its ability to model and predict the dynamics of complex systems, from the biological to the social, political actors are going to increasingly seek to undermine scientific credibility with disinformation if the results challenge existing political agendas. A source of hope is that scientific methods can continue to advance not only in the study of climate change itself, but also in the study of how disinformation regarding climate science can be mitigated. Research in collective intelligence shows how exchanging information in structured peer networks can activate social learning that systematically reduces political bias in the interpretation of climate data (Guilbeault et al.,. 2018a). This study further shows how social learning effects can be nullified if partisan framing is introduced into the communication environment. This finding points to a critical issue: social media platforms are highly politicized environments that are marred by political advertisements and partisan identity signaling on user profiles and discussion boards. The implications are twofold.

First, collective intelligence research suggests that there may be myriad ways in which social media platforms can be designed to harness communication to improve scientific literacy about climate change (Malone & Klein, 2007). One key step that social media platforms can take to facilitate social learning is to minimize the priming effects of political framing associated with the communication environment. A social media platform that has successfully undertaken such efforts is Wikipedia; Wikipedia prevents editors on the platform from explicitly representing their partisan leanings in their user profile. As a result, editors on the platform can communicate effectively across party lines, where bipartisan teams of editors (blinded to each other's political identity) have been shown to produce articles of significantly higher quality, controlling for a range of variables (Shi et al., 2017).

Second, recent studies in collective intelligence point to an alternative to existing methods of flagging suspicious and potentially false content. Instead of tagging content with warning labels decided by the content moderation teams of social media companies, platforms can embed interface features that allow users to share their own intelligence to enhance their scientific literacy. That is, platforms can inform users about how other people in their social networks have interpreted media content in a dynamic fashion that reflects changes in the networks' interpretations over time. A recent study shows that asking users to rate the credibility of media sources and aggregating across these judgments make it possible to reproduce classifications of trustworthy news sources that are highly consistent with those of media experts (Pennycook & Rand, 2018b). Thus, it may be possible to harness the endogenous collective intelligence stored in the social networks of platform users to strengthen their own ability to distinguish true from false content. This approach is especially appealing in that it no longer leaves social media companies solely responsible for solving the extremely difficult problem of classifying true and fake media content—an outcome that is likely to be appealing to both companies and users.

> "Wikipedia prevents editors on the platform from explicitly representing their partisan leanings in their user profile.

This is not to say that collective intelligence interventions are likely to be the only interventions to succeed in quelling the spread of disinformation concerning science. The finding that framing effects and other propaganda tactics can interfere with social learning points to the need to more broadly classify and examine the politicized features of online social media environments that can indirectly encourage the spread of disinformation. One promising direction of research concerns the use of large-scale user data on social media to identify the linguistic signatures of

cognitive vulnerabilities relating to motivating reasoning and susceptibility to disinformation (Matz et al., 2017; Eichstaedt et al., 2018). Nevertheless, as new avenues of intervention are considered, recent collective intelligence research provides an important example of how to employ methods in computational social science to develop scientifically robust interventions against disinformation. A number of studies in collective intelligence proceed by not only formally modeling causal hypothesis but also testing these causal hypotheses in randomized-controlled online experiments, providing high confidence in their efficacy and mechanisms. Without such rigor, interventions against disinformation are at risk of failing and at worst backfiring.

As a final note, there is a more general political obstacle concerning the use of computational social science to develop interventions against disinformation online that should be considered. Companies like Facebook and Google are driven by economic incentives that undergird a digital advertising ecosystem that can amplify the spread of disinformation and even profit off it (Kreiss & McGregor, 2018; Google Transparency Project, 2018). This creates potentially conflicting incentives when designing and implementing interventions against disinformation. If, for instance, the spread of partisan imagery and political advertisements increases user engagement by flaring up discussion and fostering sustained public debate, removing partisan symbols from the communication environment may conflict with platforms' financial incentives to evermore boost user activity (Eckles et al., 2016). The ideal scenario is one in which computational social scientists are enabled to study disinformation over social media by pursuing questions of basic science without influence from corporate interests. In this direction, novel programs such as the Social One initiative, which aims to integrate academic peer review into a collaborative framework with Facebook, provide promising next steps.

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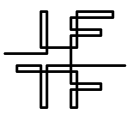

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