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# The evidence for motivated reasoning in climate change preference formation

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**Despite a scientific consensus, citizens are divided when it comes to climate change — often along political lines. Democrats or liberals tend to believe that human activity is a primary cause of climate change, whereas Republicans or conservatives are much less likely to hold this belief. A prominent explanation for this divide is that it stems from directional motivated reasoning: individuals reject new information that contradicts their standing beliefs. In this Review, we suggest that the empirical evidence is not so clear, and is equally consistent with a theory in which citizens strive to form accurate beliefs but vary in what they consider to be credible evidence. This suggests a new research agenda on climate change preference formation, and has implications for effective communication.**

A widely discussed explanation for the public divide in beliefs about climate change is that people engage in 'directional motivated reasoning'[1–4]. According to this explanation, individuals skeptical about climate change reject ostensibly credible scientific information because it counters their standing beliefs. Considering the threat that such a tendency poses to effectual scientific communication, scholars and practitioners have focused on identifying conditions that curtail or counteract directional motivated reasoning[5,6].

However, work in this area has overlooked two points that are important to effective climate change communication. First, directional reasoning is not the only source of erroneous belief: individuals who process information in an 'unbiased' way can end up with opinions that diverge dramatically from the scientific consensus (belief in climate conspiracies, for example). Second, there is scant evidence for directional motivated reasoning when it comes to climate change: the evidence put forth cannot be distinguished from a model in which people aim for accurate beliefs, but vary in how they assess the credibility of different pieces of information. In short, we have little clear evidence that can differentiate directional motivated reasoning from an accuracy motivated model—and the distinction between the two models matters critically for effective communication.

In this Review, we first present a canonical model of how individuals update their climate change beliefs in the face of new information using Bayes' theorem. Next, we discuss two possible motivations—accuracy and directional—that may influence how individuals process information about climate change within a Bayesian framework. We use this framework to understand the evidence required to support claims of directional motivated reasoning in the context of climate change beliefs, and to highlight avenues for future research.

## Introducing the Bayesian framework

Bayesian updating is a theoretical model of the process for incorporating new information into prior beliefs to arrive at an updated belief[7]. In Box 1, we offer an overview of the Bayesian process that highlights the notation we use in the following discussion. Further, in Table 1, we display a glossary of key terms used throughout the Review. Our terminology is partly consistent with previous work[4], although our approach and argument are distinct.

Our starting point is a standing (or prior) belief. This belief can be any climate change-relevant construct, such as beliefs that climate change is occurring, that climate change is anthropogenic, about a scientific consensus on climate change, about a conspiracy with regard to climate change, about who is responsible for causing and/or addressing climate change, about the efficacy of mitigation policies, about risks from climate change, about the impact of climate-relevant behaviours (such as biking instead of driving) and about the importance of climate change as a national or global issue[8].

The updating process has three steps. The first step specifies the structure of the prior belief. We characterize the prior belief as a probability distribution regarding the true state of the world. The structure of this belief is $\pi(\mu) \sim N(\hat{\mu}_0, \hat{\sigma}_0^2)$, where μ is a true state of the world, $\hat{\mu}_0$ is the individual's best guess about the true state of the world, and $\hat{\sigma}_0^2$ is the individual's uncertainty around that guess (that is, the individual's confidence in her guess, or belief strength)[9,10]. π denotes the function. The ^ is used to indicate a perception, as opposed to a state of the world[7]. Say, for example, that μ is the true impact of human activity on climate change. Then, the individual's belief π(μ) about the role of human activity in causing climate change comprises the individual's estimate $\hat{\mu}_0$ of the actual role of human activity and her confidence $\hat{\sigma}_0^2$ in that estimate.

Second, an individual encounters relevant information in the guise of an experience (for example, abnormal climate events) or communication (such as a statement about what scientists believe). We represent this new information, $x$, as a draw from the distribution $N(\mu, \hat{\sigma}_x^2)$. For now, we assume that the location of the distribution is determined by the 'world'—but note that $\hat{\sigma}_x^2$ is an individual perception: a person's evaluation of the credibility of the information drawn from that distribution. For instance, $x$ could be a message about a new scientific study showing that humans are causing climate change. The individual receiving the message has some perception of its credibility (for example, worthless or highly credible information) represented by $\hat{\sigma}_x^2$. Nothing in the Bayesian process precludes heterogeneity in what people find credible.

Third, the individual incorporates the new information with the prior belief to form an updated (posterior) belief, π(μ|x). This updating process accounts for how far the new information is from what one previously believed, the strength of one's prior belief and

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**Box 1 | The Bayesian framework**

The Bayesian framework starts with an individual's prior belief, $\pi(\mu)$. This consists of an individual's best guess ($\hat{\mu}_0$) about some condition of the world ($\mu$) and her confidence in that guess ($\hat{\sigma}_0^2$). Next, the individual encounters some new information, $x$. This information is assumed to bear some relationship to the true condition of the world, but individuals will differ in their perceptions of how closely it relates to the truth (that is, the credibility of the new information, $\hat{\sigma}_x^2$). Bayesian updating happens when the prior belief is adjusted in light of the new information, taking into account the individual's confidence in the new information relative to her confidence in the prior 'best guess'.

This incorporation is represented as

$$\pi(\mu|x) \sim N\left(\hat{\mu}_0 + (x-\hat{\mu}_0)\left(\frac{\hat{\sigma}_0^2}{\hat{\sigma}_0^2+\hat{\sigma}_x^2}\right), \frac{\hat{\sigma}_0^2\hat{\sigma}_x^2}{\hat{\sigma}_0^2+\hat{\sigma}_x^2}\right)$$

where $\hat{\mu}_0 + (x-\hat{\mu}_0)\left(\frac{\hat{\sigma}_0^2}{\hat{\sigma}_0^2+\hat{\sigma}_x^2}\right)$ is the individual's updated best guess—the prior best guess adjusted by the distance between the prior and new information, weighted by relative confidence in new information; and $\frac{\hat{\sigma}_0^2\hat{\sigma}_x^2}{\hat{\sigma}_0^2+\hat{\sigma}_x^2}$ is the individual's confidence in the posterior belief. N denotes a normal distribution.

The updating can operate according to an accuracy motivation (the updating goal is to arrive at an accurate estimate of $\mu$) or a directional motivation (the updating goal is to arrive at a predetermined conclusion, such as one consistent with the prior belief $\pi(\mu)$; see Table 2). The updating then leads to a posterior belief, $\pi(\mu|x)$. The strength of the individual's confidence in the new information relative to her strength of confidence in the prior best guess determines both the extent to which belief moves in response to the new information, and the strength of the confidence in that new belief.

one's confidence in the new information. If the individual perceived the study as highly credible, this new information would be influential, creating an updated belief in line with the study. If the individual instead perceived the study as not particularly credible, and were highly confident in her own prior belief, the new information would not carry much weight.

There are three possibilities for updating in light of new information: no effect (that is, no movement of belief), persuasion/learning that involves updating in the direction of the information (greater belief in human-induced climate change) or a back-lash effect, where belief moves in the direction opposite to the new information (less belief in human-induced climate change) (see the first three rows of Table 1c).

## Bringing in motivation

Motivated reasoning emphasizes that how an individual processes information depends on motivation (see Table 1)[11]. We discuss two possible motivations—accuracy and directional—within a Bayesian framework[12]. Although the term 'Bayesian updating' is often interpreted to mean 'unbiased' processing, the model itself makes neither assumptions nor requirements about bias. Similarly, while 'motivated reasoning' is often taken to indicate 'biased' processing, this is an oversimplification of the theory. At a base level, motivated reasoning simply presumes that all reasoning is goal driven. In Box 2, we discuss the use of various terms related to bias in more detail. Table 2 provides an overview of accuracy and directional motivations, summarizing the discussion to which we now turn.

**Accuracy motivation.** In portrayals of Bayesian updating, it is often assumed that individuals strive to be 'accurate'—aiming to arrive at a 'correct' conclusion[4,13]. This means that at the evaluation phase, the individual evaluates information, $x$, in a way that maximizes the likelihood that her updated belief is an accurate estimate of the true state of the world. For example, an accuracy-motivated individual would evaluate a scientific report on human-induced climate change in a manner aimed at arriving at an accurate assessment of the impact of human activity.

With an accuracy motivation, the evaluation of $x$ is independent of the individual's prior belief in question, $\pi(\mu)$. In this example, the individual's prior belief about human-induced climate change has no bearing on whether she evaluates the report as high or low quality. However, just as nothing in the Bayesian framework requires that all people attach the same level of confidence to new information, neither does an accuracy motivation stipulate any single level of confidence. For example, accuracy-motivated people may differ in the standing trust they place in scientists. If someone has low confidence in the credibility of the information, that information will be discounted and will carry little weight—but we cannot infer anything about the individual's motivation from this evaluation. Accuracy-motivated individuals can vary in how much faith they place in a given piece of evidence and thus update in heterogeneous ways.

Some studies find data consistent with accuracy-oriented updating. For example, Ripberger et al. explore how individuals perceive climate anomalies (departures from average precipitation and temperature) over 11 consecutive seasons[14]. Here the experienced anomalies are the new information. The authors find a strong relationship between the objective measure of anomalies and respondents' perceptions. Although they find some variations among extreme partisans, they note that these effects are small and do "not overwhelm the Bayesian process whereby both groups incorporate feedback…"[14]. Individuals update in the direction of the information regardless of their prior beliefs about climate change[13,15,16].

Yet this type of 'objective' processing, where one's prior belief $\pi(\mu)$ does not affect perceptions of the new information $x$, does not ensure that people arrive at normatively desirable belief outcomes. For example, the local warming effect suggests that people become more believing in climate change on particularly warm days, regardless of their prior beliefs about climate change and political affiliations[3,17,18]. This tallies with accuracy-motivated updating and suggests movement towards the scientific consensus. However, it also means that people are updating climate change beliefs on the basis of fleeting experiences that bear little relationship to what scientists would consider credible evidence[19,20].

Similarly, van der Linden shows that after exposure to a climate conspiracy video individuals update their beliefs in line with the conspiracy information, making respondents less likely to believe there is a scientific consensus on human-induced climate change and less likely to sign a petition aimed at reducing global warming[15]. These effects appear uniformly for liberals and conservatives—people incorporated information in the same way regardless of likely prior beliefs[21]. Even if people process information in ostensibly objective, accuracy-oriented ways, an inability to detect 'bad information' can lead to beliefs that diverge from scientific perspectives.

These examples highlight that when it comes to assessing individuals' beliefs about climate change, there can be two distinct normative foci, which are often conflated. First, one can focus on the process: whether individuals accept new information and update. Second, one can focus on posterior beliefs, and whether they match current scientific thinking[2]. The process often deemed ideal need not lead to belief outcomes that align with normative expectations; and observing whether belief outcomes match scientific consensus does not necessarily provide insight into the process.

**Table 1 | Terminology**

| Terminology | Definition |
|---|---|
| (a) Theories | |
| Motivated reasoning | An individual's goals or motivations affect cognitive processes of reasoning and judgment[11]. |
| | Two possible goals are accuracy goals (aimed at a correct conclusion) or directional goals (aimed at a particular conclusion)[11,12] (see Table 2). |
| Identity-protective cognition | A type of directional motivated reasoning in which the goal is maintenance of membership or status in an affinity group[79,80]. |
| Biased assimilation | The tendency to interpret new evidence in a manner that allows maintenance of one's prior belief[81]. |
| Selective perception | The interpretation of stimuli as consistent with previously-held values, beliefs, or attachments[82,83]. |
| Perceptual screen | A theoretical 'filter' that distorts political partisans' perceptions of the world, leading to different perceptions from the same set of facts[84,85]. |
| (b) Directional motivated reasoning mechanisms | |
| Confirmation bias | A tendency to seek out information that confirms one's prior beliefs—a form of selective exposure[22]. |
| Prior attitude effect | Perceived strength of new information is a function of its relationship to one's prior belief[22,81]. |
| Disconfirmation bias | Greater scrutiny and counter-argumentation of information contrary to one's prior beliefs (relative to information consistent with one's prior beliefs)[11,22,81]. |
| (c) Possible updating outcomes | |
| No effect | No updating of beliefs in light of the new information. The posterior belief is the same as the prior belief. |
| Persuasion/learning | Relative to the prior belief, the posterior belief moves in the direction of the information[13,16]. |
| Back-lash/boomerang/back-fire effect | Relative to the prior belief, the posterior belief moves in the opposite direction of the information[1,35]. |
| Belief polarization (between multiple actors) | Movement of updated beliefs of two individuals (or groups) in opposite and divergent directions[7,46]. |

**Directional motivation.** Instead of striving for accuracy, individuals may pursue directional goals: here the motive is to arrive at a particular conclusion[12,22,23]. The desired outcome can vary, but is often treated as a desire (perhaps unconscious) to maintain one's prior belief $\pi(\mu)$. A number of different theories—including biased assimilation, selective perception, and the perceptual screen—refer generally to directional processes (see Table 1). For clarity, we focus on the three mechanisms of directional motivated reasoning identified by Lodge and Taber[22]. With each of these three tendencies (see Table 1), which can be inadvertent or unconscious, processing is a function of the prior belief in question.

First is a confirmation bias, where a person seeks out information that confirms the prior belief. In this case, the distribution from which the person draws information ($x$) shifts such that instead of $x$ being drawn from $N(\mu, \hat{\sigma}_x^2)$—where the average piece of information represents the true state of the world (that is, the location of the distribution is determined by the 'world')—new information is drawn from $N(\hat{\mu}_0, \hat{\sigma}_x^2)$, where the average piece of information reflects the mean of the individual's prior belief. Information is now drawn from a distribution centred on the individual's standing belief. Consequently, new information is likely to reinforce that belief. If a climate change denier has a tendency to ignore sources such as the National Academy of Sciences website and instead frequents conspiracy theory websites, this would suggest a confirmation bias. The individual's prior belief $\pi(\mu)$ affects her information draw, $x$.

Second, a prior attitude effect manifests when the perceived strength of the new information is a function ($\phi$) of the prior belief in question: $\hat{\sigma}_x^2 = \phi(|x - \hat{\mu}_0|)$. Here, information more distant from the individual's prior is perceived as weaker and thus receives little weight in the updating process, whereas information closer to the individual's prior is perceived as stronger and thus receives greater weight in the updating process. This contradicts an accuracy-motivated process, where one evaluates information in an 'objective manner', independent of its relationship to the belief in question. This distinction is in the process of updating, not in the individual's overall prior or posterior beliefs. Critically, one cannot infer motivation by simply observing prior and/or posterior beliefs[23]. Indeed, giving the information little weight, and consequently not substantially altering a belief, can occur with both accuracy and directionally oriented individuals, albeit through different processes.

Consider a directionally motivated climate change skeptic who receives two pieces of information: a scientific report on human-induced climate change ($x_1$) and a news article on the 'great climate hoax' ($x_2$). A prior attitude effect would mean that the individual assesses the scientific report as weak evidence and the hoax article as strong evidence because her goal is to evaluate evidence in a way that confirms her climate skepticism. In other words, the evaluations of $x_1$ and $x_2$ are contingent on the prior belief (that is, $\hat{\sigma}_{x_1}^2 = \phi(|x_1 - \hat{\mu}_0|)$ and $\hat{\sigma}_{x_2}^2 = \phi(|x_2 - \hat{\mu}_0|)$). The result is a posterior belief $\pi(\mu|x_1, x_2)$ that remains skeptical.

Conversely, an individual who is accuracy-motivated may reject the scientific report due to low trust in science and accept the hoax report due to trust in the news source. The accuracy-motivated individual arrives at the same posterior belief as the directionally motivated individual—not from motivation to confirm a prior, but from an appraisal of what is credible. The distinction in the process matters because in the directionally motivated case, opinion change would require altering the individual's motivations (or satisfying their goals, as we discuss below), whereas in the accuracy-motivated case it would require meeting (or altering) their standards of credibility.

A final directional motivated reasoning tendency, the disconfirmation bias, involves greater scrutiny and counter-argumentation of information contrary to one's prior belief. When exposed to new information that is inconsistent with prior belief, the individual generates draws of counter-arguments, $x_c$, that pull the updating process in the direction opposite to $x$ (ref. [11]). The result is posterior beliefs that do not converge towards $x$—and in fact could even create backlash, causing an individual to update in the opposite direction to $x$ due to the consideration of $x_c$. For example, a directionally motivated climate skeptic who receives a scientific report on human-induced climate change ($x$) may not only discredit it through a prior attitude effect (a weak $\hat{\sigma}_x^2$), but also think of contrary evidence ($x_c$), leading to a posterior belief of even greater skepticism.

**Box 2 | Commonly misused terms in the discussion of bias**

The term bias is commonly used in the preference-formation literature, but it is often used in an unclear fashion. Here we clarify some terminology that frequently enters discussions of bias.

Inherently, bias exists relative to some unbiased baseline. In studies of information processing, Bayesian updating is often erroneously used as a synonym for unbiased processing. Bayesian updating, however, is simply a model of the process of incorporating new information into a prior belief to arrive at an updated belief. Nothing in the model stipulates a process that is either unbiased or biased[4,7]. Whether bias is present depends on the motivation at work and the specified baseline. For example, an individual with a directional motivation may seek out new information that is likely to confirm her prior beliefs, incorporate that new information according to a Bayesian process and arrive at an updated belief that is biased relative to the normatively determined baseline of an accuracy-motivated process.

At least three different meanings of the term bias are relevant to the preference-formation literature, although the word is often used without specifying which type of bias is involved.

**Cognitive bias.** A cognitive bias is a systematic and widely exhibited error in reasoning. This bias is relative to a norm of rationality; for example, the tendency to overestimate the frequency of an event that easily comes to mind (plane accidents, for example).

**Directional bias.** A directional bias is the result of having a directional goal, with consequent effects on information processing, and exists relative to accuracy-motivated information processing. For example, a belief-protective goal may result in confirmation bias, disconfirmation bias or a prior attitude effect. Finally, a priors bias refers to the influence of prior information, beliefs, dispositions or values on information processing.

**Priors bias.** A priors bias can be a directional bias, but is not necessarily so—a priors bias includes the influence of any standing belief, such as an assessment of whether a source (such as a corporate sponsor) is trustworthy. This is a bias relative to a situation where priors do not affect processing. Note that the influence of priors on information processing is not only compatible with an accuracy motivation, it has been described as 'rational'[86] and 'essential'[81] to learning.

Reasoning that is contorted to arrive at a particular conclusion through processes such as these can be said to have a directional bias. Directional motivated reasoning, then, is characterized by a directional bias. But other types of bias, distinct from directional bias, are not necessarily at odds with accuracy-motivated reasoning (see Box 2). For example, reasoning may be accuracy-motivated but still exhibit cognitive biases, a broad set of reasoning errors that are seemingly endemic to human cognition. And an accuracy motivation does not preclude the influence of prior information, beliefs, dispositions or values on information processing—that is, a priors bias. Whereas directional bias can be thought of as a form of priors bias that leads towards a predetermined conclusion, other manifestations of priors bias (for example, giving greater weight to certain methods of information gathering) characterize the very process of scientific learning. Returning to our example above, an individual who places more weight on the scientific study than on the climate-hoax news article, rather than weighing them equally, is influenced by priors regarding the credibility of each source. Accuracy-motivated reasoning is not necessarily unbiased processing (nor is unbiased processing necessarily desirable or even possible). The important distinction is whether the bias leads to a predetermined conclusion or allows learning to occur.

## The observational equivalence problem

Evidence for directional motivated reasoning requires documentation that an individual possesses a directional goal and that information processing is tailored to achieve that goal. These are difficult conditions to verify. The climate change literature offers suggestive (but little definitive) evidence that directional motivated reasoning occurs. Despite claims of pervasive directional motivated reasoning, most of the data are also consistent with an accuracy-motivated updating process.

Consider Feldman and colleagues' study of information selection: the authors show that certainty about global warming at one point in time led individuals to later select significantly less conservative media (which tends to be skeptical of climate change) and more non-conservative media[24,25]. This could stem from a confirmation bias, where people seek out information that supports a prior belief, or it could reflect accuracy-driven audience members seeking information from sources they perceive to be credible. (We delve deeper into source credibility in Box 3.) In the latter case, an accuracy-motivated evaluation of the source/evidence drives the observed behaviour, rather than a directional desire to confirm a prior belief.

Distinguishing these alternative processes is difficult because the very sources people find credible are the ones with whom they share common beliefs[26,27]. When individuals seek advice from sources that share their views, it could be to achieve a directional processing goal[28], or it could be because they believe that source to be the most credible, regardless of their views on the issue at hand. This is the motivated reasoning observational equivalence problem.

The same observational equivalence dilemma surfaces when it comes to studies of belief polarization (see Table 1). Polarization involves the movement of beliefs of individuals or groups in opposite directions, and is particularly pronounced in the United States[29]. For instance, Palm et al. show that, from 2010 to 2014, Democrats came to endorse more actions on climate change while Republicans did the opposite[30]. Partisanship dwarfs the effect of other variables such as education, age, gender or direct experience with climate. They conclude that this is "strong evidence for the theory of [directional] motivated reasoning…"[30]. Yet this could reflect individuals being exposed to distinct information streams, or partisans finding cues from elites in their party as more credible. Indeed, mass climate change polarization of Democrats and Republicans maps onto analogous polarization among elites who provide cues[31–33]. In this case, it is impossible to know whether people are seeking and assessing information on the basis of their prior beliefs $\pi(\mu)$, or are accuracy-driven but have heterogeneous evaluations of distinct information streams ($\hat{\sigma}^2_{x_1}, \hat{\sigma}^2_{x_2}$).

This problem of observational equivalence arises even with work that holds the information constant and finds variation based on partisanship. For example, Bolsen and Druckman exposed individuals to a scientific consensus message about climate change; it caused low-knowledge Democrats and Republicans and high-knowledge Democrats to report greater belief in human-induced climate change[34]. High-knowledge Republicans, however, were unmoved. This is consistent with a prior attitude effect where high knowledge, climate skeptic Republicans discredited the message because it contradicted their prior belief $\pi(\mu)$—the divergence between low- and high-knowledge Republicans may stem from the latter engaging in directional motivated reasoning. However, this outcome is also consistent with an accuracy-motivated Bayesian model in which knowledgeable Republicans have little confidence in a scientific consensus statement due to lack of faith in the climate change scientific community.

Another body of work shows that when individuals receive information counter to their likely beliefs on climate change, they move in the opposite direction of that information (variously called a back-lash, boomerang, or back-fire effect). Zhou randomly

**Table 2 | Updating with accuracy versus directional motivations**

| | Accuracy motivation | Directional motivation |
|---|---|---|
| Goal | Arrive at a 'correct' conclusion about the condition of the world. | Arrive at a predetermined conclusion about the condition of the world.<br>Examples of directional goals include belief maintenance and identity protection. |
| Updating process | Prior belief in question does not affect the process of updating. | Prior belief in question affects the process of updating. |
| | An effect of standing beliefs other than the belief in question is compatible with an accuracy motivation. For example, confidence in the findings of a scientific report determined by prior beliefs about the trustworthiness and expertise of the source. | It can affect:<br>• content of new information received (confirmation bias)<br>• confidence in new information received (prior attitude effect) and/or<br>• extent of counter-argument generation (disconfirmation bias).<br>For example, confidence in the findings of a scientific report determined by whether the findings support or contradict one's pre-determined conclusion. |
| Outcome | If people receive the same information AND interpret it in the same way:<br>• polarization should NOT occur,<br>• divergence can occur (one party remains unmoved by non-credible evidence, for example). | Directional reasoning mechanisms (confirmation bias, prior attitude effect, disconfirmation bias) can lead to divergence or polarization. Disconfirmation bias can result in back-lash. |
| | If people learn different things from the information:<br>• back-lash can occur (for example, from the observer effect)<br>• polarization can occur[7,41] | |

assigned Republican respondents to one of eight experimental treatment messages advocating for greater governmental action against climate change[35]. The messages came from either a Republican or Democratic former congressman and referenced economic, national security, moral justice or natural disaster issues. None of the messages increased Republicans' support for governmental action and three of the eight messages back-fired, leading to significantly less support[1,36–41]. Such back-lash effects suggest a disconfirmation bias whereby climate skeptics whose prior beliefs run counter to the message reject it and then generate counter-arguments that lead them to update in the other direction[22,35,42,43]. (There is some debate on the extent of such back-lash effects[13,16,44,45].)

For many, updating in a direction opposite to new information contradicts accuracy-motivated Bayesian models[20]. Indeed, with the simple Bayesian model in which different individuals interpret $x$ in the same way, back-lash should not occur among accuracy-motivated individuals. However, slightly more complex Bayesian models can accommodate accuracy-motivated individuals updating in the opposite direction of the information[7,39,46]. In essence, these Bayesian models account for the possibility that two accuracy-motivated individuals learn different things from the same new information.

For instance, one can incorporate the possibility that the information is received in a context where the individual is not the target audience. This is akin to Lupia and McCubbins' 'observer effect'[26]. An observer is someone who is not the speaker's target audience. If the observer believes that the speaker possesses knowledge and has contrary interests, then the observer "should take the speaker's advice and do the opposite"[26]. This could cause, for example, a partisan to move in the opposite direction of a message from an opposing party elite. In the aforementioned example, the observed back-firing among Republicans could result from disconfirmation bias (generating $x_c$), or it could result from inferring that the statements ($x$) are meant for an audience with whom they have contrasting interests (Democrats, for example) and then doing the opposite of the suggested statement. They interpret $x$ as the opposite of $x$ (that is, $-x$); they are accuracy processing, but the context generates a distinctive interpretation of the information.

The bottom line is that data showing a preference for like-minded information, polarization of beliefs among partisans or ideologues, and rejection or even contrary movement to a single piece of information are not sufficient to conclude directional motivated reasoning. A constant missing link is the demonstration that a directional goal drives information evaluation, as opposed to variable assessments of what is accurate information[47].

Bolsen et al. is one of the few studies to experimentally manipulate goals[48,49]. The authors provided participants with information about the climate-friendly US Energy Independence and Security Act of 2007. They randomly assigned participants to receive no endorsement of the Act, an endorsement by Democrats or an endorsement by Republicans. Respondents further received a directional prompt to justify their party affiliation, an accuracy prompt to justify their position on the Act, or no motivation prompt. Respondents who received the accuracy treatment displayed no evidence of an endorsement effect. For example, Democrats who received the Republican or Democratic endorsement expressed views consistent with the content of the factual information (that is, no attitude polarization occurred in response to the party cues). Without an accuracy prompt, however, people supported the policy when endorsed by their party but opposed the identical policy when endorsed by the other party (a back-lash effect).

This study has limitations as it involved a single piece of information and explicit processing instructions that may not resemble how people act outside a survey setting. Another threat is motivated responding: telling people they would have to justify their partisan affiliation may have encouraged partisan 'cheerleading'—responding in a way that expressed support for their party, even if their actual beliefs differed. We offer a more detailed discussion of motivated responding in Box 4.

## How to effectively communicate about climate change

Our account emphasizes that the success of any communication depends on the audience's motivation. If an individual strives for accuracy, then communication success requires relaying evidence in which the individual has confidence. While this may seem tautological, it is far from it—a critical point is that what science communicators view as credible, or likely to lead to an accurate belief (a scientific consensus statement, for example) may not be what many of their audience members consider credible.

**Box 3 | Source credibility**

**How does source credibility pertain to motivated reasoning research?**

Much of what people learn about climate change comes from others: scientific sources, political elites, or friends and family. How do we determine whether these and other sources are credible? A source's credibility is largely assessed on two dimensions: trustworthiness and expertise[26,87]. But importantly, source credibility is not an objective measure of a source's trustworthiness and expertise—instead, it reflects a relevant audience's perception of the source on these two dimensions[27].

At times, researchers leap from an observation that respondents deviate from some standard of source credibility to an inference about the respondents' motives. For example, researchers may impute their own beliefs about what should be credible onto a source[88], such as a scientific report, and, when others reject that source, presume that this reveals a motivation other than 'seeking the truth'. This presumption is a mistake: the respondents in question may simply differ with the researcher over whether the source can be trusted. Similarly, although often attributed to directional motivated reasoning, adherence to party cues or the partisan divide on climate change within the public could result from disagreement over who constitutes a credible source. Source credibility is subjective by definition, and different perceptions of source credibility shed no light on motivation. At times, a source's message can affect its credibility—a source (such as a liberal media outlet) who offers a message that is the opposite of what is expected (a critique of a Democrat, for example) may increase its own credibility to some audiences (for example, conservatives)[89,90].

**Why might people differ in their assessments of source credibility?**

Judgments about trustworthiness depend on the audience's perception that the source and the audience have shared goals or values[27,91]. Trust in science and scientists has been an important topic of study in the context of climate change communication[28,43,55,92]. The scientific community's credibility is closely tied to perceptions of their political neutrality and objectivity[93]. In a scientific context, these attributes indicate to an audience that the source's goal is to uncover the truth about some condition of the world, not to further an agenda. In so far as the audience is also interested in the truth about this condition, neutrality and objectivity indicate that the source is trustworthy.

Perception of an ulterior motive—a goal aside from the stated or ostensible goal—can affect assessments of a source's trustworthiness[94]. People might differ in their perception that a source has ulterior motives for a variety of reasons, but with an issue such as climate change, politicization plays an important role. First, with the growth of regulatory science, wherein scientific findings are closely associated with policy implications, individuals may increasingly perceive scientists as motivated by a policy outcome rather than solely by truth[93]. Second, when scientific findings have policy implications, interested actors have incentive to portray the scientific sources either as driven by ulterior motives (such as funding), or as neutral and objective, depending on whether the science supports the actor's policy position[95]. At the extreme, beliefs about ulterior motives can generate conspiracy beliefs[96,97]. Individuals exposed more to one set of portrayals of a source's motives are likely to have different perceptions of that source's trustworthiness than individuals exposed more to another set[98].

In short, individuals may doubt scientific advice because they believe that it is not motivated solely by truth, and will not lead to an accurate belief. This differs from a directionally motivated person who doubts scientific advice because the content of that advice contradicts an existing belief. In both cases, scientific authority is disregarded, but for different reasons.

This leaves communicators with two main options. First, one can attempt—via educational efforts—to alter what others believe to be credible or accurate information. This is difficult, however, particularly when it comes to science. Second, a communicator can identify what type of information an audience finds credible and try to offer evidence of that nature. In the case of climate change, instead of scientific information, people may rely on religion[50,51], or endorsements from religious authorities[52,53]. Alternatively, people may conform to what others do. One study shows that all types of partisans become more likely to take action to address climate change when told of a consensus and that many others take action[54]. When people are accuracy motivated, effective communication requires offering credible evidence and, for many, this is not scientific evidence: less than half of the population has a great deal of confidence in the scientific community (see Box 3)[55].

What about communication when individuals have a directional motivation? With the type of directional reasoning we have discussed so far—belief-protective reasoning—any information that contradicts the prior belief is likely to be seen with little confidence precisely because it contradicts the prior belief. Here, the most effective communication strategy may be to alter motivations, inducing an accuracy goal, as in the aforementioned study by Bolsen and colleagues[48]. The challenge then becomes identifying what techniques can alter processing goals in the real world[3,56,57].

Directional reasoning can take another form: it can instead involve an identity-protective goal, rather than maintenance of a particular belief as the desired outcome (see Table 1)[58]. In this case, new information is evaluated as either threatening or non-threatening to one's identity or values ($I$). An identity can be one's race, ethnicity, partisanship or other group connection (environmentalist, for example)[59], whereas a value is a desirable end state that guides behaviours (privileging equality or security, or, in the political domain, freedom or morality)[60]. Identity and values often shape prior beliefs on an issue.

Identity-protective cognition is a type of directional motivated reasoning in which the goal is maintenance of membership or status in an affinity group, or protection of a value (value-protective cognition)[61]. The evaluation of $x$ is not a function of a particular prior belief, but rather a function (T) of one's identity or values: $T(I \Rightarrow \Leftarrow x)$. For instance, a report on human-induced climate change may threaten free-market values because the report is seen as leading to government intervention at odds with such values. If the new information is threatening to the value or identity, it may be discredited or counter-argued as described earlier. If the new information is non-threatening (such as free-market solutions to climate change), learning can occur[4].

One effective communication strategy with identity-protective reasoning (and also more generally) is framing[35]. Framing occurs when information highlights specific considerations in thinking about a given issue (such as human-induced climate change)[62]. A frame that affirms the identity or value can lead to the new information being evaluated as non-threatening, thereby allowing updating to occur without discrediting or counter-arguing. For example, Wolsko et al. randomly assigned individuals to a control message, an individualizing morality frame (care for the environment) or a binding morality frame (protecting one's homeland)[63]. The authors find that, relative to the control or the individualizing morality frame, conservatives exposed to the binding morality

**Box 4 | Motivated responding**

Research on climate change opinions often relies on survey self-reports. When conducting such investigations, researchers should keep in mind that report and belief are distinct: people might not say what they believe, or believe what they say. Survey respondents may have motive (and little disincentive) to answer in a way that does not reflect their true belief. For example, a respondent may wish to indicate allegiances, to maintain consistency, or to express disagreement with an underlying construct or assumption discerned in the question. This is known as (directional) motivated responding: giving a response that does not accurately represent one's true belief, in an effort to satisfy an alternative goal.

Motivated responding can be thought of as answering a question different from the one that has been asked. For example, although a survey may ask a question along the lines of "Which of the following is true?" a respondent may consider it an opportunity to respond to the question "Which do you prefer?" or "What party/policy do you support?"

Motivated responding can arise with either opinion-based or factual questions, and for a variety of reasons, including when a respondent:

- does not know the correct answer, so instead indicates her preferred answer[99]
- finds the response options dissatisfying (for example, no option accurately represents her true belief, so she instead indicates party preference)
- wants to maintain consistency with her previous responses[100]
- simply prefers to express an attitude on a different question. This might take the form of partisan cheerleading[101] or be a way to express skepticism—of the data on which the question is based[102], for example.

Although often associated with partisanship, note that motivated responding is distinct from following party cues because of inferences drawn from the party label. For example, say that partisan respondents report different degrees of support for a climate-related policy depending on whether it is described as sponsored by a Democrat or a Republican. At least three different phenomena could account for this result:

- information-based cue following: preferences change because inferences about the policy content change
- directional motivated reasoning: preferences change to protect one's party identity
- directional motivated responding: preferences do not change, but responses change to express party support

Motivated responding appears to provide some degree of purely expressive benefit, for example, in response to questions of fact[99,103]. But respondents may reasonably anticipate benefits beyond the purely expressive when choosing how to answer questions about policy preferences. If respondents consider the influence (real or perceived) of public opinion polling on policy debates, they may see incentive to exaggerate their true position, especially when faced with a threat to that position. This may be relevant to findings of a back-lash effect in studies of climate change communication. Indeed, nearly all evidence of back-lash effects in this domain come from studies focusing on policy preferences[1,37,41,54].

frame became much more concerned about, and believing in, climate change. This frame affirmed their patriotic values and they felt comfortable updating their beliefs even if they held climate change skeptical priors[64,65]. Kahan et al. show that a frame accentuating market-based geoengineering as a climate solution leads free-market oriented individuals (who often are climate change skeptics) to become more likely to view climate change evidence as credible[66] (see also ref. [67]). Kahan and co-authors conclude that "framing climate change science with identity-affirming meanings can mitigate… resistance"[66].

Unfortunately, the literature offers little clarity on which frames resonate with whom[41,56,68–70]—for example, others have found no evidence of the effectiveness of certain moral frames[71]. But rather than continually testing the impact of one frame after another, the literature would benefit from exploring the conditions that lead to distinct types of motivations, and then investigating which types of messages resonate in light of motivations and particular prior beliefs, values and identities.

## Unanswered questions

We conclude with four questions that we believe can guide the next generation of research. First, among whom and when is directional motivated reasoning about climate change likely to occur? An initial step is to conduct (experimental) studies that vary goals and isolate how such variation affects information assessment and updating. This would then segue into the identification of conditions under which directional motivated reasoning occurs[5,6]—allowing communication scholars to better understand and predict when a prior belief or standing identity/values will moderate reactions to a message.

Second, when directional motivated reasoning occurs, how do people arrive at a given directional goal? When do people engage in belief-protective processing as opposed to identity-protective processing (and for which identity or value)? Different directional goals lead to distinct reactions to messages and so it is critical to understand who prioritizes what goal and when. Identity-protective processing opens up the possibility of effective framing strategies, but framing may be unproductive in the face of belief-protective processing.

Third, when accuracy motivated, how do different people evaluate the quality of evidence? The literature often assumes a homogenous standard where scientific information or other expert knowledge is uniformly privileged. There may be wide variation in how people assess the quality of evidence and whether they think 'like scientists'[72]. Oliver and Wood estimate that roughly 100 million Americans are intuitive thinkers who do not rely on systematic empirical observation, but rather on more magical thinking (for example, religion, superstition, conspiracy)[73]. Effective communication with accuracy-motivated individuals may require engagement with different kinds of evidence or persuasion about the credibility of scientific evidence.

Fourth, to what extent does directional motivated reasoning drive researchers themselves, and ultimately the scientific process? This question is outside of our purview, but all we have discussed can be used to understand how researchers proceed. The ideal, of course, is that scientists are accuracy motivated and any priors informing their evaluations are based on sound scientific standards. However, scientists are humans and undoubtedly vulnerable to directional motivated reasoning at times[74]. For example, perhaps we inadvertently sought out ambiguous evidence for directional motivated reasoning on climate change (that is, we fell victim to a confirmation bias). Just how much of a potential problem such processes are for scientific progress is an open question[75].

Lest we conclude on a pessimistic note, we want to emphasize that our critiques and questions reflect a maturing literature. The past decade has seen the introduction of the very concepts we discuss here—motivated reasoning, accuracy motivation, framing

and more—to the study of climate communication[76–78]. The next generation will surely evolve to advance what we know about how people form preferences regarding climate change.

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Authors contributed equally to the conceptualization and writing of the paper.

## Competing interests

The authors declare no competing interests.

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