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Climate change denial and beliefs about science

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Abstract
Social scientists have offered a number of explanations for why Americans commonly deny that human-caused climate change is real. In this paper, I argue that these explanations neglect an important group of climate change deniers: those who say they are on the side of science while also rejecting what they know most climate scientists accept. I then develop a "nature of science" hypothesis that does account for this group of deniers. According to this hypothesis, people have serious misconceptions about what scientific inquiry ought to look like. Their misconceptions interact with partisan biases to produce denial of human-caused climate change. After I develop this hypothesis, I propose ways of confirming that it is true. Then I consider its implications for efforts to combat climate change denial and for other cases of public rejection of science.

Keywords Climate change · Motivated reasoning · Cognitive bias · Explanation · Social psychology · Public understanding of science

1 Introduction

Nearly all climate scientists believe in human-caused climate change, but nearly half of Americans do not, or so they tell pollsters. Psychologists and cognitive scientists have proposed many explanations for this gap between scientists and non-scientists. One group of explanations for this gap focuses on *knowledge*: people reject human-caused climate change because they lack knowledge, either of the scientific consensus or of crucial scientific facts. A second group of explanations focuses on *cognition*: people reject human-caused climate change because they are reasoning poorly. A third group of explanations focuses on *identity*: people reject, or tell pollsters that they reject, human-caused climate change because saying otherwise is a betrayal of their social or political identity.

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Many of these explanations are complementary. Together, they bring us a long way toward understanding climate change denial.[1] But my focus in this paper is the possibility that there is an interesting and important group of climate change deniers that these explanations overlook—I call them *pro-science science deniers*. Pro-science science deniers think of themselves as being on the side of science. They also understand that most scientists accept human-caused climate change. Yet they do not accept it themselves. Their position presents a puzzle. How can they think they are on the side of science, yet knowingly reject what they know most scientists accept?

The research on climate change denial has not considered or tested the existence of pro-science science denial. Still, as I show in this paper, the limited data available makes a plausible case that pro-science science denial is real. I also argue that the psychological research on climate change denial sheds little light on the mechanism for pro-science science denial. The prominent explanations in the literature offer some resources for understanding the puzzle, but important questions remain.

In order to address the puzzle of pro-science science denial, I develop a hypothesis that focuses on people's *understanding of the nature of science*: that is, their understanding of how science works and what makes it such a successful tool for producing knowledge.[2] I start from the well-documented fact that Americans have serious misconceptions about what good scientific inquiry looks like (reviewed in Lederman 2007). Then I show that the organized climate change denial movement leverages these misconceptions to create the impression that climate science does not meet the standards for good scientific inquiry. This idea—that climate science does not meet the standards for good scientific inquiry—makes it easy to deny the reality of human-caused climate change, even for people who think of themselves as pro-science.

Crucially, this hypothesis does not claim that people who do not believe in human-caused climate change know less about the nature of science than people who do. Rather, it claims that near-ubiquitous misconceptions about the nature of science interact with particular partisan identities to produce climate change denial. This feature of the hypothesis makes it a candidate for explaining other cases of science denial as well. Common misconceptions about the nature of science can provide anyone—including political liberals and people with high levels of scientific education—with a rationalization for selectively rejecting parts of science.

Throughout the paper, I make a circumstantial case for the nature of science hypothesis. My goal is to identify a phenomenon that researchers have missed—pro-science science denial—and develop a possible explanation for it that fits the evidence better than the alternatives do. Making a conclusive case for the nature of science hypothesis requires further research, and in Sect. 5 I discuss specific tests that can help confirm it.

Before moving to the evidence that pro-science science denial is real, I will highlight two more features of the nature of science hypothesis. First, the hypothesis integrates all three types of explanation—knowledge, cognition, and identity—in its account

[1] I follow the literature in using the term "climate change denial," but my focus throughout the paper is on people who deny the reality of *human-caused* climate change, not any climate change whatsoever.

[2] Other philosophers who have suggested a connection between understanding the nature of science and accepting science include Heather Douglas (2015) and Philip Kitcher (2011).

of science denial. The literature on climate change denial has called for this type of integration, but has struggled to achieve it (Lewandowsky and Oberauer 2016; Ranney and Clark 2016; van der Linden et al. 2017). Second, the nature of science hypothesis has consequences for how we tackle the problem of climate change denial. If, as the hypothesis implies, beliefs about the reality of human-caused climate change are sensitive to beliefs about the nature of science, then improving understanding of the nature of science may increase acceptance of human-caused climate change.

2 The evidence for-science science denial

Other accounts of climate change denial assume that no one is *really* a pro-science science denier. According to these accounts, (we will discuss them in Sect. 3) people are either genuinely ignorant of what scientists believe about climate change (e.g. Lieserowitz et al. 2017), or there is a real sense in which they do believe in human-caused climate change, but they just will not admit it to pollsters (e.g. Kahan 2015a). People surely reject climate change for many different reasons. Some people are ignorant of what scientists believe, and others may be evasive in their responses to pollsters. But the available evidence also supports the conclusion that there are some Americans who (1) do not accept human-caused climate change, (2) personally consider themselves to be pro-science, and (3) are aware that most scientists agree on the reality of human-caused climate change. The evidence does not at present allow an estimate of how widespread pro-science science denial is. If the nature of science hypothesis is right, however, then dispelling misconceptions about the nature of science may force people to re-evaluate their rejection of climate change and ultimately help them change their minds. When it comes to influencing public opinion, we should not underestimate the value of changing the minds of even a small group of people. Small changes in the composition of a social network can still have significant effects (Christaker and Fowler 2009).

Now, let's consider the evidence for pro-science science denial.

2.1 Many Americans do not believe in human-caused climate change

Polling data reliably indicates that many Americans do not believe in human-caused climate change. Depending on the poll, the percentage of adults who either deny climate change altogether or say it is not human-caused is as a high as 52% (Funk and Kennedy 2016) or as low as 32% (Saad 2017). Researchers disagree about which numbers are most accurate, and about the rate at which Americans' opinions are changing, but most agree that climate change denial is real and sincere.

There are a few researchers who doubt the sincerity of climate change denial. They argue that when people tell pollsters they do not believe in human-caused climate change, they are primarily signaling a conservative political identification (Kahan 2015a). According to this argument, a conservative cannot tell a pollster they believe in climate change (even if they do), because it is a betrayal of their political identity. But this argument proves too much—if *saying* you believe in climate change is a betrayal

of political identity, presumably actually *believing* in it is unacceptable as well. And, if we look more broadly at the actions, speech, and voting behavior of Americans, as well as their toleration of climate denial and inaction from political leaders, it is clear that many people consistently reject the reality and severity of human-caused climate change.

2.2 Many Americans personally consider themselves to be pro-science

Researchers use many different kinds of questions to probe Americans' attitudes toward science. But regardless of how researchers ask about it, Americans consistently express pro-science attitudes. I review three kinds of evidence here. First, Americans believe that science benefits people. The Pew Research Center finds that 79% of Americans say science has made life easier for most people; over 60% say that science has improved the quality of food, healthcare, and the environment; and over 70% say the government's investments in scientific research pay off in the long run (Funk and Rainie 2015a, b).

Second, Americans are confident in scientific institutions. The General Social Survey has asked Americans on a regular basis since 1972 whether they have "a great deal," "only some," or "hardly any" confidence in the people who run U.S. scientific institutions. In the most recent survey, 88% of Americans reported positive confidence levels (39.7% say "a great deal," while "48.6% say "only some"). These numbers have remained stable since the 1970s, and they are similar for both liberals and conservatives (Smith and Son 2013). The only exception is that, compared to 10 years ago, more conservatives indicate "only some" confidence rather than "a great deal" of confidence (Gauchat 2012).[3] If these confidence levels do not seem high to you, consider that in this survey, Americans express more confidence in scientific institutions than they do in banks, organized religion, the press, the government, and organized labor. Americans are more confident in scientific institutions than they are in any other social institution, with the exception of the military (Smith and Son 2013).

Third, Americans are confident in scientific evidence as a criterion for evaluating beliefs. Even people who in fact reject ideas that are well-supported by scientific evidence say scientific evidence is a good reason for belief. In a study comparing creationists and evolutionists, for example, over 75% of creationists (compared to nearly 95% of evolutionists) rated scientific evidence as an acceptable criterion for belief (Metz et al. 2018).

2.3 Many Americans are aware that most scientists agree human-caused climate change is real

Can it really be true that there are climate change deniers who also know that most scientists agree about the reality of human-caused climate change? Conventional wisdom and some polling data say the opposite. In fact, if you directly ask Americans

[3] For a more detailed discussion of this trend, and an explanation of why it does not indicate conservative distrust of science, see this (2014) exchange between Dan Kahan and Gordon Gauchat: http://www.culturalcognition.net/blog/2014/11/25/conservatives-lose-faith-in-science-over-last-40-years-where.html.

what scientists think about climate change, 34% deny that or are unsure whether most scientists accept that global warming is occurring (Brenan and Saad 2018), and this denial goes hand in hand with rejection of human-caused climate change (Hamilton 2016). But here we must be very careful with the social scientific data.

Kahan (2015a) has argued that the current method of surveying people about what scientists accept actually fails as a measure of what Americans know about the scientific community's position on human-caused climate change. He worries that most polling questions on this issue (e.g. "Do most scientists believe global warming is caused by human activities?") trigger politicized reactions from respondents. People treat the question as an opportunity to express which political tribe they belong to, not as an opportunity to express what they know about scientific opinion.

Kahan avoids this worry by using a survey instrument called the Ordinary Climate Science Intelligence instrument (OCSI), which aims to measure what Americans know about what climate scientists believe. The instrument has nine questions which vary in difficulty. These questions do not directly ask people whether most scientists accept human-caused climate change. They are much more targeted, in an effort to avoid invoking respondents' political identities. Most of the questions start with the phrase, "Climate scientists believe that…"[4] followed by a statement about climate science which respondents rate as "true" or "false." Here are three of those questions:

1. "Climate scientists believe that human-caused global warming will result in flooding of many coastal regions." (The correct answer is "true," and 80% of people answered correctly.)
2. "Climate scientists believe that human-caused global warming has increased the number and severity of hurricanes around the world in recent decades." (The correct answer is "false," and 21% of people answered correctly.)
3. "Climate scientists believe that human-caused global warming will increase the risk of skin cancer in human beings." (The correct answer is "false," and 31% of people answered correctly.)

Question 1 is easy. Most people got it right, and political affiliation (the best predictor of climate change denial or acceptance) had only a small effect on how people answered. A liberal democrat was more than 85% likely to answer correctly, while a conservative republican was nearly 75% likely to answer correctly. In other words, people who reject human-caused climate change still know about as much about the views of climate scientists as people who accept human-caused climate change. And what they know is this: climate scientists think human-caused global warming is a real threat.

Questions 2 and 3 are difficult. Most people, regardless of political affiliation, got them wrong. The incorrect responses to these difficult questions reveal two important things. First, they show that most people are quite ignorant about climate science, and that conservatives and liberals are equally ignorant. Second, and more importantly, these responses show that even in their misconceptions, people attribute a high level of concern about global warming to climate scientists. The mistakes most people made in their answers to questions 2 and 3 indicate that people *overestimate* how dangerous

[4] Or, in a second version of the instrument (Kahan 2016), "According to climate scientists…".

scientists think climate change is. Conservatives may not believe in human-caused climate change, and most of them may know very little about it, but they *do* believe that scientists think it is real and dangerous.

A complementary source of evidence comes from examining the tactics of the organized climate science denial movement. It is well-documented that this "denial machine" (Begley 2007) tries to generate suspicion, not only about the results of climate science (Oreskes and Conway 2010), but also about the credibility of climate scientists (Dunlap et al. 2011). What is less often noticed is that it is possible to generate such suspicion without challenging the idea that the majority scientists believe in human-caused climate change. In fact, it is common to see the organized denial movement start by recognizing this majority, before trying to discredit it. Consider this paragraph from the *National Review*:

> Given the politics of the modern academic and the scientific community, it's not unlikely that most scientists involved in climate-related studies believe in anthropogenic global warming, and likely believe, too, that it presents a problem. However, there is no consensus approaching 97%. A vigorous, vocal minority exists. The science is far from settled (Tuttle 2015).

The author, Ian Tuttle, assumes a world in which "most" scientists are against him and his readership. He does not accept that the consensus is at 97%, but he does acknowledge that scientists who reject human-caused climate change are in the minority. Tuttle makes a distinction between *what most scientists believe* and a *scientific consensus*. The existence of a consensus would imply that the science is "settled." But to say only that most scientists believe in human-caused climate change is a weaker claim, one that preserves space for disagreement. In Sect. 4, I will argue that Tuttle is an example of a doubt-monger who manipulates his audience's flawed view of how science is supposed to work. For now, the takeaway is that both Kahan's study and the words of organized climate science deniers make a case that many of the Americans who do not believe in human-caused climate change still understand what the majority view among climate scientists is, even if they also underestimate the magnitude of that consensus.

3 Existing attempts to explain climate change denial

Now that we have built the case for pro-science science denial, we can ask: Do the general explanations for climate change denial in the literature account for pro-science science denial? After surveying the most prominent explanations, we will see that, though they take us part of the way toward an explanation, they are incomplete. An important part of the mechanism behind pro-science science denial remains a mystery.

3.1 Knowledge explanations

The most popular knowledge explanation proposes that people reject human-caused climate change because they are not aware of what most scientists believe. As a result,

most of this century's efforts to increase Americans' acceptance of human-caused climate change have focused on communicating the scientific consensus to the public. Websites such as the Consensus Project have the mission of "communicat[ing] the overwhelming scientific agreement on anthropogenic (human-caused) climate change to the public at large." Advertising campaigns such as one led by Organizing for Action, a progressive community-organizing group, and Al Gore's Climate Reality Project have invested hundreds of millions of dollars in this messaging strategy (Kahan 2015a).

There is ongoing controversy about the effectiveness of this "communicate the scientific consensus" strategy (e.g. Lewandowsky et al. 2012; van der Linden et al. 2016; Kahan and Carpenter 2017), but we can set it aside. While it may be true that some people reject human-caused climate change because they do not know what scientists believe about it, we are explicitly interested in pro-science science deniers, those who *do* know what most scientists believe about climate change. Explanations for climate change denial that appeal to ignorance about what most scientists believe are of no help to us.

There are other types of knowledge explanation. Researchers have considered whether poor science literacy, low numeracy, or ignorance about the mechanism of global warming could be responsible for climate change denial. Each of these explanations is, however, beset by the same problem: people who reject human-caused climate change are not more ignorant than those who accept it. Studies that test for differences in general science literacy and quantitative skills (Kahan et al. 2012) or mechanistic knowledge (Ranney and Clark 2016) find no significant differences between people who accept and reject human-caused climate change. Differences in knowledge do not explain differences in belief.[5]

Knowledge explanations for climate change denial are attractive in many ways. After all, the problem of climate change denial is not so difficult if we can solve it by changing the information that people have. But the parity in knowledge between those who accept and reject human-caused climate change has prompted many people to consider alternatives. The most influential alternative appeals to a combination of cognitive and identity-based factors.

3.2 Cognitive and identity explanations

Cognitive explanations for climate change denial propose that there is something about the way climate change deniers reason that explains their rejection of the scientific consensus. While some cognitive explanations propose that differences in thinking style between conservatives and liberals are related to climate change denial (see Jost et al. 2003; Deppe et al. 2015; Baron 2017), a more promising kind of explanation focuses on cognitive biases that affect everyone. These biases, which underpin the phenomenon known as *motivated reasoning*, contribute to climate change denial by

[5] This does not rule out the possibility that increasing knowledge can promote acceptance. In their provocative study, Ranney and Clark (2016) provide evidence that although understanding of the mechanism of global warming is very low throughout the population, interventions that teach people about the greenhouse effect can increase acceptance of human-caused climate change. But these results, while exciting, still do not explain what produces and maintains climate change denial in the first place.

causing people to reason in a way that lets them reach the conclusion they want to be true, even if the evidence for that conclusion is not very good (Kunda 1990; Lodge and Taber 2013). Motivated reasoning is very common across ideological, religious, ethnic, gender, and educational divides, and it predicts that people who do not want to believe in human-caused climate change will be more critical of the evidence for it than they are of the evidence against it (Sinatra et al. 2014; Hart and Nisbet 2012).

There is wide agreement that motivated reasoning contributes to climate change denial, even among researchers who disagree about related issues.[6] Motivated reasoning is ubiquitous, and many people have strong reasons for not wanting to believe in climate change. What are those reasons? This is the question that identity explanations seek to answer.

The common thread in all identity explanations is the importance of political conservatism. Most people who believe in human-caused climate change are liberals or democrats, while most people who deny it are conservatives or republicans. Inaction on climate change is an explicit part of conservative policy, in large part because conservative attitudes toward corporate power are difficult to reconcile with the regulatory environment required for an adequate response to climate change. Many identity explanations (e.g. Sinatra et al. 2014) propose that political identity produces the desire (perhaps not a conscious one) to deny climate change, and that motivated reasoning then allows people to reach the conclusion that their political identity causes them to desire.

Does this combination of motivated reasoning and political identity explain pro-science science denial? The literature on motivated reasoning assumes that climate change deniers use motivated reasoning to reject the idea that most climate scientists think human-caused climate change is real (e.g. Bolson and Druckman 2018). But this way of thinking about the role of motivated reasoning merely denies that climate change deniers know what most climate scientists believe. It rules out pro-science science denial rather than explaining it.

There is, however, another way in which motivated reasoning may be relevant. Motivated reasoning may allow people—even pro-science people—to conclude that the majority of scientists are wrong about climate change. It may help people who have independent reasons for wanting to side with a minority of scientists (a) overestimate the size of that minority and (b) treat the arguments and evidence presented by that minority more favorably than the arguments and evidence presented by the majority in favor of human-caused climate change. Thinking of the role of motivated reasoning in this way does shed light on how it is possible to be a pro-science science-denier.

But the explanation is still incomplete. If true, it identifies a causal relationship between motivated reasoning and climate change denial, but it fails to specify the scope, or application conditions, of that relationship. That is, the explanation does not tell us about the conditions under which motivated reasoning produces the behaviors or beliefs it is supposed to explain. Will people use motivated reasoning to deny climate change no matter what? Or are there particular beliefs and commitments which allow them to knowingly reject what most scientists say while still believing themselves to be on the side of science? If so, what are they? Would changing these beliefs

[6] See the exchange between Kahan and Carpenter (2017) and van der Linden et al. (2017).

and commitments change the conclusions about climate change that are available to people?

As Angela Potochnik has recently argued (2016, 2017), specifying the scope of a causal relationship is a central task of explanation. Specifying the scope helps us understand both the phenomenon we are interested in explaining (When should we expect to see it? How is it related to similar phenomena?) and the cause that produces the phenomenon (How general and robust is it? What factors make it so?). Until we have provided information about scope, our explanatory work is not done.

Psychologists, too, have recognized the need for information about scope in explanations that appeal to motivated reasoning. Nearly 30 years ago, one of the scholars who conducted pioneering research on motivated reasoning wrote:

> An explanation for how directional goals affect reasoning has to account not only for the existence of motivated biases, but also for the findings suggesting that such biases are not unconstrained: People do not seem to be at liberty to conclude whatever they want merely because they want to. Rather, I propose that people motivated to arrive at a particular conclusion attempt to be rational and to construct a justification of their desired conclusion that would persuade a dispassionate observer. They draw the desired conclusion only if they can muster up the evidence to support it (Kunda 1990, pp. 482–483).

Some recent work also recognizes that there must be a limit to the scope of motivated reasoning (Redlawsk et al. 2010), but there is very little research that explicitly investigates those limits. What we still need to know is, what sets the limits on climate change denial for pro-science science deniers? What beliefs and commitments make their position possible? Only when we have answered these questions will we have a satisfactory explanation.

4 The nature of science hypothesis

So far, we have seen that an explanation in terms of motivated reasoning and identity can partially, but not entirely, resolve the puzzle of pro-science science-denial. We have identified, though not yet confirmed, a causal relationship that can produce pro-science science denial. But we still need to know more about the scope of that causal relationship. Here I introduce the nature of science hypothesis and show that beliefs about the nature of science can provide the missing information about the scope of the relationship between motivated reasoning and climate change denial. In particular, I show how misconceptions about *objectivity*, the *scientific method*, and the *tentativeness of knowledge* can provide motivated reasoners with a justification for rejecting human-caused climate change.

4.1 The role of beliefs about science

Suppose you are a person whose political identity gives you motivation to deny human-caused climate change. If you also think you are pro-science, and yet you understand

that most climate scientists believe in human-caused climate change, how exactly do you arrive at the conclusion that human-caused climate change is not happening? How do you justify this to yourself? How would you explain it to others?

In order for a pro-science person to be justified (by their own lights) in rejecting some part of science, they must believe either that (a) it is always epistemically permissible to reject the results of science, or (b) there is something wrong with the particular part of science they are rejecting. Someone who believes that it is always epistemically permissible to reject the results of science clearly has a flawed understanding of the nature of science. But what about someone who rejects a part of science because they think there is something wrong with the science? This case is more complicated.

There is, of course, a valid argument for such pro-science science-denial:

i. In order for us to accept its results, science must meet the standards for good science.
ii. Climate science does not meet these standards.
iii. So we should not accept the results of climate science.

All of us, accepters and deniers alike, can agree that if climate science did not meet the standards for good science, we should not accept its results. In fact, scientists themselves often appeal to arguments of this form in their disagreements with one another. The interesting question is *why* pro-science science-deniers might doubt that climate science meets the relevant standards. There are two options. One is that there are widely accepted standards for good science, shared by accepters, deniers, experts, and non-experts—and that deniers just think differently about how well climate science meets those standards. The second option is that deniers think differently than experts do about what the standards for good science are.

The first of these options is implausible. Many science educators and communicators believe that the audiences they are trying to teach have deep-seated misconceptions about how science works and the standards for judging its results. Their belief is supported by several decades of research on science students in both high school and college (reviewed in Lederman 2007). This research uses different survey instruments to assess understanding of the nature of science, and there is a considerable literature dedicated to critiquing and improving these instruments. Nonetheless, these studies consistently find that science students have an inadequate understanding of the following elements of the nature of science (Liang et al. 2006; Chen 2006; McComas 1998; Miller et al. 2010; Allchin 2011; Lederman et al. 2002; Ryan and Aikenhead 1992):

1. the tentativeness of scientific knowledge;
2. observations and inferences in science;
3. scientific objectivity;
4. creativity and rationality in science;
5. the socio-cultural embeddedness of scientific findings;
6. scientific theories and laws; and
7. scientific methods.

Further, these topics are often ignored in science textbooks, or given inadequate or misleading treatment when they are explicitly discussed (Abd-El-Khalick et al. 2017).

In light of this research, it is more likely that disagreement about the standards for judging good science, rather than disagreement about how well climate science meets those standards, is what makes pro-science science-denial possible.

I propose that misconceptions about the nature of science, and the standards for good science in particular, are what allow people to maintain a pro-science science-denial position. These misconceptions both allow, and set limits on, pro-science science-denial. I do not mean that people who reject human-caused climate change have explicit mental models about the nature of science. Rather, I mean that many people, liberals and conservatives alike, have implicit yet wildly inaccurate ideas about how science is supposed to work. In reality, science rarely if ever lives up to the standards encoded by these misconceptions. Precisely because people do not spend much time reflecting on the nature of science, they do not realize that there is a difference between how science is normally conducted and how they imagine it ought to be conducted. As a result, much of science gets by unquestioned, even though the details might scandalize the typical citizen. When, however, doubt-mongers try to get people to reject a scientific consensus, they leverage these misconceptions in order to produce doubt. By presenting normal features of science as abnormal, they are able induce selective rejection of scientific consensuses.

To provide a feel for how this reasoning works, I show how three kinds of common misconceptions about science are used by organized climate science denial to discredit both the scientific results about climate change and the people who produce those results. The purpose is not to mark these misconceptions as the only or most important ones, but to provide a richer picture of how misconceptions about science can allow people to reject climate change.

4.2 Misconceptions about objectivity

Our first category of misconceptions about the nature of science is misconceptions about objectivity. Students often think of scientists as more objective than other people (McComas 1998), and they may have the naïve idea that scientists do not use imagination or creativity because doing so interferes with objectivity (Liang et al. 2006). Lederman et al. (2002) find that many subjects also do not understand that observations are theory-laden and social and that cultural values may influence scientific research.

These ideas about objectivity track an influential thesis about objectivity in science called the value-free ideal. According to the value-free ideal, the evaluation and acceptance of scientific results should be as free as possible from social and ethical values (Douglas 2009, p. 45). To the extent that such "extra-scientific" values creep into scientific reasoning, the objectivity of science—and the reliability of its results—is compromised. The value-free ideal was influential among philosophers, scientists, and policy-makers throughout much of the twentieth century, and it still informs much of science policy and science education in the United States (Douglas 2009; Abd-El-Khalick et al. 2017).

Unfortunately, however, the value-free ideal encodes serious misconceptions about scientific objectivity and the role that values can play in scientific investigation. Per-

haps most seriously, it assumes that in order for scientific results to be trustworthy and accurate, the individual researchers who produce those results must be disinterested truth-seekers, free from the influence of bias or wishful thinking. This view has been widely critiqued in the philosophical literature. While substantive academic questions remain about how to best understand scientific objectivity, there is a robust consensus among nature-of-science researchers and philosophers that the objectivity of scientific results is not secured through the disinterestedness individual scientists, but by community-wide mechanisms that recognize and interrogate the biases that individual scientists inevitably have. Objectivity, on this view, is a social rather than an individual achievement. It depends on communal mechanisms such as recognized avenues for criticism, shared standards, and community response (Longino 1990; Douglas 2009; Elliott 2017).

To the extent that this social conception of objectivity is largely unknown to the general public, people may trust science less when they encounter scientists that do not shy away from acknowledging the importance of values and interpretation and sociality in securing objectivity. In addition, opinion leaders can cast doubt on scientific results by selectively pointing out the role of values in specific domains. The *National Review* article discussed in Sect. 2 does just that, suggesting that most scientists believe in human-caused climate change because of their "politics." More generally, a large part of the strategy of the organized climate change denial movement is to position itself as objective while casting doubt on the objectivity of mainstream scientists. As Dunlap and McCright write, "Conservative media consistently present contrarian scientists…as 'objective' experts, in stark contrast to their portrayal of scientists working for the IPCC as self-interested and biased…" (2011, p. 152).

This brittle picture of objectivity also fails to provide resources for thinking about the role of funding in science, which makes it easy for doubt-mongers to use the reality of funding to stir up worries about corruption. Once people have been given a reason to see climate science as a corrupted enterprise, rejecting its results does not threaten their pro-science stance, and their initial doubt may make them susceptible to increasingly outlandish claims about the dishonesty of climate scientists. Motivated reasoning can also make it easy not to think about the ways in which funding operates in other parts of science that the denier *does* accept. If, however, people had more sophisticated views about the (admittedly imperfect) mechanisms that exist to prevent money from corrupting science, along with an understanding of the fact that most science is funded by the government, it could go a long way toward shutting down this easy route to discrediting climate science.

4.3 Misconceptions about the scientific method

The traditional picture of the scientific method, and the one that children generally learn in schools, is the hypothetico-deductive method, in which scientists formulate specific hypotheses and conduct controlled experiments both to confirm the hypothesis in question and to rule out alternatives. This picture, though accurate in part, is also misleading in two important ways. It suggests that there is a universal, step-by-step scientific method and that experiments are the primary route to scientific

knowledge—both of which are well-documented misconceptions about the nature of science (Liang et al. 2006; McComas 1998; Miller et al. 2010).

These misconceptions distort the way science commonly works. Rather than following a single method, scientists are opportunistic, making use of whatever tools are available to them to gather data and answer questions (Currie 2015). Often, scientific research is exploratory, rather than focused on hypothesis testing. Even when scientists do test hypotheses, they are rarely (if ever) able to test them in isolation. Instead, they test hypotheses in groups (Duhem and Pierre-Duhem 1954) which greatly complicates their efforts to identify and confirm the existence of causal relationships between variables. Finally, models are central to scientific investigation, no less important than experiments and no less capable of generating insights about the natural world.

This last point is perhaps the most important one for our purposes. Models—especially simulations—are a crucial tool in climate science, and while there are fascinating epistemic questions about how to get the best results using climate models, it is all too easy to manipulate the uncertainties inherent in the modeling process to engender doubt about and rejection of climate science. For example, in a widely re-posted article, a fellow at the Heartland Institute [a key actor in organized climate change denial (Dunlap et al. 2011)] listed six reasons to be a climate skeptic. The first two focus on the failures of climate models to make highly accurate short-term predictions about sea level rise, temperature fluctuations, and extreme weather events (Haskins 2017). These failures are presented as evidence that climate models cannot be trusted in general. More broadly, criticisms of climate models are a common theme in the literature dedicated to casting doubt on climate science (McCright and Dunlap 2000).

Such criticisms are quite compelling if your picture of good science has no place for model-based research in it or if you think experiments are the primary route to scientific knowledge. Modeling techniques such as atmospheric data assimilation are different enough from experimentation that it is easy for a motivated reasoner to dismiss them as unscientific, or for doubt-mongers to paint them as untethered from empirical reality. If, however, people understood how ubiquitous modeling is in science, merely pointing out the role of models in climate science might be a less powerful strategy for generating doubt about its findings.

4.4 Misconceptions about the tentativeness of scientific knowledge

Science is continually open to revision. At the same time, it is able to treat particular questions as "settled" for the purposes of further research. Sometimes, voices of dissent within the scientific community turn out to be right; other times, they are wrong. How should non-experts treat scientific conclusions, given that they are provisional, frequently contested, and sometimes even reversed? To a crude first approximation, trusting the all-things-considered position of the scientific community is usually the best epistemic bet for a non-expert. This is the case even though the established scientific position is not always right, and if you trust it, you will certainly be wrong sometimes. The basis for this trust is the idea that science—its institutions and processes of inquiry—is in a better (though still imperfect) epistemic position relative to the questions it investigates than the rest of us are. One reason is that science,

if it is worth anything at all, has that worth precisely because it has self-correcting mechanisms which we trust to catch mistakes, even though it cannot prevent them.

A qualification: this prescription to "trust the consensus" does not necessarily hold for experts in a given area of science. Expertise can certainly put someone in a good position to question an established consensus. But even those of us who can claim to be experts in one area are non-experts in most other areas, so if we have a legitimate claim to dissent in certain contexts, there are still many other contexts in which trusting a scientific consensus is our best epistemic bet.

There is quite a bit to say about why science is in the privileged epistemic position I have just described, and, of course, science and its conclusions are not immune to outside criticism. There is a considerable literature dedicated to understanding what separates a trustworthy or reliable scientific consensus from a non-trustworthy or unreliable one. Bayesian analyses highlight the importance of one's priors when evaluating scientific claims, as well as the independence and reliability of scientific experts (e.g. Hahn et al. 2016). Other work emphasizes the importance of shared theoretical and methodological commitments among researchers, consilience of evidence, and the social diversity of those contributing to a consensus (e.g. Miller 2013, 2016).

All of this amounts to a complex view about scientific fallibility and the weight that non-experts should give to dissenting views within the scientific community. But most people do not think about science in this way. Instead, they often think of scientific investigation as progressing toward certain knowledge: hypotheses and theories are ideas that have not yet achieved the iron-clad empirical support that scientific laws enjoy (McComas 1998; Miller et al. 2010). As such, hypotheses and theories are always open to dispute, and scientists who dissent from the mainstream are modern-day Galileos. As Douglas Allchin (2003) has shown, these ideas about the heroism of dissent are often cemented by the mythic treatment that scientists such as Galileo, Mendel, and Darwin receive in science textbooks.

The organized climate change denial movement exploits these misconceptions. People who consume conservative media are told that claims about the existence of a scientific consensus are themselves unscientific: "There is nothing more anti-scientific than the very idea that science is settled, static, impervious to challenge" (Krauthammer 2014). Of course, people are very happy to think of most areas of science as settled. My claim here is that these background views about fallibility, consensus, and dissent do not provide the resources for thinking through the implications of dissent in an area like climate science. Quite the opposite: their views make it easy to dismiss any science they want to dismiss in the name of keeping an open mind and not prematurely shutting down debate.

5 Intervening and testing

This proposal—that misconceptions about the nature of science enable many people to reach the conclusion that human-caused climate change is not real—raises two important questions: (1) What are the implications for changing people's minds about the reality of human-caused climate change? And (2), what can we do to test this proposal?

When it comes to changing minds, the strategies that the nature of science hypothesis recommends are different than those recommended by the other explanations for climate change denial that we have discussed. This hypothesis implies that if people had different beliefs about the nature of science, particularly about what the standards for good science are, a different range of conclusions about climate change would be available to them. We should expect, at the very least, that having a more nuanced and sophisticated view of science will change *how* people are able to reject climate change. But hopefully it will do something more. Hopefully it will render some of the common appeals from doubt-mongers ineffective. Hopefully it will make it so difficult to reconcile a pro-science stance with rejection of human-caused climate change that some people will not reject it anymore.

Now, perhaps even people with a sophisticated and nuanced view of science would find other justifications for rejecting human-caused climate change. Perhaps doubt-mongers would find other ways of making their case. We do not know. What we do know is that broadcasting the scientific consensus has not worked. We also know that climate change is a deeply politicized issue. Calls to depoliticize it are noble, and efforts in that direction are important. But the issue became politicized in the first place through the deliberate efforts of the organized climate change denial movement (Oreskes and Conway 2010), and counteracting this movement's ongoing efforts is difficult. If intervening on people's beliefs about science is quixotic, it is no more quixotic than attempting to depoliticize climate change. It is also an easier factor to intervene on than political identity or the tendency toward motivated reasoning, which are the other two causally relevant factors we have discussed. So if it is true that beliefs about the nature of science set the limits on pro-science science-denial, then attempts to combat climate change denial should absolutely consider interventions on these beliefs.

But *is* the nature of science explanation true? I have argued that beliefs about the nature of science plausibly fill the explanatory gap in explanations of climate change denial, but I have not presented positive empirical evidence in support of this hypothesis. This is because social scientists have barely studied it.[7] In the absence of data from the social sciences, I can only identify the phenomenon of pro-science science-denial, show that it stands in need of a complete explanation, and make a circumstantial case that the nature of science hypothesis provides this explanation. But now that I *have* done this, there is much more to do, because the nature of science explanation makes specific, testable predictions.

The most important prediction is that conservatives who have a good understanding of the nature of science [as measured by something like Coburn's (2001) Thinking About Science survey instrument, or one of the many other nature of science survey instruments] will accept the reality of human-caused climate change at a higher rate than conservatives who do not. A corollary is that having a good understanding of the nature of science will have less influence on liberals' acceptance of human-caused

[7] Though psychologists have studied the relationship between understanding the nature of science and accepting evolution (e.g. Lombrozo et al. 2008), at present there is only one preliminary study on the relationship between understanding the nature of science and accepting human-caused climate change (Carter and Wiles 2014).

climate change, because liberals accept human-caused climate change for identity-driven reasons just as much as conservatives reject it for identity-driven reasons.

Second, the nature of science explanation predicts that understanding the nature of science will not be tightly correlated with knowledge of the *content* of science. (In contrast to understanding the nature of science, having knowledge of the content of science means knowing scientific facts, such as "electrons are smaller than molecules."). Conservatives and liberals become more polarized about climate change as their education level and general science literacy increases (Drummond and Fischhoff 2017). Apparently, the more science you know, the better able you are to use this knowledge to support whatever conclusions you want to be true. Since I predict that people do not become more polarized as their understanding of the nature of science increases, I also predict that understanding the nature of science and science literacy will come apart.

These predictions come at a good time. The knowledge, cognitive, and identity explanations have been battling in the literature for several years, but recently, conciliatory voices have insisted that these different factors interact to produce climate change denial. The literature is now full of calls to examine the interaction of these factors (Lewandowsky and Oberauer 2016; Ranney and Clark 2016; van der Linden et al. 2017). These calls are a starting point for investigation, and the hypothesis I have developed provides guidance for how that investigation should proceed. The nature of science hypothesis is partially knowledge-based. It claims that climate change denial often stems from deficient knowledge about what science is and how it works. The nature of science explanation also has cognitive elements. It identifies patterns of reasoning that contribute to climate change denial and are attractive to people as a result of their deficient understanding of the nature of science. Finally, the nature of science explanation recognizes an important role for identity. Identity provides a *motivation* for rejecting human-caused climate change, while a deficient understanding of science is an important piece of the *mechanism*.

6 Conclusion

This paper is about what it means to fully explain the phenomenon of pro-science science-denial. But it is also relevant to two more general issues in social epistemology.

First, it is relevant to the public's understanding of all of science, not just climate science. That is because the explanation for climate change denial I have developed is symmetrical. As far as we know, misconceptions about the nature of science are evenly distributed throughout the population. Liberals do not understand science better than conservatives, and even people with a lot of education or scientific knowledge may not have particularly sophisticated views about how scientific inquiry works and what makes it successful.

As a result, we should expect liberals to deny science if they have identity-driven reasons to engage in motivated reasoning about it. A possible example is the high rate of distrust of nuclear power among liberals relative to conservatives (Funk and Rainie 2015a, b). We should also expect rejection of science across political divides when people have identity-driven, yet non-political, reasons to engage in motivated

reasoning. A possible example is distrust of GM foods, as this distrust is spread evenly across the political spectrum (Funk and Rainie 2015a, b). In all of these cases, misconceptions about the nature of science play the same role: they are a powerful tool for generating suspicion about any area of science that people have some independent reason to want to reject.

The second issue is the question of how psychosocial and epistemic factors interact in belief formation. Some of the recent work on motivated reasoning portrays it as a nearly irresistible force, something that can only be combatted by disconnecting the thing being reasoned about from the reasons we have for favoring a particular conclusion (Kahan 2015b; Druckman and Bolsen 2011). But the nature of science explanation suggests another possibility, one that is in line with nascent social scientific research on the boundaries of motivated reasoning (Redlawsk et al. 2010). Background beliefs may set the limits on the conclusions we can reach through motivated reasoning. If this is true, then even though motivated reasoning is not a truth-seeking process, it still operates within important epistemic constraints. Discovering these constraints and working to shift them can be a powerful avenue for epistemically combating motivated reasoning.

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