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When beliefs and evidence collide: psychological and ideological predictors of motivated reasoning about climate change

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ABSTRACT

Motivated reasoning occurs when we reason differently about evidence that supports our prior beliefs than when it contradicts those beliefs. Adult participants ($N = 377$) from Amazon's Mechanical Turk (MTurk) system completed written responses critically evaluating strengths and weaknesses in a vignette on the topic of anthropogenic climate change (ACC). The vignette had two fictional scientists present prototypical arguments for and against anthropogenic climate change that were constructed with equally flawed and conflicting reasoning. The current study tested and found support for three main hypotheses: cognitive style, personality, and ideology would predict both motivated reasoning and endorsement of human caused climate change; those who accept human-caused climate change will be less likely to engage in biased reasoning and more likely to engage in objective reasoning about climate change than those who deny human activity as a cause of climate change. (144 words)

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It is obvious that we live in an ever polarised society, split into incommensurable political and ideological camps. Whatever the number and kind of divisions we wish to make–whether Blue/Red, Urban/Rural, or Smart/Just/Free/Real America (Packard, 2021)–it is clear that people live more and more in different worlds where they only get information that their already agree with and have trouble understanding how other groups can think and believe what they do. Social media and personalised feeds of news and

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Portions of these findings were presented at the 2016 Western Psychological Association, Long Beach, CA and the 2015 Society for Social Studies of Science, Denver CO.

information have only exacerbated this trend (Baum & Potter, 2019; Sinatra & Lombardi, 2020).

One psychological construct that can shed light on the effects of siloed information processing is motivated reasoning, which addresses the question: How do we reason about information when it either confirms or contradicts our previous beliefs? Clearly, different people respond differently when presented with information that contradicts what they already know and think. Some are highly guarded and closed to new and challenging information, whereas others are more open and tolerant of it. An exemplar of motivated reasoning was provided by Donald Trump's recent statement about his views on political polls: "If it's bad, I say it's fake. If it's good, I say that's the most accurate poll ever." (Cillizzia, 2021).

The question, therefore, is: What causes these differences in reasoning? The current study examines how people are motivated to reason differently after receiving information that is consistent with or challenges their prior belief system and attempts to understand the individual differences and psychological factors involved in that process. More specifically, we conducted a study that examined the predictive effect that three psychological processes have on reasoning about consistent and inconsistent information about a politically charged debate, namely climate change. The three predictive psychological processes are cognitive style, personality, and ideological attitude.

Beliefs about anthropogenic or human-caused climate change (ACC) are a prime candidate for motivated reasoning due to politicised campaigns of disinformation to confuse and misinform the public about the science behind it (Lewandowsky, 2021; Mooney, 2011). A frequent complaint about how climate science has been discussed in the news is the representation of "two-sides to the debate." Although the available scientific evidence overwhelmingly supports anthropogenic climate change, news sources, however, often have two individuals debating the merits of two competing views. Cook and colleagues (2013), for instance, reviewed 11,944 scientific paper abstracts and found that of those that offered an opinion on ACC, 97.1% of scientists agreed that it is occurring. Only 27% of American adults, however, know that science has reached a consensus about human-caused climate change and only 65% of Americans agree with that consensus (Gallup, 2016).

The practice of journalistic "balance," can lead to an issue being falsely presented as not settled scientifically when in fact it is (Boykoff, 2008; Boykoff & Boykoff, 2004; Lewandowsky, 2021). For example, Boykoff (2008) analysed news programming on climate change in the U.S. for major news outlets (e.g. news from ABC, CBS, CNN, NBC) from 1995 through 2004. Boykoff's analysis found that 70% of climate change coverage had

"balanced" explanations–highlighting both human-behaviour and natural variations in the climate as potential causes. On a positive note, there is evidence that the journalistic practice of balance seems to have improved over the last 15 years. In a review of print news media on climate change in Germany, India, the U.K. and the U.S., researchers' found a shift from journalistic balance to greater contextual framing when presenting arguments related to ACC denial (Brüggemann & Engesser, 2017). However, print news outlets still highlighted views that are contrary to the scientific consensus, while also playing up the narrative of two competing camps (the "warners vs. deniers"; Brüggemann & Engesser, 2017). Regardless of whether contextual framing of ACC denial is present or not, prominent ACC deniers have been found to be disportionately presented in the media (Petersen et al., 2019). A reasonable consequence to the journalistic practices of highlighting dissenting views related to ACC is that some people will have an incorrect understanding of the consensus among scientists on ACC.

But why are people so easily dismissive of information that contradicts their beliefs? A core assumption in the current investigation was that although reasoning is primarily a cognitive activity, it is not only cognitive. Rather, a person's motives, values, beliefs, personality, emotions, and life experiences all impact how they reason. Indeed, this assumption stands at the centre of motivated reasoning.

Motivated reasoning

The starting point for the research on and theory of motivated reasoning is motivation shapes how we construct beliefs and evaluate evidence (Bayes & Druckman, 2021; Kahan, 2015a, 2015b; Klaczynski, 1997; Kruglanski et al., 2020; Kunda, 1990; Ripberger et al., 2017; Slothuus & De Vreese, 2010). Kruglanski and colleagues (2020) go so far as to say that all reasoning has motivational aspects and the dichotomy between motivational and cognitive forms of processing information is a bogus and false dichotomy. The general idea of motivated reasoning theory is that the stronger people's beliefs are tied to their values, their attitudes, their identity and their lifestyle, the more they will be motivated to dismiss ideas or information that challenges their beliefs. The flipside to this is they will also readily take in and accept information that confirms and is consistent with their values, attitudes, beliefs, and lifestyle.

From the outset, however, researchers have distinguished between two primary forms of motivated reasoning, namely directional and non-directional (aka, accuracy) (Bayes & Druckman, 2021; Druckman & McGrath, 2019; Kruglanski & Klar, 1987; Kunda, 1990). In directionally motivated reasoning, the person is unwittingly intent upon arriving at a conclusion that fits with

prior beliefs; in non-directional/accuracy motivated reasoning the person is driven mostly by a desire to arrive at accurate and valid conclusions. Moreover, directionally motivated reasoning can be driven by many different goals and values: maintaining a sense of identity or status with a group (social identity protection); maintaining coherence of opinion in a group (social consensus seeking); being consistent with scientific norms and evidence (scientific consensus seeking); maintaining a moral or ideological belief system (value affirmation); and maintaining a prior belief (belief consistency seeking) (Bayes & Druckman, 2021). Other scholars have argued that directionally motivated reasoning can be driven by a need to protect one's ego; that is, if people's sense of self, identity, and values are challenged and threatened, they intuitively defend and protect themselves and their belief system by rejecting and arguing against that challenging information (Klaczynski & Narasimham, 1998; Lindeman, 1998).

To be clear, motivated reasoning is intrinsically related to, but distinct from, confirmation bias and cognitive dissonance. Confirmation bias is viewed as the act of seeking evidence that confirms prior beliefs (Nickerson, 1998). Nickerson (1998) reviewed scientific literature on the topic of confirmation bias and stated that confirmation bias, in part, encompasses a lack of awareness towards alternative evidence, unfounded preference for confirming information, and a bias for positive sources versus negative sources of information (i.e. the addition of information instead of the absence). Confirmation bias can be viewed as half of the motivated reasoning machinery, the other half being the disconfirmation bias. As the name implies, disconfirmation bias is the preference for disconfirming certain sources of information. The confirmation and disconfirmation biases work in tandem to motivate an individual's reasoning to a specific conclusion. In essence, confirmation bias is a component of motivated reasoning. Confirmation bias, however, leaves out non-cognitive mechanisms such as motive and value.

Over the last decade a growing body of evidence has used motivated reasoning theory to explain how people reason about climate change information (Bayes & Druckman, 2021; Druckman & McGrath, 2019; Kovaka, 2021; Ripberger et al., 2017; Sinatra et al., 2014). In general, this research supports the role that motivated reasoning plays in evaluating evidence of climate change, but it is not all directionally motivated reasoning. Although Druckman and McGrath (2019) argue that motivated reasoning does influence climate change attitudes, they believe it is often accuracy-based more than directional motivated reasoning that is involved. That is, people are motivated to be accurate but they differ in their assessment of what sources are credible. In addition, they argue that the process of updating beliefs to new evidence can be explained using a Bayesian framework. If someone

views the source of information as credible they update their prior beliefs; if they view it as not credible, they do not update their belief. Supporting this Bayesian approach, Ripberger and colleagues (2017) found that regardless of prior beliefs on ACC, people were able to accurately detect changes in climate over an 11 year period. Ripberger and colleagues did find small differences in perception of changes based on prior beliefs, but overall the effect was small. We should point out, however, that Ripberger and colleagues did not evaluate the explanations for changes in climate data but rather just whether people could perceive them. Still, other researchers have made similar arguments, for instance, in some cases it can be rational for two individuals with contrasting prior beliefs to arrive at polarised conclusions from the same data (Jern et al., 2014). Additionally the difficulty in teasing apart directional versus non-directional reasoning has been noted by a number of researchers (e.g. Druckman & McGrath, 2019; Jern et al., 2014; Tappin et al., 2020). Lombardi and colleagues (2016) argued that the plausibility of the evidence is a critical factor in whether people–both scientists and laypeople–change their minds. Their model of plausibility includes both cognitive (epistemic disposition) and non-cognitive (motivation and emotion) factors. Finally, Kovaka (2021) argues that motivated denial of ACC happens even when people claim to be pro-science due to their misconceptions and misinterpretations of the scientific method and evidence.

The primary purpose of the current study is to examine which of the following psychological processes are the strongest predictors of the tendency to engage in motivated reasoning concerning evidence about climate change: information processing/cognitive style, personality, and ideology (authoritarianism, conservatism, and traditionalism).

Predictors of motivated reasoning

Cognitive style

Cognitive style, information processing, and epistemic motivation are global constructs that describe individual differences in people's preferred ways of organising and processing information (Amit & Sagiv, 2013; Messick, 1976, 1984; Stanovich et al., 2016). We believe that how people process information and tend to think will be related to their tendency to engage in motivated reasoning.

Perhaps the most influential model of processing information to be discussed by psychologists is the so-called "dual processing" model. Over the decades, beginning with Freud, many psychologists have proposed the presence of two distinct systems for processing information (Epstein, 1990, 1994; Freud, 1900/1981; Kahneman, 2011). These dual process theories have been discussed in varying terms, but the most recognisable is

System 1 and System 2 (Kahneman, 2011). System 1 involves automatic, associative, fast, intuitive, and effortless processing, whereas System 2 involves controlled, deductive, slow, and effortful processing (Evans, 2011; Evans & Over, 1996; Kahneman, 2011; Kahneman & Frederick, 2002; Stanovich et al., 2016; Stanovich & West, 1998; West et al., 2008).

Dual-processing models of information processing can shed light on reasoning differences. People often respond with quick, intuitive and automatic System 1 processing when confronted with challenging information. They may then develop deliberative, reflective and effortful reasons for these beliefs, but the foundation of their response is intuitive and automatic. Haidt (2001), for instance, showed how moral judgments are often caused by automatic, gut reactions, and the reasons for these moral judgments occur only after it has already been made. Dual processing approaches have shown that certain kinds of automatic processing are linked to poorer reasoning and sometimes even delusional thinking (Ball et al., 2018; Bronstein et al., 2019; De Neys, 2012, 2018; Ward & Garety, 2019). In general, the act of reflecting upon information and the ability to detect conflicts are important aspects of sound reasoning.

In addition to information processing, there are at least three distinct modes of cognitive style or epistemic motivation that we believe impact motivated reasoning, two of which should be negatively related to motivated reasoning (need for cognition, scientific attitude), and one of which should be positively related (dogmatism) (cf. Amit & Sagiv, 2013; Neuberg et al., 1997; Stern & Axt, 2020).

First, need for cognition is a non-dichotomous cognitive style and is defined as "an individual's inclination to pleasurably participate in thinking" (Cacioppo & Petty, 1982, p. 119). People who are curious, enjoy solving complex problems, enjoy science, and engage in critical thinking have a high need for cognition. Need for cognition has been researched in numerous ways, including its relation to interest in science, beliefs, intelligence, political orientation, personality, and religiosity (Feist, 2012; Kardash & Scholes, 1996; McAuliff & Kovera, 2008; Pennycook et al., 2014; Pennycook & Rand, 2019; Sadowski & Cogburn, 1997; Woo et al., 2007). For example, research has demonstrated that higher need for cognition levels are associated with critical thinking abilities. Kardash and Scholes (1996) presented undergraduate students with two separate pieces of texts that gave two conflicting arguments on whether or not AIDs came about from HIV. Participants then wrote a concluding paragraph to the texts. Results showed that those who scored higher in need for cognition were more likely to expand on the inconclusiveness of the varied evidence to which they were subjected.

Second, as BF Skinner argued back in the 1950s, science is first and foremost an attitude (Skinner, 1953). Specifically, he put forth three core attitudes of scientific thinking, namely a willingness to accept facts even when they go against our wishes; intellectual honesty or objectivity; and a willingness to avoid premature conclusions or to be open-minded. We can add to this list rationality, scepticism, curiosity, and aversion to superstition (Billeh & Zakhariades, 1975; Lacap, 2015). In theory, people who reason and think scientifically should be less likely to engage in motivated reasoning those those who do not.

Third, dogmatism is a cognitive style that stands in opposition to open-mindedness, need for cognition, and scientific attitude. It is defined as "unjustified certainty" (Altemeyer, 1996, p. 201). Altemeyer reasoned that those who are high in dogmatism are more likely to be driven by directional goals in reasoning than those who score lower in dogmatism. Researchers found that dogmatism is negatively related to need for cognition and rational engagement, but positively related to the following: experiential engagement (i.e. use of intuition and emotion during decision making), a personal need for structure, close mindedness, and right-wing authoritarianism (Crowson et al., 2008).

Personality

Another proposed predictor of motivated reasoning is personality. Beginning in the 1980s, the study of personality converged on the presence of five dominant personality traits, commonly known as the Five-Factor Model (FFM) or the "Big Five" (Digman & Inouye, 1986). The five traits are openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. Beyond its' relationship with need for cognition, personality has been connected to a wide range of constructs, many of which are related to motivated reasoning.

Given that motivated reasoning is a defensive response to information that contradicts our beliefs, we predict the personality dimension of openness to experience should be negatively related to motivated reasoning. There have been very few studies, however, directly examining motivated reasoning and personality traits. One exception has been Stanovich and West (1997), who had college students evaluate an argument after stating their own beliefs on the matter. Students were explicitly asked to evaluate the quality of the argument regardless of their prior belief. The quality of the student's evaluation was its match with the objective expert rating. Stanovich and West then created a composite "open-minded thinking" score that was the sum of personality traits of openness to ideas and values, plus a flexible thinking score minus absolute, dogmatic and categorical thinking scores. They found that the objective expert ratings of argument

quality were a strong predictor of the students' ability to evaluate the argument independent of their prior beliefs. In addition, open-minded thinking skills were correlated with the ability to divorce one's prior beliefs from one's evaluation of an argument's quality.

Ideological beliefs

Political orientation and belief are important influences on motivated reasoning because political beliefs, especially strongly held ones, stem from and are consistent with one's values, goals, ideals, and motives. In this sense, they are directional. Few areas of life lead to more motivated reasoning about evidence than political ideology. People generally believe evidence that confirms their political beliefs and are critical towards evidence that contradicts them.

Duckitt and colleagues (2010) argued for three related but distinct ideological dimensions: authoritarianism, traditionalism, and conservatism. We believe these dimensions form a triad of ideological beliefs that will explain variance in motivated reasoning on climate change. Traditionally, authoritarianism and conservatism have been linked (Adorno et al., 2019; Altemeyer, 1996). Yet, as more recent scholars have pointed out, authoritarianism is more a disposition to be intolerant of difference and diversity and a preference for simplicity than it is per se for law and order through harsh punitive measures (Appelbaum, 2020; Stenner, 2009). This view is better able to explain left- and right-winged authoritarianism. Traditionalism consists of attitudes that favour upholding old-fashioned social norms and moral codes, such as prohibition of premarital sex, believing that marriage is between a man and woman, and that attending religious services regularly is a good thing (Duckitt et al., 2010). Political conservatism generally can be defined as wanting to preserve traditional values and ideals and to have less government intervention in people's lives (*Conservatism*, n.d.). Connected to political conservativism is belief and activity in organised religion.

Conservative political and religious views have been linked to disbelief and/or denial in anthropogenic climate change (Gallup, 2016; Lobato & Zimmerman, 2018; McCright, 2011; Pew Research Center, 2016; Stanley & Wilson, 2019). In general, self-identified liberals and Democrats are more likely to identify with pro-environmental views than their more conservative counterparts (McCright, 2011; Stanley & Wilson, 2019). In 2016 Pew Research Center (2016) reported that 15% of conservative Republicans, 34% of moderate Republicans, 63% of moderate Democrats, and 79% of liberal Democrats endorsed ACC. Trends between 2006 and 2016 show the political divide on ACC acceptance to be relatively constant, with a trend upwards (from 53% to 69%) for Democrats and a slight trend downwards

for Republicans (from 28% to 23%) (Bayes & Druckman, 2021). More recently, however, the overall rate of ACC endorsement appears to be rising in the U.S., with 79% of Americans overall endorsing it (60% for Republicans and 90% for Democrats) (Dennis et al., 2019).

As Hart and Nisbet (2012) reported, receiving factual information about controversial topics like climate change can and does lead to a "boomerang effect," whereby after exposure to scientific information, politically conservative sceptics become even more sceptical of ACC than before the information. They argue that motivated reasoning and social identity are behind the increased polarisation in attitude following information. Similarly, McCright and Dunlap (2011) found robust evidence for differences in anthropogenic climate change belief based on levels of conservatism in 10 separate nationally representative polls. They examined a number of nationally representative samples from the years 2001–2010 and found that educational attainment and understanding of climate change beliefs were moderated by political beliefs. Lastly, in 2019 a Pew survey of U.S. adults reported that the amount of scientific knowledge an individual had was associated with a decrease in support for ACC in Republicans but an increase in Democrats (Funk & Kennedy, 2020).

Hypotheses

Hypothesis 1: Cognitive style, personality, and ideology will predict motivated reasoning (MR) about climate change after holding demographic variables (age, gender, college education) constant. In particular, we predicted that variance in motivated reasoning will be explained by the predictors of need for cognition, openness, scientific attitude, neuroticism, conservatism, dogmatism, authoritarianism, traditionalism together and individually.

Hypothesis 2: Cognitive style, personality, ideology will predict belief in anthropogenic climate change (ACC) after demographic variables (age, gender, education) are held constant. In particular, we predicted that variance in ACC will be explained by the set of predictor variables: neuroticism, conservatism, dogmatism, authoritarianism, traditionalism, need for cognition, openness and having a scientific attitude. We also predicted each of these variables individually will explain variance in ACC belief.

Hypothesis 3: We expected that those who accept human caused climate change (ACC) will be less likely to engage in motivated reasoning about climate change than those who deny human activity as a cause of climate change.

Method

Procedure

The survey software Qualtrics was used for data collection in conjunction with Amazon's Mechanical Turk (MTurk). All data were collected online. The participants completed an informed online consent form prior to starting the study by clicking a box that stated they had read and consented to participate. Participants were first exposed to two vignettes of hypothetical but plausible scientific studies made to have an equal number of methodological strengths and weaknesses (see Appendix A for vignettes). Participants then completed, at their own pace, written vignette responses where they identified the study's strengths and weaknesses, two scales from the Big Five Inventory (openness to experience and neuroticism), a need for cognition measure, a measure of dogmatism, conservatism measure, an adoption of scientific attitudes measure, and a demographic and belief questionnaire. Next, all psychological and ideological measures as well as the belief questionnaire were randomly ordered in their presentation to participants. The demographic questionnaire was always presented after the above measures. Before completion, participants were asked a validity check question of "Did you answer all of the previous questions honestly and to the best of your ability?" Lastly, participants were debriefed and thanked for their participation as well as given a task completion code for payment on the MTurk system.

Participants and design

Participants

Amazon's Mechanical Turk (MTurk) was used for the participant pool for data collection. MTurk is a crowdsourcing surveying system and has been found to offer a more representative sampling procedure than that of convenience samples and also is a valid sampling technique for political ideology (see Berinsky et al., 2012; Buhrmester et al., 2011; Clifford et al., 2015; Thomas & Clifford, 2017). MTurk respondents are "workers" who are reimbursed small amounts of money by the researchers for their participation. Participants were limited to only those who lived in the United States, which was verified by IP address. All participants were 18 years old and above.

The total collected sample consisted of 477 participants. Thirty-one participants were removed from analysis for either not giving consent, missing at least one of the three filter questions (e.g. "please select '4' for this answer"), or not completing the majority of the survey. One participant was removed for analysis for answering no to the last question of the survey,

"Did you answer all of the previous questions honestly and to the best of your ability?" This reduced the number of participants to 446. An additional 69 participants (15.47%) were removed from the vignette ratings due to not answering the prompt. In all, 377 participants provided rated vignette responses. To check for differences in attrition within vignette responses, we dummy coded missing data groups (0 = missing; 1 = not missing) across important variables. We determined there were no mean differences between missingness groups on age (t (88.33) = −1.40, p = .16), gender (t (97.9) = −1.30, p = .18) or belief in ACC (t (94.8) = .60, p = .56).

Measures

Demographic and predictor variables

A questionnaire asking about age, gender, parental education, income, religious affiliation/belief, ethnicity, and country of residence was administered.

Cognitive style. Three measures of cognitive style were administered: need for cognition, scientific attitude, and dogmatism. The short form of the Need for Cognition Scale (NFC) assessed cognitive style (Cacioppo et al., 1984). The NFC is an 18 item, self- report Likert scale and is a revision of Cacioppo and Petty's longer "Need for Cognition Scale" (1982). The two Need for Cognition scales were correlated at .95 (Cacioppo et al., 1984). The scales' responses range from 1–5, with: 1 = extremely uncharacteristic; 2 = somewhat uncharacteristic; 3 = uncertain; 4 = somewhat characteristic; 5 = extremely characteristic. Nine of the 18 items are reverse scored. Cacioppo et al. (1984) reported a Cronbach's alpha coefficient of .90. Additionally, other researchers have reported test-retest reliability of .88 (Sadowski & Gulgoz, 1992). Sample items include the questions: "I would prefer complex to simple problems" and "The notion of thinking abstractly is appealing to me."

One scale from the Test of Science-Related Attitudes (TOSRA) scale was administered, namely the Adoption of Scientific Attitudes (ASA) (Fraser, 1981). It assesses one's disposition towards curiosity, willingness to revise one's opinion, and open-mindedness, traits listed by eminent scientists as being important in their scientific work. The ASA is a 10-item scale and has a Likert response, ranging from strongly agree to strongly disagree. Cronbach alpha reliability coefficients for the ASA in four separate samples ranged from .64 to .69 and had a one year test-retest reliability of .75 (Fraser, 1981). For the current sample (N = 439), Cronbach alpha was .76. Example items include: "I enjoy reading about things which disagree with my previous ideas" and "I am curious about the world in which we live."

Dogmatism, defined as "unjustified certainty," was measured with the Dogmatism (DOG) Scale (Altemeyer, 2002). The DOG Scale is a 20-item measure with Likert scale responses ranging from −4 to +4, which we changed from 1 to 9, representing: "very strongly disagree" to "very strongly agree" (Altemeyer, 2002). Items from the DOG Scale include: "I am so sure I am right about the important things in life, there is no evidence that could convince me otherwise" and "I am absolutely certain that my ideas about the fundamental issues in life are correct." Researchers have reported Cronbach's alpha coefficients between .90 and .93 in three samples (Crowson et al., 2008). In the current sample the Cronbach alpha was .91 ($N = 446$) for the DOG Scale. The DOG Scale has acceptable levels of both validity and reliability (Crowson, 2009). Three cases were had missing values for various items so we use expectation maximisation imputation to impute missing values before summing items.

Personality. Two personality dimensions were measured using the Big Five Inventory (BFI): openness to experience and neuroticism (John & Srivastava, 1999). The BFI measure consists of 18 items with a 5-point Likert scale. Sample items include: "I see myself as someone who is curious about many things" and "I see myself as someone who is relaxed, handles stress well." The five dimensions of the BFI have test-retest reliability coefficients of .80-.90 (John et al., 2008; John & Srivastava, 1999). In the current sample, Cronbach alpha reliabilities were .84 ($N = 438$) for Openness and .91 ($N = 440$) for Neuroticism. Further evidence for the validity of the BFI can be found in John and Srivastava (1999).

Ideology. The Authoritarian-Conservatism-Traditionalism (ACT) Scale measured conservatism, more specifically social conservatism (i.e. in contrast to economic conservatism), authoritarianism, and traditionalism (Duckitt et al., 2010). The ACT Scale is a 36-item 9-point Likert agreement response scale. Example items include: "What our country needs most is discipline, with everyone following our leaders in unity" and "It is important that we preserve our traditional values and moral standards." Reliability coefficients for ACT ranged from .83-.94 in five separate samples (Duckitt et al., 2010). In the current sample, Cronbach alpha ($N = 419$) was .97 for the ACT scale as a whole.

Prior beliefs about climate change. Participants completed a short three-item questionnaire related to beliefs about climate change called the Brief Climate Change Belief Questionnaire (Caddick, 2015). The three items each answered "yes" or "no" were: "Do you believe that climate change (i.e. global warming) is occurring," "Do you believe that human activity is primarily

causing climate change (i.e. global warming)," and "Do you believe that addressing climate change will cause an unnecessary tax burden." Responses to the second question about whether humans are causing climate change formed the participant's status on ACC.

Motivated reasoning vignettes. Participants completed written responses critically evaluating a vignette on the topic of anthropogenic climate change. The vignette introduced fictional scientists who speak as authorities on the issue of ACC, with one in support and one against ACC. The scientists were created to have comparable credentials and present similarly flawed reasoning in support of their belief. The vignette design was created across five separate pilot samples. The piloting process aided in the creation of a vignette and allowed for both the elicited written responses from participants and a rating system to be assessed and refined. The implemented vignettes featured equivalent errors in reasoning, seen in two logical fallacies (red herring and appeal to authority), and poor research methodology. The scientists had equivalent types and numbers of logical reasoning errors used in support of their belief. The presentation order of the scientists and their arguments was counter-balanced between two otherwise identical vignettes. Participants were prompted to identify both strengths and weaknesses, if any, they found in the argument provided for each scientist. Responses were written in a separate text box for each scientist.

Participant vignette responses were coded by a team of trained raters. Statements within responses were categorised by whether they addressed a strength or a weakness in the argument and if the statement was valid or invalid (see Appendix B for Vignette Response Rating Manual used by raters). That is, some answers were deemed valid (e.g. "comparing temperature from two years is not enough evidence to solely support belief in anthropogenic climate change") and others invalid because they were not consistent with known evidence (e.g. "there is no way to measure past climates"). Raters added a value of one for every unique instance of strengths or weaknesses referenced in responses (i.e. expanding on a point did not result in an increase in score). Each participant had eight categories of points based on vignette responses; there were four for each scientist: valid strengths, invalid strengths, valid weakness, and invalid weakness.

Focussing on strengths for a congruent belief and weaknesses or an incongruent belief was classified as *biased reasoning*, whereas focussing on weaknesses for the congruent belief and strengths for the incongruent belief was classified as *objective reasoning* (see Table 1). Individual's *motivated reasoning* scores were derived from the ratings from the eight categories of participant's statements as well as participants' measured belief in

Table 1. Motivated reasoning variable derivation.

Variable	Deriving Formula
Biased Reasoning	$\text{Weaknesses}_{\text{incongruent view}} + \text{Strengths}_{\text{congruent view}}$
Objective Reasoning	$\text{Strengths}_{\text{incongruent view}} + \text{Weaknesses}_{\text{congruent view}}$
Motivated Reasoning	Biased Reasoning − Objective Reasoning

Note. Congruent and incongruent view subscript denote alignment of scientists' view with participant's anthropogenic climate change belief (yes/no).

ACC (yes/no). Thus, motivated reasoning was operationalised as arguing for weaknesses in the information that was incongruent with the individual's personal view, as well as arguing for the strengths in the information that was congruent with their own view (see Table 1). The rating system for participant responses, and the vignette itself, were developed and modified over the course of five separate pilot samples (see Vignette Ratings Scoring Manual in Appendix B). All raters were blind to participants' belief in ACC. Inter-rater reliability was assessed with Gwet's AC2 using a linear weight (see Gwet, 2008), due to the analysis' not having an assumption of independence among coders, the ordinal nature of the data, and the range of our ratings (0–4).

After four individuals, first author included, trained on pilot data and obtained reliability between .66 and .94 (46% above .80) for all eight categories being rated, we were confident that all individuals understood the rating system. After initial inter-rater reliabilities had been established, the first 100 vignette responses (91 valid responses) in the presented data were rated independently by raters who then met to collaboratively deliberate over any differences in ratings until 100% agreement was reached (agreement ranged from .66 to .95 before deliberation; 80% above .80). The remaining participants ($n = 347$; 283 valid responses) were divided between three of the raters, with one rater (the first author) rating all remaining responses. Inter-rater reliability for these responses ranged from .74 to .96 (with 75% being $> .80$). The two raters' score for each of these three sections was averaged into a single score which was used for analysis along with the first collaboratively deliberated section.

Results

Descriptive statistics

All participants resided in the United States, with a mean age of 35.53 (range 18 to 75) and 64.12% female. European-Americans were 79.28% of the sample, Hispanic/Latinx 6.53%, Black/African-American 6.53%, and Asian-American 4.28%. The largest religious groups were Christian (47.52%), Agnostic-Atheist (32.88%), Other (13.96%), Buddhist (1.58%), and Jewish (1.35%). Sixty-seven percent (295 of 439) of the sample had at least some

Table 2. Descriptive statistics for all major variables in the study.

Variable	*Mean*	*SD*	*N*
Motivated Reasoning	0.16	1.14	378
Objective Reasoning	1.50	0.86	371
Dogmatic Thinking	73.95	26.37	378
Neuroticism	21.55	8.18	378
Openness to Experience	39.11	6.81	378
Need for Cognition	66.70	14.81	378
ACT	150.41	58.53	378
Scientific Attitude (TOSRA)	40.28	4.54	378
Age	36.53	12.60	371

NOTE: ACT = Authoritarian, Conservatism, Traditionalism Scale; TOSRA = The Test of Science-Related Attitudes.

college education. About 57% of those who went to college majored in some Science-Technology-Engineering-Math (STEM) field (including the social sciences). Although we did not directly measure political orientation, our sample distribution on the overall scale of the ACT (Authoritarianism-Conservatism-Traditionalism) was normal (skewness ratio = 1.99) and only slightly more "liberal" than an average mean score (4.29 on a 1 to 9 rating scale of the ACT). Descriptive statistics for all the major predictor and outcome variables in the study are listed in Table 2.

Climate change (CC) was endorsed by 91.03% of participants and anthropogenic climate change (ACC) by 72.13%. The belief that addressing climate change would cause an unnecessary tax burden was agreed to by 30.04% of the sample. There was no gender difference in acceptance of ACC, with 70% of men accepting ACC and 73% of women (χ^2 (1) = 1.21, ns). There was, however, an age difference, with those endorsing ACC having a being younger (mean age of 35.71) than those rejecting ACC (mean age 40.43; t (442) = 3.51, $p > .001$). Non-Christians were more likely to accept ACC than Christians (82.3% versus 60.7% respectively, χ^2 (1) = 25.73, $p < .001$). Those who had at least some college education compared to those who did not were no more likely to endorse ACC (74.1% versus 66.7% respectively, χ^2 (1) = 2.67, ns). Finally, those who studied science in college were more likely to agree that human activity is causing climate change (79.6%) than those who did not study science in college (67.0%) (χ^2 (1) = 7.99, p = .005).

Descriptively and without prediction we conducted a series of t-tests to examine whether participants who endorsed climate change, went to college, or studied science in college differed from those who did not on reasoning, cognitive style, ideology, personality, and scientific attitude. Compared to those who denied human activity as a cause of climate change, those who endorsed ACC had lower scores on biased reasoning, motivated reason, dogmatism, and authoritarianism-conservativism-traditionalism, and higher scores on objective reasoning and neuroticism (see Table 3). With the exception of neuroticism, these effect sizes were either

Table 3. Mean differences between participants who endorse human caused climate change (ACC) and those who did not on reasoning, cognitive style, ideology, personality and scientific attitude.

	Deny ACC			Endorse ACC					
Variable	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*t*	*p*	*d*
Biased Reasoning	107	1.93	0.71	270	1.56	0.88	−3.89	.000	.46
Objective Reasoning	107	1.10	0.87	270	1.66	0.81	5.84	.000	.65
Motived Reasoning	107	0.82	0.95	270	−0.10	1.11	7.57	.000	.89
Dogmatism	124	87.19	30.76	321	71.09	22.96	−6.00	.000	.60
Need for Cognition	124	66.16	15.14	321	65.90	14.57	>−1.0	ns	.02
ACT	124	186.70	58.40	321	141.43	54.86	−7.77	.000	.80
Neuroticism	124	19.36	7.58	321	21.85	8.17	2.94	.03	.32
Openness	124	38.27	7.19	321	39.00	6.62	1.02	ns	.11
Scientific Attitude	124	39.82	4.78	321	40.16	4.72	<1.0	ns	.07

Table 4. Multiple regression: Motivated reasoning regressed on cognitive style, personality, ideological beliefs, and scientific attitude.

Predictor	*Zero-order correlation*	*β*	sr^2	*R*	R^2
Need for Cognition	−.04	−.03	.000		
Dogmatism	.15***	.08	.004		
Neuroticism	−.15**	−.14	.017**		
Openness	−.05	−.02	.000		
ACT	.15**	.08	.004		
Scientific Attitude	−.08	−.21	.000		
All Variables				.22*	.05*

Note: ACT = Authoritarianism, Conservatism, Traditionalism Scale.
*$p < .05$; **$p < .01$; ***$p < .001$.

medium or large. There were no differences between the ACC groups on need for cognition, openness, or scientific attitude. Attending some college (versus none) was only related to lower scores on the ACT ($r_{pb} = -.11$, $N = 439$, $p = .02$).

Planned analyses

Predicting motivated reasoning

To test the first hypothesis that various psychological variables would predict motivated reasoning, we conducted a multiple regression with motivated reasoning as the outcome variable, and need for cognition, dogmatism, neuroticism, openness, authoritarianism-conservatism-traditionalism (ACT), and adoption of scientific attitude as the predictor variables (see Table 4). We had intended to conduct a hierarchical multiple regression and hold age, gender, and some college education (yes/no) constant, but these demographic variables were not correlated with motivated reasoning and therefore there was no need to hold them constant. As a set, the psychological variables significantly predicted variation in motivated reasoning ($R = .22$; F (6, 371) $= 3.12$, $p = .005$). These predictors explained

Table 5. Hierarchical logistic regression: endorsement of Anthropogenic Climate Change (ACC; Yes/No) regressed on cognitive style, personality, ideological beliefs, and scientific attitude holding age constant.

Predictor	*B*	*Wald* χ^2	*df*	*p*	*OR*
Step 1					
Age	-.03	-.08	1	.001	.97
Step 2					
Need for Cognition	-.02	1.63	1	.20	.98
Dogmatism	−.02*	9.49	1	.002	.98
Neuroticism	.01	.32	1	.57	1.01
Openness	.03	1.79	1	.18	1.03
ACT	−.01*	23.56	1	.000	.99
Scientific Attitude	-.06	3.48	1	.06	.94

Note: ACT = Authoritarianism, Conservatism, Traditionalism Scale.
*$p < .05$; **$p < .01$; ***$p < .001$, OR = odds ratio.

5% of the variance in motivated reasoning ($R^2 = .05$), so its effect size is small. We found significant zero-order relationships between motivated reasoning and dogmatism ($r = .13$), neuroticism ($r = -.15$), and ACT ($r = .15$). The only predictor variable that was uniquely correlated with motivated reasoning once its shared variance with other predictors was removed was neuroticism ($sr^2 = .017$). A higher level of neuroticism was associated with less motivated reasoning.

Predicting ACC

To test the second hypothesis that the same set of psychological variables would predict group membership in endorsing anthropogenic climate change (yes or no), we conducted a hierarchical logistic regression, holding age constant in step 1 (see Table 5). Age was correlated with ACC endorsement ($r_{pb} = -.16$, $N = 444$, $p < .001$) and hence it was a covariate in the model. Gender ($\phi = .03$) and some college education ($\phi = .08$) did not covary with ACC endorsement and therefore were not covariates in the model.

The full model in step 2 significantly predicted ACC endorsement (χ^2 (6, $N = 444$) = 65.07, $p = .000$), with 78% of the 444 cases being correctly classified. As a set, these psychological predictors explained 23% of the variance in ACC group membership (Nagelkerke $R^2 = .23$). As seen in Table 5, only dogmatism (*Wald* χ^2 (1) = 9.49, $p = .002$) and ACT (Wald χ^2 (1) = 23.56, $p < .001$) were significant unique predictors of ACC endorsement membership. High scorers on dogmatism and on ACT were less likely to endorse ACC.

Relationship between reasoning and ACC

For our third hypothesis that there would be reasoning differences between those who deny compared to endorse human caused climate change (ACC) we conducted a 2 × 2 mixed ANOVA. The between-subjects independent variable was participants' belief in ACC (yes/no). The within-subjects variable was reasoning scores, namely biased and objective reasoning. Recall

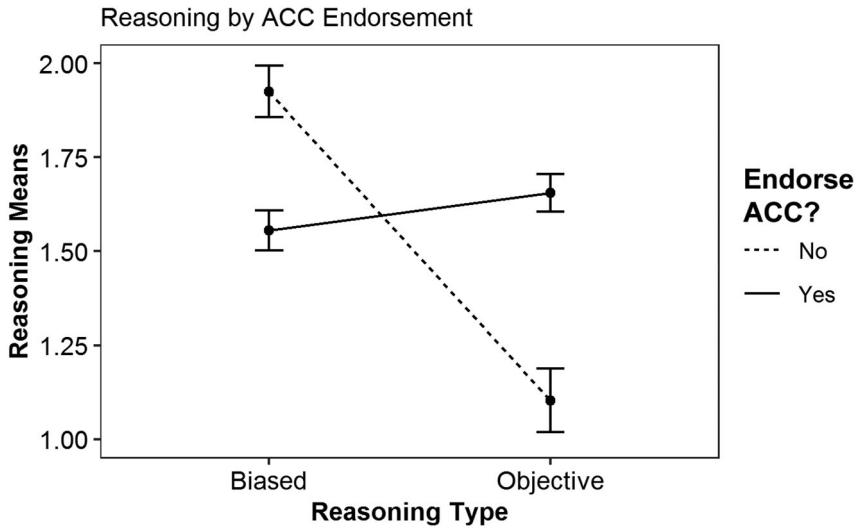

Figure 1. Interaction between two within-group reasoning types (biased and objective) and two between-group endorsement types (yes and no) on anthropogenic climate change.
Note: Errors bars represent 95% confidence interval.

that focussing on strengths for a congruent belief and weaknesses for an incongruent belief was biased reasoning, whereas focussing on weaknesses for a congruent belief and strengths for an incongruent belief was objective reasoning. Although there were main effects for both the within (reasoning type) and between (ACC endorsement), they were overridden by the significant interaction (Wilks $\Lambda = .87$, F (375) $= 57.27$, $p < .001$, partial $\eta 2 = .13$). This finding suggests that participants who did not believe in ACC were more likely to exhibit biased reasoning than objective reasoning, while participants who accept ACC were equally likely to engage in objective or biased reasoning (see Figure 1).

Post hoc analyses

With a data set as rich as this one, there are always some unexpected and non-predicted findings. Our primary expectation was that psychological variables would predict motivated reason on climate change, and they did. But the amount of variance explained was quite small (5%). Although not a prediction, when we examined the model with the same variables predicting objective reasoning only (seeing strengths in incongruent and weaknesses in congruent evidence), the explained variance increased across the board. As seen in Table 6, two demographic variables (age and some college education) covaried with objective reasoning and therefore were held constant

Table 6. Hierarchical multiple regression: objective reasoning regressed on cognitive style, personality, ideological beliefs, and scientific attitude holding age and college education constant.

Predictor	*Zero-order correlation*	β	sr^2	R	ΔR^2
Step 1: Demographics					
Age	−.08*	−.08	.01		
College Education	.11***	.10	.01		
Step 1 Variables				.14*	.02*
Step 2: Psychological Variables					
Need for Cognition	.09*	.08	.003		
Dogmatism	−.19***	−.10	.007		
Neuroticism	.15**	.14	.017**		
Openness	.09*	.03	.000		
ACT	−.21***	−.12	.010*		
Scientific Attitude	.11*	−.01	.000		
Step 2 Variables				.29***	.09***

Note: ACT = Authoritarianism, Conservatism, Traditionalism Scale.
*$p < .05$; **$p < .01$; ***$p < .001$.

in step 1 of the hierarchical multiple regression. These demographic variables explained 2% of the variance in objective reasoning. The psychological variables, however, added an additional 9% explained variance over and above the demographic variables. Moreover, each psychological variable had a significant zero-order correlation with objective reasoning. Removing shared variance between individual predictors we see that neuroticism explained about 2% unique variance in objective reasoning and authoritarianism-conservatism- traditionalism (ACT) about 1% unique variance. One interesting finding on an item from the Test of Scientific Related Attitudes (TOSRA) and Motivated Reasoning showed that there was no association between people engaging in motivated reasoning and their self-reported willingness to change their mind if the evidence shows no support for their ideas. The TOSRA item read "I am unwilling to change my ideas when evidence shows that the ideas are poor" (reverse scored) and was not correlated −.01 ($N = 377$) with Motivated Reasoning. There was a small significant negative correlation between Motivated Reasoning and the TOSRA item "I like to listen to people whose opinions are different from mine." ($r = -.10$, $N = 376$, $p = .04$). Objective Reasoning was correlated with three Scientific Attitude items: "Finding out about new things is unimportant" (reverse scored; $r = .14$, $N = 377$, $p = .007$); "I dislike repeating experiments to check that I same results (reverse scored; $r = .10$, $N = 377$, $p = .05$); and "I am curious about the world in which we live ($r = .10$, $N = 378$, $p = .05$). Biased Reasoning was not correlated with any of the 10 TOSRA items.

Discussion

The current study tested the hypotheses that cognitive style, personality, ideology, and scientific attitude would predict both motivated reasoning as

well as endorsement of human caused climate change. Our third hypothesis was that those who accept human caused climate change (ACC) will be less likely to engage in biased reasoning and more likely to engage in objective reasoning about climate change than those who deny human activity as a cause of climate change.

We found support for these predictions. Although small in effect size, the set of psychological variables did significantly predict motivated reasoning, with a multiple R of .22 and R^2 of .05. Individually, those who scored high in dogmatism and authoritarianism- conservatism-traditionalism tended to engage in more motivated reasoning than those who scored lower on those characteristics. The only predictor variable with a unique (removing shared variance) relationship to motivated reasoning was neuroticism. Participants with higher levels of dispositional anxiety were less likely to engage in motivated reasoning. We predicted that participants with higher levels of adoption of scientific attitudes and need for cognition would engage in less motivated reasoning, but this was not supported by the current study.

In the second prediction, after holding age constant, a logistic regression model with psychological predictor variables correctly classified 78% of who endorsed or rejected human-caused climate change, explaining 23% of the variance. Only neuroticism and ACT were significant unique predictors of ACC endorsement membership, with high scorers on neuroticism being more likely to endorse ACC. Moreover, those who rejected ACC also had higher levels of authoritarianism, conservatism, and traditionalism. We predicted that higher levels of adoption of scientific attitudes would be associated with belief in anthropogenic climate change, but this was not supported by the current evidence. In support of the third and final prediction, we found that those who endorsed human-caused climate change engaged in less biased and more objective reasoning than those who rejected human influence on climate change.

Descriptively, we examined the frequency of endorsing climate change as well as any gender age, and religious differences in such endorsement. In our sample of nearly 400 U.S. adults, 91% believed climate change is real, and 72% believed it is being caused by human activity. Although there were no gender difference in this belief, there was an age difference, with older compared to younger participants being less likely to endorse human-caused climate change. Moreover, there was a religious affiliation difference, with Christians (61%) being less likely to endorse ACC than non-Christians (82%). Finally, there was no significant difference in ACC endorsement rates between those who never went to college (67%) and those who had at least some college education (74%). Those who studied science in college were more likely to agree that human activity is causing climate change (80%) than those who did not study science in college (67%).

Compared to those who denied human-caused climate change, those who endorsed ACC engaged in less biased reasoning, and had lower levels of dogmatism and authoritarianism- conservativism-traditionalism. In addition, acceptors of ACC engaged in more objective reasoning and tended to be higher in dispositional neuroticism. There were no differences in level of ACC endorsement and need for cognition, openness, or scientific attitude.

College education mattered. Those who attended some college compared those who did not had higher scores on objective reasoning and biased reasoning and lower levels of belief in authoritarianism-conservativism-traditionalism. In effect, having some college education was associated with an increased number of unique arguments/statements in participant responses. College education did not make a difference on motivated reasoning, dogmatism, need for cognition, openness, or scientific attitude, however. Finally, studying science in college was associated with higher levels of objective reasoning and lower scores on authoritarianism-conservatism-traditionalism.

Although we did not predict this finding, we discovered that the set of psychological variables in hypotheses 1 and 2 explained more variance in objective reasoning alone than it did in motivated reasoning. Recall that objective reasoning is seeing strengths in evidence that contradicts our prior beliefs and seeing weaknesses in evidence that confirms our prior beliefs. Because we found that older participants scored lower on objective reasoning than younger ones, and those who attended college scored higher than those who did not, we held these constant. Over and above these demographic differences, we found that almost 10% of the variance in objective reasoning was explained by need for cognition, dogmatism, neuroticism, openness, ACT, and scientific attitude. Each one of these predictors had a significant zero-order relationship with objective reasoning, and neuroticism and ACT explained unique variance in objective reasoning once shared variance with other predictors was removed.

Importantly, most of participants' statements were deemed to be valid reasoning by our raters. This finding demonstrates that biased (or directional) reasoning does not inherently have to involve invalid reasoning. Exemplified in the use of red herrings in the vignette, which cue information that may very well be true, but is not central to the main question. For example, an individual who denies anthropogenic climate change may state "the climate has always changed" as a reason for their disbelief. While this statement is technically true, it does not address the central question, which is: Are humans primarily driving the current change in our climate? Similarly, individuals may at times selectively draw arguments and evidence that support one's prior view, while also failing to acknowledge evidence that does not support one's view.

One surprising set of null results concerned scientific attitude. Scientific attitude did not covary with reasoning scores as we would have expected. More specifically, certain scientific attitude items that had to do with changing one's ideas with new evidence and listening to people with opposing points of view were not related to motivated reasoning, objective reasoning, or biased reasoning.

Implications of the findings

The present study supported the notion that motivated reasoning is impacted by cognitive, personality, and ideological forces. We examined a particular context of motivated reasoning, namely a scientific-political controversy concerning people's views on the existence of human-caused climate change. As expected, one's political and religious orientation coloured one's interpretation of evidence for or against anthropogenic climate change (McCright, 2011; McCright & Dunlap, 2011; Pew Research Center, 2016). People who were conservative, dogmatic, traditional and Christian were more likely to engage in motivated reasoning and see strengths in evidence that confirmed their view that humans were not the cause of climate change and ignore the weaknesses in the evidence that contradicted that view.

Although the primary divider between belief in anthropogenic climate change was political orientation and religion, the strongest predictors of motivated reasoning in ACC were higher levels of dogmatism and emotional stability. Such findings support the idea that beliefs create a filter through which we process information. It was not that those who rejected anthropogenic climate change were unable to reason effectively. In fact, these individuals in many cases were making valid points to support their belief. Instead, their prior beliefs biased their ability to focus on both congruent and incongruent information in equal terms. There is an impediment to recognising flaws related to evaluating one's own beliefs, even if he or she can readily find errors in someone else's belief.

Holding a belief congruent with scientific consensus may lower the likelihood of engaging in biased reasoning, but does not mitigate it completely. Indeed, there is evidence that many individuals who claim to be scientific and objective in their views also hold beliefs that stand in conflict with empirically gained knowledge. People with high "need for cognition" and scientific attitudes were just as disposed towards motivated reasoning as those who did not possess these predilections and attitudes (cf. Kahan, 2012). To be sure, researchers have long reported that although professional scientists may in general be better able than non-scientists to put distance between their beliefs and evidence and reasoning rationally, they

are nevertheless not immune to biased or non-optimal reasoning (Druckman & McGrath, 2019; Evans, 2002; Feist, 2006; Gorman, 1992; Koslowski, 1996; Mercier & Heintz, 2014; Thagard, 2004; Tversky & Kahneman, 1971; Tweney, 1998; West et al., 2012). As Evans (2002) argues, however, prior belief, as in Bayesian inference and statistics, is in fact a necessary component to hypothesis testing and scientific reasoning. Both motivated reasoning and Bayesian reasoning are influenced by prior beliefs. Where they diverge is that Bayesian reasoning ultimately requires revision of belief (priors) based on new evidence (Mandel, 2014). Similarly, Druckman and McGrath (2019) argue that Bayesian reasoning (updating prior beliefs based on new evidence) is at the heart of both scientific reasoning and reasoning about climate change.

The relationships between dogmatism, neuroticism, and motivated reasoning are noteworthy. One reason dogmatism continues to be a robust predictor of denial of ACC, may be in part due to its relationship with emotional stability. Beliefs can be comforting to individuals. For instance, Gray and Gallo (2016) found individuals who believed in psychics had higher levels of life satisfaction than those who did not. This has been discussed in terms of extrinsic religiosity as well. Individuals with extrinsic reasons (e.g. seeking comfort, security, and social connections) or intrinsic reasons (e.g. trying to live by a holy book) have been distinguished in their religious orientation (Allport & Ross, 1967). Additionally, people may find comfort in not challenging their views. The act of challenging our own beliefs can result in uncomfortable or unpleasant feelings as we wrestle with uncertainty.

Limitations

As is true of all studies, this one has its limitations. Participant responses were completed over the internet and although steps were taken to maintain the integrity of the collected data, accuracy of provided information cannot be guaranteed. Due to the reliance on Amazon's Mechanical Turk system for participants, the collected sample may not be entirely representative of the larger nation. But the evidence on the representativeness and validity of MTurk samples is mixed (Chmielewski & Kucker, 2020).

Our sample was liberal overall, with sample 72% endorsing ACC, which mirrors the more liberal Democratic stance of 74% (with medium scientific knowledge; Funk & Kennedy, 2020). In general, evidence for the representativeness of MTurk samples supports that they are more representative than convenience samples, but less representative than samples derived from nationally stratified methods (Berinsky et al., 2012; Buhrmester et al., 2011; Huff & Tingley, 2015; Paolacci & Chandler, 2014). Clifford and colleagues (2015) compared MTurk samples to large national samples in the U.S. and

found that there are few overall differences on political ideology of MTurk samples and national samples. Conservatives on MTurk were found to mirror conservative values in national samples. However, Liberals on MTurk are slightly more liberal than national samples. Clifford et al. conclude that MTurk samples are a valid assessment tool for political ideology. MTurk samples tend to have gender parity but also tend to include more non-white (36% v 23%) and older (mean age of 33 vs 24) individuals than other Internet samples (Buhrmester et al., 2011). Additionally, older MTurk participants in particular tend to be more liberal compared to nationally representative samples (Huff & Tingley, 2015).

Although the acceptance rate of ACC may be higher than was typical at the point of time that data was collected (in 2015), the extent to which having a more liberal-leaning sample influenced our results is unclear. To be clear, many researchers do question the validity and representativeness of research arising from MTurk samples (see Moss et al., 2020; Paolacci et al., 2010; Peterson & Merunka, 2019). How issues with sample representativeness may directly interact with detecting logical fallacies around climate change is less clear. We relay the importance of replication in our research, as in all research. We also feel that our findings offer a worthy contribution to the scientific literature, even with the caveats of our sampling methodology.

The creation of two new measures (ACC vignettes and Brief Climate Change Belief Questionnaire) had not been validated prior to the study. Some vignette responses appeared to be driven by motivated reasoning: however, they were removed due to not meeting the inclusion criteria of assessing strengths and weaknesses in the submitted vignette responses. Due to this standard, motivated reasoning was not captured in all of its forms. Additionally, although the ratings were made blind to the participants' belief, it is still possible that the raters' own biases influenced participant scores. The use of two separate rating systems within a single study may have influenced outcome variables used in analysis as well.

The current study does not tease apart or address the various forms of motivated reasoning (directional versus accuracy) much less the various forms of directional reasoning. For example, Bayes and Druckman (2021) put forth five different kinds of directional reasoning goals, such as social identity protection, social consensus seeking, scientific consensus seeking, value affirmation, and belief consistency seeking. Each of these has the goal of maintaining identity or a social connection or maintaining consistency with a value or belief system. Relatedly, our study does not examine whether requesting people be as accurate as they can (i.e. priming them with non-directional goals) would mitigate the level of motivated reasoning on ACC evidence. The current study fails to answer which of these motivations is behind the motivated reasoning seen by participants and hence

more research is required to tease apart the different motivations and goals behind motivated reasoning and climate change.

Future directions and concluding points

The present research examined motivated reasoning in an issue that has strong political polarisation (McCright & Dunlap, 2011; Pew Research Center, 2016). An obvious direction for future research could be a similarly designed study that primarily drives those on the political left to hold a view incongruent with current scientific understandings. However, an issue where there is roughly equivalent division across the political spectrum may be more fruitful. An example that may fit this criterion is the debate around genetically modified foods (GMOs). Although this topic is popularly viewed as an issue where liberals tend to be incongruent with science (see Azarian, 2015), recent research suggests that GMOs are actually not polarising (Kahan, 2015b). That is not to say that misinformation is not widely present, however. A Pew Research Center poll found that 88% of American Association for the Advancement of Science scientists say that genetically modified foods are generally safe, a fact that contrasts with the 57% of the public who feel that genetically modified foods are unsafe (Pew Research Center, 2015). The staggering 45-point difference in opinions between scientists and the general public on this issue highlights the need for more effective transfer of scientific knowledge.

The vignettes used in the present study were purposely written to be structurally similar to how information might be delivered on a television news show (conflict oriented vs. clarity). Two authority-like figures are presented on either side of the issue along with their credentials, followed by the individuals offering reasoning behind their belief. Evidence was introduced based on a study, but was presented in a shallow manner and not scrutinised. As the present study shows, this format is ripe for motivated reasoning to occur within an individual receiving the information. Such a finding is congruent with a prior finding that controversy in presented news information creates more uncertainty in the receiver (Corbett & Durfee, 2004).

Empirical evidence suggests that scientific reasoning skills can mitigate against epistemically questionable beliefs (Čavojová et al., 2020). Further, it is possible to reduce incorrect beliefs about climate change through educational information (Ranney & Clark, 2016). By describing the process through which ultraviolet light turns into infra-red energy and creates heat, individuals were able to reduce their level of disbelief in climate change. It is important to expand our understanding of how we can find the 'most distilled representation of an idea' or 'most potent argument' and combine it with an effective presentation in both space and time.

There is concern that individuals are increasingly living in echo chambers (Du & Gregory, 2016). The ability to filter and customise one's media to only include information from sources already approved of and endorsed has never been easier. An individual can easily foster and reinforce an unwillingness to engage with contradicting information by selectively choosing their own news sources. News coverage has been identified as creating a platform for misinformation (e.g. MMR vaccination; see Speers & Lewis, 2004). Although social media is no exception to spreading misinformation, it also has the potential to remedy, or alleviate it (Kim et al., 2018; Pennycook et al., 2020; Van Bavel et al., 2020). Bode and Vraga (2015) found that by presenting correct information in an adjacent visual space ('related stories'), misperceptions can be reduced. Kim and colleagues (2018) combined human crowd sourcing and computer algorithms to detect and reduce the spread of fake news and misinformation. Admittedly, finding successful strategies for getting individuals the right information can be challenging–though the importance should not be understated.

Climate change as a topic was chosen partly because in the 21st century we have the ability to utterly transform Earth's landscape in a way unlike any other point in time. To be clear, motivated reasoning, misinformation, and dogmatism are not unique features of our modern world. However, the abilities to create, alter, and destroy have never been so great in their magnitude nor ease. Given the potential for greater consequences, there is greater importance upon our decision making and reasoning about issues in relatively objective and less biased ways (Lobato & Zimmerman, 2018). Recognizing that motivated reasoning is a widespread phenomenon, information generation should be artful in its dissemination. The ability to make good decisions depends on good information, or more specifically, on well understood and well-reasoned-about information—especially when that information may contradict our already held beliefs. By understanding the psychology of motivated reasoning, perhaps we move one step closer to lessening its effect on our reasoning about climate change.

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Appendix A

Vignette argument structure annotations

#1

An issue that has received considerable public attention is that of climate change.

[*Introduce topic*] Climate change has inspired a great deal of debate and has prominent individuals on all sides of the issue. [*Introduce disagreement*] The biggest disagreement arises not so much about whether climate change exists, but rather whether the current period of change is caused by humans or is just in a natural cycle. [*Framing issue*] Dr. Helmholtz and Dr. Freedlander are both scientists who study climate change. [*Introduce individuals*] Dr. Helmholtz, a member of the American Meteorological Society, does not believe that humans' contribution to rising CO^2 levels is primarily driving global climate change. [*Identify stance & appeal to authority*] He conducted a study that found that climate has varied throughout its history and cites this as his primary reason for his belief. [*Methodological reasoning error & red herring*] Dr. Freedlander, however, a member of the World Meteorological Organization, does believe that humans' contribution to rising CO^2 levels is primarily driving global climate change. [*Identify stance & appeal to authority*] He primarily believes this due to a study he conducted that found that 2014 was hotter than 1990. [*Methodological reasoning error & red herring*]

#2

An issue that has received considerable public attention is that of climate change.

[*Introduce topic*] Climate change has inspired a great deal of debate and has prominent individuals on all sides of the issue. [*Introduce disagreement*] The biggest disagreement arises not so much about whether climate change exists, but rather whether the current period of change is caused by humans or is just in a natural cycle. [*Framing issue*] Dr. Freedlander and Dr. Helmholtz are both scientists who study climate change. [*Introduce individuals*] Dr. Freedlander, a member of the World Meteorological Organization, believes that humans' contribution to rising CO^2 levels is primarily driving global climate change. [*Identify stance & appeal to authority*] He conducted a study that found that 2014 was hotter than 1990 and cites this as his primary reason for his belief. [*Methodological reasoning error & red herring*] Dr. Helmholtz, however, a member of the American Meteorological Society, does not believe that humans' contribution to rising CO^2 levels is primarily driving global climate change. [*Identify stance & appeal to authority*] He primarily believes this due to a study he conducted that found that climate has varied throughout its history and cites this as his primary reason for his belief. [*Methodological reasoning error & red herring*]

Note. Annotations in brackets are of the preceding sentence.

Appendix B

Vignette response rating manual

Each scientist's position (both Freedlander [for human caused climate change] and Helmholtz [against human caused climate change]) will be rated on four dimensions: two weakness (valid and invalid) and two strengths (valid and invalid). Each

box (8 altogether for each participant) will have either a 0 or 1 in it depending on whether it is present or absent.

Coding System

0 = not present (weakness or strength) per weakness/strength (i.e. one box can get a score > 1)

1 = present (weakness or strength) per weakness/strength (i.e. one box can get a score > 1)

Weaknesses

- Valid: legitimate logical or methodological flaws are correctly identified Invalid: misinterpreted or misunderstood flaw (e.g. they think something is a flaw but it is not)

Strengths

- Valid: legitimate logical or methodological strengths are correctly identified if the person simply describes the position in the vignettes without describing it as a strength or a weakness, then it gets a 0
- Invalid: misinterpretations or misunderstood strength (e.g. think something is a strength that is not)

Coding Rules

- If redundant with another answer count as only 1
- If someone misinterprets a weakness point (e.g. they argue the opposite of what the Dr. was saying), then mark 1 for invalid weakness; if they misinterpret a strength point, then mark 1 for invalid strength
- If irrelevant, mark a zero
- If someone says the method of collecting data over time is a strength, that is valid but if they use that to draw a conclusion about human caused change that is invalid
- If someone says one argument is more valid than another that is invalid (b/c they are equally flawed) strength or weakness depending on context
- If blank/nothing written, give zero
- If someone argues for one vignette in the context of the other vignette, still rate the first vignette on its own (as if it were in the correct box)
- If someone confuses one scientists for the other but it's clear they are discussing one vignette but labelled it with the other name, then rate the vignette not the name
- If people agree with a stance but give no reasoning give it a zero
- If the person merely describes a point in the vignette, count that as a 0; but if they label it as a strength or weakness and it is such, then rate 1 point:
- If the reason is vague (eg., -he doesn't have enough proof|) then count as a 0
- Rate each response after taking overall content of both boxes (F & H) into account (i.e. sometimes what they say in one box affects how you rate what they say in another box)
- If they argue that this one study is the main or sufficient evidence then rate that as a invalid strength (by itself one study can't be sufficient evidence)

- If the person makes an inference that goes beyond the vignette (e.g. -A weakness is that CO^2 increase could be caused by cattle rather than humans|) and it is valid, then rate it as such (1); if it is invalid, rate it as such (0)
- If the person says doing a study is a strength, then rate that a valid strength

Partial List of Valid Weaknesses

- No details of how studies were conducted; too small of a time frame (1990–2014; Freedlander)
- Freedlander believes humans are causing climate change
- Draws overall conclusions from just one study
- No evidence of how reliable and valid the assessments were.
- No evidence presented that directly implicates humans or natural cycles; differences (over time) don't identify cause of difference; no evidence of cause
- Both ignore the real evidence of looking at pre and post-Industrial Revolution changes (when humans really started to use carbon based machines and engines)
- No evidence of the overall scientific literature (what do most studies show?); only one study presented
- Ignores evidence that modern CO^2 levels are higher than ever
- Argument is mostly just opinion
- Helmholtz doesn't compare CO^2 levels over time, just states they are changing
- Helmholtz: time points are not clear
- If they point out that these studies are not sufficient to draw conclusions from

Partial List of Invalid Weaknesses

- Scientist defends his study
- It may be biased
- Can be attributed to cattle (because cattle contribute to methane not CO2)
- Helmholtz: believes we are not responsible when we are at least a bit
- Only climatologists can make scientific statements about climate
- One person did the study
- If someone argues that the article/paper was not peer reviewed and therefore is a weakness, we will rate that as invalid weakness
- Study is not logical/makes sense/intuitive/common sense

Partial List of Valid Strengths:

- Conducted an (empirical/scientific) study
- Measured temperature over time (Freedlander's increases and Helmholtz varied temperature)
- Has data on temperature increase
- Helmholtz: studies temperature over a long(er) period of time
- If they state the person was a scientist and that the person conducted a study
- The studies presented say nothing about other sources of climate change such as methane (produced by cattle)

Partial List of Invalid Strengths:

- Members of scientific organizations
- Someone believes or doesn't believe humans are causing it based on this one study
- He has studied this question
- If they only state the person was a scientist and that is all
- If they argue that two time points are enough to draw a valid conclusion
- Study is logical/makes sense/intuitive/common sense