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Understanding and countering climate science denial

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Abstract

Science denial causes a range of damaging impacts on society. This is particularly the case with climate science denial, which has resulted in strong polarization around a non-controversial scientific issue, and prolific dissemination of climate misinformation. This in turn has had the effect of reducing public acceptance of climate change, and eroding support for policies to mitigate climate change. In order to develop effective responses to science denial, it is necessary to first understand the drivers of science denial, which leads to deeper understanding of the techniques employed to cast doubt on the reality of climate change. Analysis of denialist techniques can inform development of interventions that neutralize misinformation. Inoculation has been shown to be an effective way to preemptively reduce the influence of climate science denial. Two methods to practically implement inoculation are misconception-based learning (teaching science by addressing scientific misconceptions) and technocognition (an interdisciplinary approach that implements psychological principles in the design of technological solutions to misinformation). Interventions and procedures developed for the countering of climate misinformation may also be applied to other scientific topics rife with misinformation, such as vaccination and evolution.

Introduction

There is an overwhelming scientific consensus that humans are causing global warming. Between 90 to 100% of climate scientists have concluded that humans are causing global warming, with a number of studies converging on 97% consensus (Cook et al., 2016). Despite the strengthening consensus, a small proportion of the U.S. public continue to reject the findings of mainstream climate science (Leiserowitz et al., 2017). This small but vocal minority has persistently and prolifically produced misinformation about climate change, with the purpose of confusing the public about the reality of human-caused climate change.

Misinformation is commonly defined as information that is initially presented as true but later shown to be false (Lewandowsky et al. 2012). There is growing awareness of the damaging and significant impacts of misinformation. In 2014, the World Economic Forum named online misinformation as one of the top ten trends of global concern (WEF, 2014). In recognition of the salience of misinformation, Oxford Dictionary named "post-truth" the 2016 word of the year (Flood, 2016). One year later, Collins Dictionary named "fake news" the 2017 word of the year (Flood, 2017).

Climate misinformation has contributed to public misperceptions about climate change (McCright and Dunlap, 2010). For example, there is a significant gap between scientific understanding of climate change, and public perceptions, with only 12% of the American public aware that the scientific consensus on climate change is greater than 90% (Leiserowitz et al. 2017). Students hold a number of misconceptions about

the greenhouse effect and its role in causing global warming (Chang and Pascua, 2015). These misconceptions are dangerous because they reduce concern about climate change and support for mitigation policies (van der Linden, 2017; Ranney and Clark, 2017).

Understanding science denial

Science denial is the unwillingness to accept existing scientific evidence. In the case of climate science denial, this may apply to evidence supporting the existence of climate change, humanity's role in causing recent global warming, and/or the severity of climate impacts. A number of terms have been used to characterize climate science denial, such as scepticism, contrarianism, dismissal, dissent, doubt, or anti-climate change. Most common is the term *sceptic* (e.g., Capstick and Pidgeon, 2013; Rahmstorf, 2004). However, using the term sceptic to describe the rejection of scientific evidence is problematic and misleading (Lewandowsky et al., 2016; Odenbaugh, 2016). Genuine scientific scepticism requires an evidence-based approach, eschewing pseudo-scientific principles. This is the polar opposite to science denial, which involves denial of inconvenient evidence and eager adoption of pseudo-scientific arguments if they support preconceptions. Consequently, this paper refers to the rejection of mainstream climate science as *climate science denial*. We begin our examination by first exploring what motivates some people to reject climate science.

Psychological drivers of science denial

A survey-of-surveys found that the strongest drivers of climate beliefs are political affiliation and political ideology (Hornsey et al. 2016). Politics is a greater influence on climate perceptions than education, income level, gender, race, and even science literacy levels. Why would political beliefs influence a person's views on a scientific matter such as climate change? The answer is aversion to proposed policies to mitigate human-caused global warming. When political conservatives are presented with information about climate change as well as one of two proposed solutions to climate change (either regulation of pollution or nuclear energy), they respond positively to the nuclear version but negatively to the regulation version (Campbell and Kay, 2014). Disliking the solution to climate change, political conservatives are predisposed to deny that there's a problem that needs solving.

While individual cognition plays a strong role in people's climate attitudes, social and external cues are also important. One of the strongest external influences are cues from political elites (Brulle et al., 2012). Public concern about climate change dropped dramatically around 2009. Analysis of public surveys conducted over this time found that the change in climate attitudes was due primarily to elite cues (Mildenberger and Leiserowitz, 2017). Over this same time period, there was a sharp up-tick in the production of misinformation targeting climate science (Boussalis and Coan, 2016; see Figure 2). Putting these disparate studies together, we see that misinformation disseminated by conservative leaders played a strong part in reducing public concern about climate change.

Figure 1, derived from Cook and Lewandowsky (2016), provides a concise visual summary of some of the contributing factors to misconceptions about climate change. The graph shows survey results of perceived consensus, with the horizontal axis representing political ideology, depicting clearly the gap between public perceptions of consensus and

the actual 97% agreement among climate scientists that humans are causing global warming.

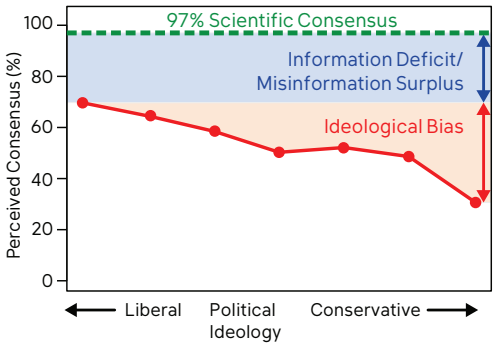

Figure 1: The consensus gap (Cook and Lewandowsky, 2016).

While political ideology has a strong influence on climate perceptions, there is still a large "consensus gap" among political liberals who possess no ideological reason to reject climate science. This "liberal consensus gap" is driven by either lack of awareness of the consensus, or misinformation that casts doubt on the consensus. Climate misperceptions are the result of both cultural biases and informational deficiencies.

The origin of climate science denial

Climate change hasn't always been a polarized, partisan issue. In 1989, Republican President George H. W. Bush promised to "fight the greenhouse effect with the White House effect" (Peterson, 1989, p. A1). However, the issue gradually became polarized due to misinformation campaigns in the early 1990s conducted by conservative think-tanks with the purpose of undermining the Kyoto Protocol (McCright and Dunlap, 2000). These campaigns were enabled and amplified by billions of dollars of funding from the fossil fuel industry (Brulle, 2014; Farrell, 2016a; Farrell, 2016b). Initially, conservative think-tanks disseminated their misinformation through the publication of a number of books sceptical about environmental science and policy (Jacques et al., 2008).

To disseminate their messages, think-tanks relied on a small number of contrarian scientists. Only a small minority of climate scientists reject human-caused global warming (Anderegg et al., 2010; Doran and Zimmerman, 2009), and climate misinformation has a vanishingly small presence in the scientific literature (Cook et al., 2013; Oreskes, 2004). The few number of papers that do manage to get published in peer-reviewed journals have been shown to possess fatal flaws in their analysis (Abraham et al., 2014; Benestad et al., 2016). However, conservative think-tanks have exploited the journalistic norm of media balance to ensure that contrarian voices receive roughly equivalent media coverage to mainstream climate scientists (Painter and Ashe, 2012). The prevalence of false balance coverage in mainstream media has had broad impact, with analysis indicating semantic similarities between misinformation, media coverage, and U.S. Presidential statements (Farrell, 2016b). The spilling of misinformation into public statements by political leaders is especially significant given that cues from political elites has been found to be a crucially important influence on public concern over climate change.

Rejection of climate science continues unabated. An analysis of conservative think-tank articles about climate change found that misinformation casting doubt on climate science has been on the increase relative to arguments against climate policy, as depicted in Figure 2 (Boussalis and Coan, 2016). In 2016, the most shared climate story on social media featured the Global Warming

Petition Project: an online petition listing tens of thousands of dissenting people with a science degree as evidence that there was no scientific consensus on climate change (Readfearn, 2016).

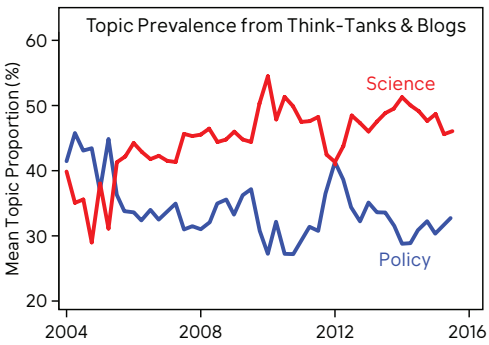

Figure 2: Relative increase of climate science denial relative to climate policy denial (Boussalis & Coan, 2016, with updated data incorporating blog posts).

Impacts of misinformation

Climate misinformation causes a number of negative impacts. First, it can lower public perceptions of climate change. Ranney and Clark (2016) found that exposing people to just a few misleading statistics lowered acceptance of climate change as well as confidence in their understanding of the science. Similarly, showing a single piece of misinformation about the scientific consensus on climate change significantly decreases perceived consensus (Cook et al., 2017; van der Linden et al., 2017). These manufactured misconceptions have consequential flow-on effects. Understanding of the greenhouse mechanism and perceived consensus both have a strong influence on acceptance of the reality of human-caused global warming, and support for mitigation policies (Ranney and Clark, 2016; van der Linden, 2015).

Second, misinformation can cancel out the positive effect of accurate information. McCright et al. (2017) found that denialist frames reduced the positive effect of a number of different climate frames. Van der Linden et al. (2017) found that when participants were presented with information about the scientific consensus alongside misinformation casting doubt on the consensus, the overall effect was no significant change in perceived consensus. Cook et al. (2017) found that false balance media coverage of climate change, where factual information was presented along with misinformation, resulted in a decreased in perceived consensus.

Third, misinformation has a polarizing effect, disproportionately influencing political conservatives (Cook et al., 2017; van der Linden et al., 2017). Consequently, communities that receive misinformation show a divergence in climate attitudes along political lines.

Lastly, another mostly overlooked but dangerous effect of climate denial is the misconception of pluralistic ignorance—the lack of awareness among people concerned about climate change that most people share their concern. National surveys of the U.S. public find that most of the public are alarmed or concerned about climate change (Leiserowitz et al., 2017), but also that they think they are in the minority. This causes people to self-censor and refrain from discussing climate change with their friends (Geiger and Swim, 2016). This silence in turn reinforces the misconception of pluralistic ignorance, resulting in a "spiral of silence" (Maibach et al., 2016). Pluralistic ignorance and the subsequent climate silence is another insidious impact of a small but vocal dissenting minority.

The techniques of science denial

Content analysis of conservative think-tank articles about climate change has identified three major topics in denialist text: science, policy, and scientific integrity (Boussalis and Coan, 2016). Within the science topic, Rahmstorf (2004) lists three categories of misinformation: trend (global warming isn't happening), attribution (humans aren't causing it), and impact (climate impacts are not bad). Poortinga et al. (2011) found that denial of one aspect of climate science (e.g., trend) was associated with denial of other aspects of climate science (e.g., impact).

However, there is little coherence across these positions—a denialist blog can be seen arguing that global warming isn't happening one day, then claiming that global warming is caused by the sun the next day (Lewandowsky et al., 2016). The one consistent theme among denialist claims is the conclusion of each argument—opposition to climate mitigation policies. Climate science denial is not a coherent, evidence-based worldview—rather, it is a collection of rhetorical arguments pursuing political objectives.

Among the various movements that reject a scientific consensus, whether it be on climate change, evolutionary biology, or the health impacts of smoking, five characteristics or techniques of science denial are observed (Diethelm and McKee, 2009; Hoofnagle, 2007).

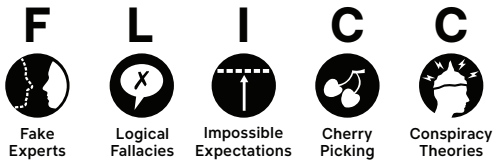

Figure 3: FLICC—the five characteristics of science denial (Cook et al., 2015; Hoofnagle, 2007).

Fake experts: This involves spokespeople who convey the impression of expertise on a topic and yet possess little relevant expertise. The Global Warming Petition Project is the most prevalent form of this technique within climate misinformation, featuring 31,000 signatories of an online petition dissenting against human-caused global warming. However, 99.9% of the signatories, while holding a science degree, possess no expertise in climate science. This petition has been found experimentally to be one of the most effective denialist arguments in lowering acceptance of climate change (van der Linden et al., 2017).

Logical fallacies: Arguments designed to persuade people consist of one or more premises, leading to a conclusion. Climate denialist arguments typically contain fatal logical flaws (Cook et al., in review). There are three classes of logical fallacies found in climate misinformation: fallacies of relevance (where the premises are irrelevant to the conclusion), scope (where not all relevant evidence is considered), and presumption (where the argument contains false premises).

Impossible expectations: This involves demanding unrealistic levels of proof, or misrepresenting the nature of scientific uncertainty. As science is typically probabilistic, calls for absolute scientific certainty are an effective method of casting doubt on scientific findings. This denialist technique is known as "Scientific Certainty Argumentation Methods" (SCAMS, Freudenberg et al., 2008).

Cherry picking: This technique is defined as "selectively chooses data leading to a desired conclusion that differs from the conclusion arising from all the available data" (Cook et al, in review). A common example of cherry

picking is arguing that global warming isn't happening because of cold weather in a particular location at the same time that the planet as a whole is experiencing record high temperatures.

Conspiracy theories: Around 20% of the U.S. public believe that climate change is a scientific hoax (Lewandowsky et al., 2013). Conspiracy theories have a number of negative effects, even when people are not convinced by them. They can lower support for climate action (van der Linden, 2015), decrease one's intent to reduce one's carbon footprint (Jolley and Douglas, 2014), and decrease trust in government (Einstein and Glick, 2014).

It is important to recognise that denialist techniques may manifest from both genuine belief and intentional deception, and that it is virtually impossible to distinguish between the two. This is because ideologically-driven denial causes psychological biases that manifest in the same type of denialist behaviour as intentional deception. For example, people ascribe greater expertise to spokespeople whom they agree with, resulting in the vulnerability of relying on fake experts (Kahan, 2011). Correia (2011) argues that motivational biases can cause people to use a number of logical fallacies in false arguments, which also explains why these types of arguments tend to be so persuasive. Impossible expectations can arise from disconfirmation bias—where threatening evidence is vigorously opposed. The flip side of disconfirmation bias is confirmation bias—where people place greater weight on evidence that supports their prior beliefs—resulting in cherry picking. Lastly, climate science denial has been associated with conspiratorial thinking (Lewandowsky et al., 2013).

Responding to science denial

As the use of denialist techniques may arise from genuine belief, accusing people who adopt these techniques of intentional deception is problematic (and often incorrect). A more robust response is to focus on the techniques employed, rather than the often-unknowable intentions of the misinformer. Diethelm and McKee (2009) argue that identifying and exposing denialist tactics are necessary in order to counter science denial. Critical thinking analysis of climate myths is useful in developing refutations (Cook et al., in review).

Debunking

Once misinformation has taken hold, it is extremely difficult to dislodge (for a review of research into debunking misinformation, see Lewandowsky et al. 2012; Swire and Ecker, in press). If a refutation threatens a person's worldview, it can even cause a counterproductive backfire effect (Hart and Nisbet, 2012). Informing people that a piece of information is false creates a gap in their mental model of the world. If the gap is not filled by a replacement fact, the myth will continue to influence people (Seifert, 2002). Consequently, refutations are most effective when they include a factual replacement that meets the causal explanations supplied by the original misinformation (Ecker et al., 2015). Another element of an effective debunking is a warning preceding the myth, which makes people cognitively alert and less likely to be influenced by the misinformation (Ecker et al., 2010).

Inoculation

Research indicates that wherever possible when countering misinformation, prevention is better than cure (Bolsen and Druckman, 2015). Inoculation theory offers one framework for pre-emptive strategies to neutralize misinformation. This approach applies the concept of vaccination to knowledge (McGuire and Papageorgis, 1961). Just as exposure to a weak form of a virus helps people build resistance to the actual virus, similarly when people are exposed to a weak form of misinformation, they become less vulnerable to being influenced by actual misinformation. An inoculating text requires two elements: a warning of the threat of being misinformed, and counterarguments explaining how the misinformation is false.

The efficacy of inoculation against misinformation has been found in several studies involving climate misinformation. One experiment found that after specific flaws in the Global Warming Petition Project were explained to participants, the misinformation was mostly neutralized (van der Linden et al., 2017). In another experiment, when participants received an explanation of how false balance media coverage can mislead people, the typical negative impact of false balance media coverage was removed (Cook et al., 2017). This study also found that explaining a general technique of misinformation was effective in neutralizing the misinformation without actually mentioning the specific myth. Figure 4 shows how climate misinformation has a disproportionate effect among political conservatives (orange line) but is completely neutralized across the political spectrum after receiving an inoculation treatment (blue line).

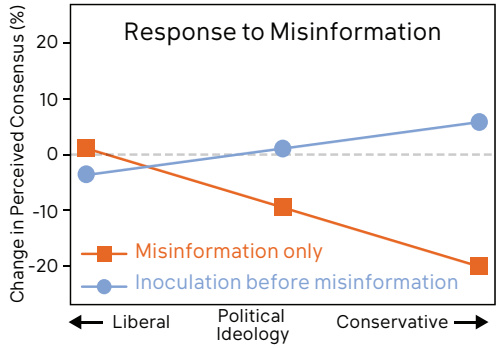

Figure 4: Inoculation (Cook et al. 2017).

This approach of general inoculation without mentioning a specific myth is consistent with the idea of an "umbrella of protection", with inoculation found to convey resistance to other arguments besides the one mentioned in the inoculation (Parker et al., 2012; Pfau et al., 1997). It also echoes a millennia-old approach advocated by Aristotle, who argued that understanding the logical fallacies of false arguments provides a universal safeguard against misinformation (Compton, 2005). This is particularly relevant with climate science denialist arguments, which employ recurrent fallacious errors (Cook et al., in review).

Another benefit of inoculation is that people exposed to an inoculation are more likely to talk about the issue (Ivanov et al., 2015). This is particularly relevant given the prevalent "climate silence", with even people who are alarmed or concerned about climate change mostly not talking about climate change with family and friends (Maibach et al., 2016). One of the drivers of this climate silence is fear of looking incompetent (Geiger and Swim, 2016). Consequently, it is possible that inoculating people against counter-arguments from denialists mitigate this fear.

Misconception-based learning

Misconception-based learning offers a powerful and practical way to apply inoculation in an educational setting. This involves teaching scientific concepts by examining misconceptions and how they distort the science, or by critiquing misinformation and the techniques employed to mislead. Misconception-based learning has been found to be one of the most powerful ways of teaching science, with a number of benefits in comparison to standard science teaching that fails to address misconceptions. It leads to greater and longer lasting learning gains (McCuin et al., 2014), improved argumentative and critical thinking skills (Kuhn and Crowell, 2011; Berland and Reiser, 2008; Todd and O'Brien, 2016), and is more engaging to students (Mason et al., 2008).

Consequently, teachers are recommended to benefit from courses that target climate misconceptions (Frankie, 2014). Educators have already employed this teaching approach in classrooms (Bedford, 2010; Cook et al., 2014; Lambert and Bleicher, 2017; Lovitt and Shuyler, 2016). There have also been attempts to develop educational resources for educators, in the form of a textbook (Bedford and Cook, 2016) and a Massive Open Online Course (Cook et al. 2015). Nevertheless, there remains a dearth of educational resources that adopt a misconception-based learning approach (Tippett, 2010), and further development of resources using this approach is required.

Technocognition

While psychological research offers best practices for designing refutation content in response to misinformation, there is also a need to develop ways to deploy such content in a timely and scaleable fashion. Given that social media and the Internet have contributed to the dissemination and amplification of misinformation, it is fitting (and indeed necessary) that technology should be employed to neutralize misinformation's influence. However, technological solutions can be ineffective or counterproductive. Zollo et al. (2017) found that Facebook fact-checks caused conspiratorial users to increase their engagement with conspiratorial posts. General warnings about fake-news run the danger of breeding cynicism about news articles in general (Pennycook and Rand, 2017; van Duyn and Collier, 2017).

In order for technological solutions to be most effective, they should incorporate the findings of psychological research, an approach known as "technocognition" (Lewandowsky et al., 2017). This is an interdisciplinary approach that combines research findings from psychology, critical thinking approaches from philosophy, and behavioural economics principles, in the design of information architectures deployed via scaleable, technological solutions.

For example, automatic detection and instant assessment of the veracity of articles is considered the "holy grail" of fact-checking (Hassan et al., 2015). There are a number of ways that researchers are exploring the detection of misinformation, with the approaches grouped into linguistic or networking approaches (Conroy et al., 2015). Linguistic approaches include analysing language structure, discourse analysis, and using machine learning to sort text into categories. Network approaches include social network analysis and construction of knowledge networks in order to assess how new claims integrate within existing knowledge structures.

While automatic detection of misinformation is a steep challenge, the characteristics of climate science denial mean that real-time debunking is a practical reality. The denialist arguments deployed today are the same arguments deployed in the early 1990s (McCright and Dunlap, 2000). The static nature of climate misinformation means that the last few decades offer a vast corpus of data containing consistent textual patterns, potentially allowing the detection of specific denialist claims. Automated analysis of climate misinformation is already being conducted, with Boussalis and Coan (2016) analysing conservative think-tank articles using a supervised machine-learning technique. This enabled them to detect overarching topic categories such as science, policy, and scientific integrity. This research needs to be extended to be able to detect specific denialist claims about climate change, which could then be mapped to refutations in real-world, automated applications.

Conclusion

Fake news and post-truthism has become a highly salient issue in recent times, with misinformation playing prominent roles in the Brexit and U.S. Presidential elections. While the mainstreaming of post-truthism is a recent phenomenon, climate misinformation has existed for decades and there is a corresponding large body of research studying its nature and how to counter it.

This research tells us that the damaging influence of misinformation cannot be ignored. Fortunately, there is a large and growing body of psychological research into understanding and responding to climate misinformation. These lessons need to be implemented in technological solutions that seek to neutralize the influence of misinformation in broad, scalable applications.

The lessons learnt from the study of climate misinformation can also be applied to other disciplines. Misinformation abounds in other scientific topics such as vaccination, health, and evolution. Consequently, the procedures and applications being developed to counter climate misinformation may also be adapted and applied to science denial in general.

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