



Attentional and perceptual biases of climate change

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Climate change is the most significant global challenge facing humanity. Despite the unequivocal scientific evidence and the overwhelming adverse impacts of climate change, there is a growing divide in the beliefs on the anthropogenic causes of climate change. To explore the underlying cognitive mechanisms of this divide, we review recent studies revealing a number of attentional and perceptual biases that can give rise to the divergent opinions on climate change. With these cognitive insights in mind, we discuss several communication approaches (e.g. framing, visualization) that have the potential to mitigate the attentional and perceptual biases, with the broader goal of minimizing polarizing views and promoting actions to address climate change.

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Introduction

Climate change has emerged as a significant global issue with unequivocal scientific evidence showing anthropogenic causes. In fact, scientific consensus on climate change has been reached by 90–100% of actively publishing climate scientists according to six independent studies [1]. Despite the overwhelming scientific evidence, some people still remain skeptical about anthropogenic climate change and refuse to take actions to mitigate the adverse impacts. For example in the United States, public opinion tends to polarize along political parties, where 89% of the Democrats see global warming as mainly due to human activities, but only 35% the Republicans do [2]. This gap has not only persisted but grown over time, along with a widening divide in climate policy priorities and support [3]. For example, states where people pay more attention to climate change

and perceive climate change as a threat are more likely to adopt climate policies [4].

What explains the growing divide between different groups? In this paper, we review recent studies revealing a number of attentional and perceptual biases that can give rise to the polarizing views on climate change and subsequent actions. This is also an opportunity to demonstrate how cognitive science can offer unique theoretical perspectives, methods, and evidence to complement insights from social psychology, in the service of addressing global challenges. At the end of the paper, we discuss several communication approaches that target some of the attentional and perceptual biases to minimize the divide and promote actions to mitigate climate change. **Table 1** shows a summary of attentional and perceptual biases and the corresponding communication tools to mitigate these biases.

Attentional biases to climate information

A growing body of evidence suggests that people tend to pay attention to information consistent with their pre-existing beliefs, motivations, and values [e.g. Refs. 6,7]. In the context of climate information, the motivated attention framework has been proposed to describe the attentional biases that are driven by prior motivations and can shape climate perception and actions [5*]. In a series of eye-tracking experiments by Luo and Zhao, participants who were more liberal tended to pay more visual attention to the rising phase of the global temperature curve (after 1990) relative to the flatter phase (from 1940 to 1980). To seek causal evidence for the role of attention in climate actions, the authors manipulated attention by highlighting the rising phase (i.e. stronger climate change evidence) in red in one condition, and highlighting the flatter phase (i.e. weaker climate change evidence) in red in another condition. By deliberately drawing their attention to the rising phase the global temperature curve, liberals were more likely to sign climate petitions and to donate to environmental causes than when attention was drawn to the flatter phase. However, this effect was absent for conservative participants. This framework suggests that people with different political orientations have different attentional biases to climate change information, and these biases can alter their subsequent climate actions [5*].

In addition to global temperature information, another study using an attentional blink paradigm showed that liberals high in climate concerns were more accurate at

Table 1

Attentional and perceptual biases and the corresponding communication tools

Type of bias	Examples	Communication tools
Attentional	<p>People with different political orientations attend to different aspects of global temperature information [5*]</p> <p>People concerned with climate change attend more readily to climate-related words or images [8*,9]</p> <p>Attended environmental risks are judged to be more severe than unattended risks [11*]</p>	Align climate communication with people's ideologies and motivations to capture their attention
Perceptual	<p>Predispositions (e.g. knowledge, personal experience) increase climate risk perception [13,14]</p> <p>Perception of both in-group and out-group norms of climate beliefs can be biased [15–18]</p> <p>Perception of greenhouse gas emissions associated with individual actions or objects is often incorrect [21–23,24*]</p>	<p>Frame climate change consistently with people's values</p> <p>Provide accurate information on in-group and out-group norms</p> <p>Simplify complex information through visualization</p>

identifying climate-related words (e.g. carbon) than neutral words (e.g. coffee) in a rapid serial visual presentation; in contrast, conservatives low in climate concerns were no better at seeing climate-related words over neutral words, suggesting that people with different political orientations show distinct attentional priorities to climate change [8*]. Another study used a dot-probe task [9], where a climate-relevant image and a neutral image were presented on the left and the right side of the screen, followed by a target dot presented briefly on one side of the screen, and participants had to respond to the location of the dot as fast as they could. The response time difference between the two image locations was used to measure the attentional bias to climate change. For example, faster responses to the dot presented on the same side as the climate-relevant image than the neutral image would indicate an attentional bias toward climate image. The findings showed that people with greater pro-environmental attitudes were faster to respond to climate change-relevant images (e.g. melting ice) than to neutral images (e.g. buildings), suggesting a greater attentional bias to climate change stimuli for these individuals [9]. In a follow-up experiment, positively valenced images of climate change solutions (e.g. windmills) captured attention more strongly than negatively valenced images of causes (e.g. pollution) and effects of climate change (e.g. flood) [10].

Greater attention to climate change is not only a product of prior attitudes and orientations, but also a cause for greater concerns for climate change. In a series of spatial cueing experiments by Mrkva *et al.*, participants viewed images of environmental risks (e.g. hurricane) and their attention was drawn to a subset of these risks either through bottom-up salience or top-down guidance. It was found that participants subsequently rated attended risks as more severe, more frightening, and of higher priority than unattended risks, suggesting that attention can increase risk perception [11*].

These studies together provide evidence for a central tenet in the motivated attention framework [5*], where prior beliefs and motivations shape visual attention to climate change, and increased or decreased attention to climate change in turn reinforce prior beliefs and motivations, thus creating a positive feedback loop, leading to more polarized views. This framework is based on previous work on motivated reasoning. For example, the identity-protective cognition thesis suggests that people with high numeracy skills use their quantitative reasoning capacity to selectively interpret quantitative information on controversial issues like climate change to comply with their prior political values [6,7]. Likewise, people with high science literacy and education tend to show greater polarization on controversial topics, because they are more proficient in interpreting evidence in the direction conforming to their identity [12]. Attention could be a mediator of motivated reasoning: people with higher numeracy skills and science literacy are more capable of selectively attending to information consistent with their motivations during the reasoning process, and the resulting interpretation can further reinforce their pre-existing motivations.

Perceptual biases of climate change

Attentional biases can often give rise to subsequent perceptual biases. For example, in the eye-tracking experiments mentioned earlier, more dwell time on the rising phase of the global temperature curve relative to the flatter phase was positively correlated with higher estimates of global temperature [5*]. Greater visual attention to images of environmental risks can heighten the perception of risks [11*]. A conceptual model proposed that the perception of climate risks is determined by a number of factors, including knowledge about the causes, impacts, and responses to climate change [13], personal experience with extreme weather events, and social norms [14]. Under the motivated attention framework, it is conceivable that greater knowledge about climate change can bias attention to climate-related information,

which can generate more knowledge and higher perceived climate risks. Personal experience with extreme weather events can increase the salience of climate-related information, in similar ways as people with post-traumatic stress disorder tend to perceive greater threats of certain stimuli that trigger the stress response. In other words, the relationship between climate risk perception and factors such as knowledge and personal experience can be moderated by attentional and perceptual processes.

Regarding social norms, the perception of out-group norms can be biased. One account suggests that people often exaggerate the degree of opposition from out-group members, forming a false sense of polarization on climate change [15,16]. The misperceived out-group norms can be a psychological barrier to bipartisan climate policy making in the U.S. In addition, the perception of in-group norms can be biased as well. In one study, people are less willing to share their true opinions on climate change if they believe other in-group members hold different views on climate change [17]. This may suppress different voices to be heard within the group, thus distorting the perception of in-group norms. This said, speaking up can sometimes backfire. For example, conservative individuals remain skeptical about climate change even when the message is conveyed by a religious authority who aligns with conservatives' values. In one study, conservative individuals perceived Pope Francis to be less credible after becoming aware of the encyclical stating that climate change is a serious issue [18].

Beyond attention, a number of biases have been found to shape the perception of climate change information, contributing to greater polarization. People who regard the economic system as justified (i.e. system justification bias) are motivated to falsely recall climate evidence to be less serious, which is associated with higher skepticism in the existence of climate change [19]. Another bias is that people selectively expose themselves to news media that is consistent with their dispositional motivations, which can further reinforce their pre-existing beliefs about climate change [20].

In addition to selective perception, many people are skeptical about human-caused climate change because they do not understand the mechanism of greenhouse gas (GHG) emissions. One study showed that people have virtually no knowledge of the chemical or physical mechanism of global warming, particularly the carbon dioxide accumulation problem, which could lead to the denial of the existence of global warming [21]. However, when an explanation of the mechanism was provided, people are more likely to believe in climate change [22].

Another perceptual bias is the underestimation of carbon footprints associated with actions or objects. One study

found that people tend to underestimate the GHG emissions associated with individual actions and they are incapable of translating the climate impacts across different actions [23]. Another study demonstrated the negative footprint illusion, which is the tendency to estimate a lower carbon footprint of a combined group of environmentally friendly items and ordinary conventional items, than the carbon footprint of conventional items alone, even though the combined group contains more items [24*]. These findings suggest that the perception of GHG emissions is often incorrect and there is a large gap between what they think they know and what is the reality.

Designing climate communication tools

So far we have reviewed a number of attentional and perceptual biases that can contribute to the divergent opinions on climate change. With these cognitive insights in mind, we will discuss several communication approaches (e.g. framing, visualization) that have the potential to mitigate the attentional and perceptual biases, with the broader goal of minimizing polarization and promoting actions to address climate change.

Since people with different political orientations show different attentional biases to global temperature information, climate communication needs to align with the ideological beliefs and motivations to capture people's attention. For liberals or people who are concerned about climate change, one method is to draw their attention to salient climate change information, such as rising global temperature and climate solutions, to encourage them to take climate actions. However, for conservative individuals or people who are skeptical about climate change, drawing their attention to the rising global temperature may backfire [5*]. An alternative approach could be to draw their attention to aspects of climate change which are more consistent with their ideologies (e.g. national security, public health).

Another approach is to frame climate change consistently with their values, such as framing actions that mitigate climate change as benefiting collective economic development or building a more moral and caring community [25], or framing pro-environmental options as benefits for future generations [26]. While these are gain frames, loss frames can also be used to highlight the potential losses from a collective failure to address climate change [27]. To avoid negative reactions, carbon offsets can be framed as an upstream remedy for service provider's actions (e.g. flight fuel production) rather than a downstream tax imposed to consumers' behavior (e.g. airplane travel) [28]. Other positive frames include promoting national security, Christian stewardship, and public health, but they were largely ineffective in changing climate beliefs; however, one negative frame on climate change denial significantly reduced conservatives' belief in climate

change and their support for climate policy [29]. Since the perception of in-group and out-group norms is often biased, one approach is to provide accurate information on social norms for both in-groups and out-groups [16], and also ensure that the source of evidence is credible to the specific group [30].

To mitigate the gap between perception and reality, one method to inform people about GHG emissions of actions and items is to use simple, accessible, and interactive visualizations [31]. For example, showing the extent of GHG emissions of the life cycle of food with light-bulb minutes can effectively deter consumers from purchasing food with higher emissions [32]. When presenting future global temperature information, providing individual model estimates in addition to the statistical range can be an effective tool to influence policymakers [33]. Thus, simplifying complex climate change information and providing more transparent information can correct the misperceived reality of climate change.

Another communication tool is to create an open-minded state to encourage the acceptance of climate change, such as offering a self-affirmation task before exposing people to climate information [34], encouraging discussions on global warming with friends and family to learn influential facts [35], sharing information from the opposite partisanship [36], or providing additional information that explains the scientific consensus information [37,38]. In designing specific communication methods, we should target-specific cognitive processes associated with the audience group to effectively persuade people, for example, correcting distortions in their memory with repeated engagement or implementing retrieval cues [39].

Communicating climate evidence to the public and correcting misperception of climate change are only the first steps. The ultimate goal is to promote personal actions to mitigate climate change. Several studies have shown that climate change risk perception does not fully reflect a behavioral willingness [40,41] and people with low cognitive resources have difficulties to project their pro-environmental attitudes to daily pro-environmental behavior [42]. Thus, future studies need to focus on translating attitude to actions to mitigate climate change. In the last decade, interventions based on behavioral insights have gained a lot of traction as tools to address climate change. For example, providing the increasing prevalence of vegetarian diets increased meatless meal orders [43]. However, a recent meta-analysis of randomized controlled trials showed that many interventions to change household behaviors had a small effect on actual climate change mitigation actions and failed to sustain behavior change over time [44*]. Given this finding, effective and lasting behavioral interventions remain to be discovered.

Conclusions

The current review provides an exploration of the attentional and perceptual biases that can contribute to the divergent opinions on climate change. As the need to address anthropogenic climate change becomes increasingly urgent, it is imperative to promote effective solutions to change human behavior using cognitive insights. This is also an opportunity to demonstrate the value of cognitive science in addition to social psychology in solving global challenges. As an initial effort, we have provided a number of communication approaches that have the potential to reduce polarization and promote climate actions.

Conflict of interest statement

Nothing declared.

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