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Exploring the roles of analytic cognitive style, climate science literacy, illusion of knowledge,
and political orientation in climate change skepticism

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Abstract

The issue of climate change has become central in recent years as alarming data accumulate. It nevertheless has its critics, consisting of people denying climate change or minimizing the responsibility of human beings in the process. This skepticism partly derives from the complexity of the topic, encouraging people to rely on cognitive shortcuts to grasp the phenomenon. We question the role of analytic cognitive style, general and climate change-related knowledge, overconfidence, and political partisanship (plus additional expected confounding variables) in this process through a package of three studies (total $N = 1031$). In a first study, we showed that an intuitive mindset predicted greater skepticism relative to an analytical mindset while controlling for cognitive ability and the degree to which individuals value science, suggesting that reasoning cognitive style and trust are key parameters of climate change skepticism. A second study highlighted that climate science knowledge stands as strong and independent predictors of skepticism relative to analytic cognitive style. A final study revealed that analytic cognitive style and climate change knowledge generated less influence on climate change skepticism among conservatives than among liberals and moderates, suggesting that reliance on deliberative thinking and knowledgeability on climate science are not sufficient to mitigate climate change skepticism among conservatives. We discuss the critical interplay between cognitive processes and political partisanship in this ongoing debate.

Keywords: Climate change skepticism; Analytic cognitive style; Illusion of knowledge; Belief in Science; Numeracy; Science literacy; Political orientation

Introduction

The issue of whether climate change has anthropogenic roots spawns heated controversies in the public opinion all over the world. A poll addressing public opinion on climate change in the USA (University of Michigan's Center for Local, State, and Urban Policy: 2012) showed that 60 % of people acknowledged a human influence on climate change, leaving a non-negligible segment of climate change skeptics. Skepticism is present despite the large scientific evidence about climate change and the role of mankind in the process: a comprehensive content analysis of climate science publications revealed that 97% of active climate scholars comply with the conclusions supported by the Intergovernmental Panel Climate Change regarding the anthropogenic influence on climate change (Anderegg, 2010; see also Bedford & Cook, 2013; Oreskes, 2005). Thus, it is questionable whether this form of pseudoskepticism (Torcello, 2016) does rest or not on informed, well-reasoned critical thinking, or else on climate science denialism. Considering the possibly irreversible environmental damage caused by human activity and the necessity to hearten efficient pro-environmental policies and behaviors, climate change skepticism represents a major challenge.

The reasons for the opinion gap between climate experts and lay climate change skeptics are multifaceted (Milfont et al., 2015). Among the multiple causations, political ideology is an important factor (Jacques et al., 2008), with conservatives expressing fewer concerns about climate change than democrats (McCright & Dunlap, 2011; Gromet et al., 2013). Climate change denial has also to do with the endorsement of conspiracy narratives questioning the actual intention of scientific elites (e.g., return on renewable-energy investment, promotion of nuclear power, etc.), leading some people to question the value of scientific speech (Douglas & Sutton, 2015).

Of importance is how lay people process information, since cognitive functioning stands as a decisive component of risk perception and skepticism (Van der Linden, 2015). The topic of climate change is filled with explanatory models and concepts which are often difficult to comprehend, generating misconceptions (Markowitz & Shariff, 2012; Weber & Stern, 2011). Inaccuracies start from conceptual confusions (e.g., people conflate weather with climate, climate change with ozone depletion; Reynolds et al., 2010) to a weak understanding of dynamic models (e.g., people mistakenly believe that drop in CO₂ emissions would cause a drop in CO₂ concentrations and global temperature; Sterman & Sweeney, 2007). Climate change education in the classroom remains underinvested and recent evidence suggests that most teachers deliver mixed messages about the anthropogenic nature of climate change, underestimate levels of consensus among experts and report poor knowledgeability about climate functioning (Plutzer et al., 2016). In addition, the use of different framings to characterize the very same phenomenon (conservatives favoring the label “global warming” when liberals favoring “climate change”) impairs the transmission of relevant climate information, making a large-scale educational policy more complicated (Schuldt et al., 2011). Thus, the existence of conflicting and misleading sources of information shapes lay people's understanding of climate change, leading to decreased perceived risks compared to experts (Whitmarsh, 2011). The possibility that skepticism is informed by individual differences in information processing is warranted, especially in the perspective that climate change understanding requires sound deliberative thinking. Moreover, there is a critical interest to examine the cognitive dimension in conjunction with ideological preferences in order to draw a comprehensive picture of climate change skepticism.

The main purpose of this research is to examine the relative importance of thinking processes, knowledge, self-assessment of knowledge, and political orientation in the development of climate change skepticism. The final purpose is to provide a general picture

of the way information processing and knowledge levels shape climate change skepticism in the light of political orientation. Study 1 tests the predictive value of analytic cognitive style in the context of climate change skepticism above and beyond that of numeracy and science literacy. Study 2 tests the importance of general and climate change-related knowledge and targets the role of overconfidence in one's knowledge, at both domain-general and domain-specific levels. Finally, Study 3 explores the impact of political orientation, for which data accumulate which suggest an important implication of this factor in the context of climate change.

Data analyses

All measures and conditions are reported and all analyses, inclusions/exclusions were determined a priori, with any deviation disclosed. Data were analyzed using R software. Each multiple regression model was computed while adjusting for potential confounding demographic factors (age, gender, and education). All data, materials, and scripts are available from the Open Science Framework platform (<https://osf.io/uz yax/>).

Study 1: Climate change skepticism from a dual-processing perspective

The complexity of the climate change topic inevitably makes lay people rely on cognitive shortcomings. For instance, an averaging bias makes people mistakenly believe that environmentally-harmful actions (e.g., taking one's car to work) can be counterbalanced by environmental-friendly ones (e.g., sorting waste) (Holmgren et al., 2018). There is also evidence of attribute substitution, whereby people use less relevant but accessible information (e.g., current temperature) in place of more relevant but less accessible information (e.g., global climate change patterns) to draw inferences about climate change (Zaval, et al., 2014). Else, high levels of psychological distance to damaging climate change consequences lead to

abstract representation of the issue, which mitigates motivation for environmentally-friendly initiatives (Ejelöv et al., 2018). If part of the population relies on easy-going information-search strategy, the relevance of pointing reasoning as a determinant of skepticism is worth investigating.

That lay people rely on inaccurate mental models or heuristics to apprehend climate change can be investigated under the framework of dual-process theories of thinking. The generic version of the dual-process theory (Epstein, 1994; Evans & Stanovich, 2013; Kahneman, 2011) postulates that people have two different thinking processes. Type 1 processes are fast, do not require much cognitive resources, and are based on an intuitive mode of understanding the world. As such, intuition can be viewed as an easy route by which to understand how the world works even though diagnostic information is lacking and/or of challenging complexity. By contrast, Type 2 processes are assumed to be slow, deliberative, greedy in limited cognitive resources, and are based on a mode of thinking favoring evidence-based information. People's motivation and ability to engage in analytic thinking in the presence of conflicting responses is conceptualized as cognitive reflection (or analytic cognitive style), which is largely dependent on the ability to detect and override cognitive conflict (for a review on conflict detection in reasoning, see De Neys, 2014; see also Pennycook et al., 2015b for temporal specifications). Recent data showed that analytic thinking promotes sound reasoning in many areas, with people more analytic showing decreased endorsement of fake news (e.g., Pennycook, & Rand, 2019), conspiracy theories (e.g., Swami et al., 2014), and many other epistemically suspect beliefs (e.g., Pennycook et al., 2015a; Svedholm & Lindeman, 2013; Trémolière & Djeriouat, 2019); and it does so independently of cognitive ability (i.e., people's ease to correctly rely on the analytic system in the absence of a conflicting intuitive response). There is support for the classic view of analytic thinking regarding climate change skepticism. Lay people use an intuitive mode of

thinking in the case of climatic change perception, relying mainly on simple mental models and experiential cues (Weber & Stern, 2011). For instance, vivid experiences of climate change increase global climate change risk perception (Akerlof et al., 2013; Brody et al., 2008), while the lack of personal experience of climate change leads to call into question the perceived seriousness and the anthropogenic roots of the phenomenon (see Spence et al., 2011).

Moreover, climate change skepticism may arise when short-term personal experience is misdiagnosed as incompatible with long-term global warming trends. Short-term ambient temperature can be used as a proxy to such a point that unusually cold weather could help extenuate the plausibility that climate change operates globally (Egan and Mullin 2012). The recent accumulation of data has evidenced that cognitive reflection, compared to cognitive ability, was a better predictor of sensitivity to cognitive biases and endorsement of intuitive beliefs. Of critical value in this comprehension is the degree of trust placed in the scientific community and the extent to which people approve of scientific claims. Climate change skepticism might appear when intuitively appealing material about climate outweighs consensual scientific claims due to a lesser belief in the value of science. This rationale mirrors the observation that lay people are unwilling to trust scientific evidence that is counterintuitive in character (Miton & Mercier, 2015).

Study 1 aims to evaluate the predictive influence of analytic cognitive style on climate change skepticism while controlling for general science literacy and cognitive ability, two measures which were confounded in Kahan et al. (2012). In the present study, rather, we distinguish analytic cognitive style (the willingness and ability to overcome Type 1 responses) from cognitive ability (the ability to conduct Type 2 operations) to directly test the validity of the classic view of analytic thinking in the framework of climate change skepticism. In addition, we will also examine belief in science to control for the possibility that climate

change skepticism partly stems from a disregard for the values of science and the scientific community (see Hamilton et al., 2015). Should the motivation and ability to correctly handle cognitive conflict be central components predicting epistemically suspect beliefs, we predict that people more intuitive will hold stronger levels of climate change skepticism above and beyond these variables.

Method

Sample size determination. An a priori power analysis was conducted using Gpower (Erdfelder et al., 1996). The analysis indicated that a sample size of 360 would be sufficient to detect a significant effect of our predictors with a power of 0.95 and an alpha of 0.05, based on an effect size (F^2) of 0.05. Anticipating drop out and exclusion issues, we requested about 480 participants.

Participants and design: A total of 479 American participants were recruited on the Amazon Mechanical Turk online data collection platform. Among the initial sample, 106 participants did not complete the questionnaire ($N = 37$) and/or failed ($N = 69$) to correctly answer the attention check. They were then removed from any further analysis, leaving a final sample of 373 participants (226 females, 1 “other”; $Mean_{age} = 37.6$, $SD_{age} = 13.2$) (see supplementary material S1 for detailed demographic information).

Material:

Analytic cognitive style

Cognitive Reflection Test. To assess reasoning cognitive style, we used a 7-item version of the Cognitive Reflection Test (CRT; 3-item original version by Frederick, 2005; additional items by Thomson & Oppenheimer, 2016). CRT captures people's ability to override an appealing but incorrect intuitive response. An example of item reads as follow:

In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?

When addressing this problem, one would be easily tempted to answer 24 days (as 24 is half of 48). However, this intuitive response is incorrect, and one has to inhibit it to give the correct response (47 days). Participants scored 1 point per correct response, and a composite score was computed (out of 7). Higher scores indicate greater cognitive reflection.

Thinking disposition. To assess thinking dispositions, we used the Actively Open-minded Thinking scale (AOT; Baron et al., 2015; Stanovich & West, 1997). We used a 8-item version of the scale, which assesses people's willingness to reconsider one's beliefs (e.g., 'People should revise their beliefs in response to new information or evidence') and targets attitude toward evidence (see Pennycook et al., 2020). Participants answered using a 5-point scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). A composite score was then computed (out of 8), with higher scores reflecting greater open-minded thinking. The scale showed good reliability (Cronbach's $\alpha = .76$).

Exploring the extent to which analytic cognitive style predicts climate change skepticism, and to avoid collinearity issues (see Berry, & Feldman, 1985), we transformed CRT and AOT into ratio scores, and we combined the two measures into a composite analytic cognitive style score (Cronbach's $\alpha = .78$).

Cognitive Ability. We used the 3-item version of the numeracy scale (Schwartz et al., 1997), a task which has been regularly used to assess cognitive ability (e.g., Liberali et al., 2012; Pennycook et al., 2014). Each item consists in a short mathematical problem that participants have to solve, capturing people's ability in performing simple mathematical operations. An example of problem reads as follow:

Imagine that we rolled a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up even (2, 4, or 6)?

A composite score of numeracy was then computed out of three, with higher scores indicating greater numeracy.

Belief in Science. We used the 10-item belief in science scale (Farias et al., 2013). The scale assesses the extent to which people believe in and value science (e.g., “Science is the most efficient means of attaining truth”). Participants answered using a scale ranging from 1 (Strongly disagree) to 6 (Strongly Agree). A composite score was then computed, with higher scores indicating stronger belief in science. The scale showed excellent reliability (Cronbach’s $\alpha = .94$).

Science Literacy. To assess science literacy, we used the 8 questions used by Kahan et al. (2012), which were originally drawn from the National Science Foundation’s “Science and Engineering Indicators”, and are largely used as an index of public understanding of basic science (see Allum et al., 2008). An example of question reads as follows: “Electrons are smaller than atoms” [true/false]. Participants scored 1 point per correct answer and a composite score was computed (out of 8).

Climate Change Skepticism. To examine skepticism about climate change, we used the 12 items targeting skepticism in the measure originally proposed by Whitmarsh (2011)¹. The items capture various issues about climate change, such as the causes for climate change (e.g., ‘Claims that human activities are changing the climate are exaggerated’) or else evidence of climate change itself (e.g., “The evidence for climate change is unreliable”). Participants answered each item using a scale ranging from 1 (Strongly disagree) to 5 (Strongly Agree). The scale showed excellent reliability (Cronbach’s $\alpha = .96$).

¹ The original measure taps four dimensions, but only the first one, which targets the belief component of skepticism, was administered to the participants.

Attention Check. In order to ensure that participants gave sufficient attention to the survey, and to collect good quality data, we included in each study an attention check within the climate change skepticism scale. This item read as follows: “This is a control question, please respond Somewhat Agree”. Participants who gave another response were excluded from the analyses.

Results and Discussion

Table 1 displays semi-partial correlations as well as a multiple linear regression model including our variables of interest. Analytic cognitive style ($\beta = -0.24$) and belief in science ($\beta = -0.18$) independently predicted climate change skepticism, with analytic cognitive style found to be the strongest predictor (full details in Table 1). Science literacy and numeracy were overshadowed by the inclusion of the other variables.

These results give substance to the notion that analytic cognitive style is a decisive component of public opinion on climate change. People more intuitive seem more likely to endorse skepticism despite scientific evidence and consensus as compared to people more analytic. These data align with research showing that unscientific, epistemically suspect beliefs partly derive from reasoning cognitive style (see Pennycook et al., 2012). Interestingly, belief in science emerged as an independent predictor of climate skepticism, suggesting that lack of recognition of science as a valuable, reliable method of inquiry belonging to a trustworthy institution also paves the way for climate change skepticism. Hence, for some people, rejection of scientific consensus and climate change scientific claims might stem from an alternative epistemology, leading them to validate or disapprove statements on grounds other than that of science. This tendency reflects environmental anti-science (see Ehrlich, 1996) and is consistent with prior results related to scientific mistrust toward climate models and data (see Malka et al., 2009).

Table 1. Semi-partial correlations and multiple regression results using climate change skepticism as the criterion (Study 1).

Predictor	<i>b</i>	<i>b</i> 95% CI [LL, UL]	β	β 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	<i>r</i>	Fit
(Intercept)	57.57**	[47.36, 67.78]						
Age	0.01	[-0.09, 0.11]	0.01	[-0.08, 0.11]	< .001	[-.00, .00]	.03	
Gender	-5.68**	[-8.33, -3.04]	-0.20	[-0.30, -0.11]	.04	[.00, .08]	-.18**	
Education	0.54	[-0.20, 1.29]	0.07	[-0.03, 0.16]	.00	[-.01, .02]	.03	
Belief in Science	-0.20**	[-0.31, -0.09]	-0.18	[-0.27, -0.08]	.03	[-.00, .06]	-.21**	
Science literacy	-0.49	[-1.50, 0.52]	-0.05	[-0.16, 0.05]	.00	[-.01, .01]	-.18**	
Numeracy	-1.52	[-3.16, 0.12]	-0.10	[-0.21, 0.01]	.01	[-.01, .02]	-.23**	
Analytic Cognitive Style	-18.58**	[-26.95, -10.21]	-0.24	[-0.35, -0.13]	.04	[.01, .08]	-.33**	
								$R^2 = .186^{**}$ 95% CI [.11, .24]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. β indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively. * indicates $p < .05$, ** indicates $p < .01$.

Study 2: Knowledge and illusion of knowledge

Analytic cognitive style left aside, a knowledge-deficit account is often raised for diagnosing lack of adherence to climate change (see Milfont, 2012). The general rationale is that a low reception of appropriate scientific information decreases the potentiality of climate concerns. There is evidence that a lack of scientific information is conducive to negative attitudes toward science (Rutjens et al., 2018). More specifically, lacking scientific knowledge about specific scientific issues (e.g., innocuousness of GMO foods) increases the level of suspicious, mistrustful attitudes toward these issues (McPhetres et al., 2019). Yet,

increasing education in these domains helps reverse aversive attitudes (McPhetres et al., 2019).

Not only may climate change skepticism be a matter of knowledge, but it may also be a matter of one's own subjective evaluation of climate change knowledgeability. Aside from considering the extent of knowledge people have about a topic, it would be fruitful to evaluate whether self-assessment of domain-specific knowledge (i.e., the illusion of knowledge; Kruger & Dunning, 1999) is also at stake when it comes to subscribing to climate change skepticism. Indeed, some findings illustrate that people display poor climatology literacy and have a very limited understanding of how the mechanism of climate change works (Weber and Stern, 2011). Yet, some people hold strict conviction about the non-anthropogenic nature of climate change, even though they are in opposition to the scientific doxa. It follows that some climate skeptics might believe that they detain sufficient information on the issue to challenge evidence-based claims (see Torcello, 2016). As such, the exploration of overconfidence is an important novelty in the context of climate change skepticism, since overconfidence in one's own knowledge has direct consequences on the motivation to confirm one's prior beliefs (i.e., exhibiting confirmation bias), rather than to seek reliable information (see Hart et al., 2009). By contrast, awareness of domain-specific incompetence, or intellectual humility, is more likely to make people rely on evidence, thereby enhancing recognition of scientific authority.

Study 2 tests the level of knowledge and the illusion of knowledge (or confidence bias) as possible mechanisms explaining climate change skepticism. We investigate knowledge and overconfidence both at the dispositional level (general knowledge) and the specific level (knowledge about climate change topic). The choice to use both a general and specific knowledge measure is motivated by differences in results obtained between the two types of measures ; although general knowledge has been shown to support political identity

in the framework of climate change, specific climate change knowledge positively correlates with the acceptance that climate change is occurring (Guy et al., 2014). In addition, Study 2 will also provide the testing of competing accounts to explain climate change skepticism, the classic view of analytic thinking, as it was explored in Study 1, and the knowledge deficit account (see also McPhetres, & Pennycook, preprint).

We hypothesize that general and climate change knowledge would stand as independent negative predictors of climate change skepticism while overconfidence in this knowledge would be a positive condition for holding climate change skepticism. We also maintain our initial hypothesis regarding the role of analytic cognitive style. The relative importance of knowledge and illusion of knowledge will be appraised relative to analytic cognitive style by including them in the same linear regression equation.

Method

Sampling rationale: An a priori power analysis was conducted using Gpower (Erdfelder et al., 1996). The analysis indicated that a sample size of 460 would be required to observe a significant effect of our predictors with a power of 0.95 and an alpha of 0.05, based on an effect size (F^2) of 0.05.

Participants and design: A total of 496 American participants were recruited on the Amazon Mechanical Turk online data collection platform. Among the initial sample, 110 participants did not complete the questionnaire ($N = 82$) and/or failed to respond to the attention check question ($N = 67$). They were then removed from any further analysis, leaving a final sample of 386 participants (246 females, 1 “other”; $Mean_{age} = 40.2$, $SD_{age} = 13.2$) (see supplementary material S2 for detailed demographic information).

Material:

The climate change skepticism scale (Cronbach's $\alpha = .96$), the cognitive reflection measure (CRT) and the cognitive ability measure (Numeracy) were the same as the measures used in Study 1. We detail the new measures.

Rational Experiential Inventory: We used the 10-item version of the Rational-Experiential Inventory (REI-10 Epstein et al., 1996), which includes two independent constructs operating in parallel. Five items assess people's Need For Cognition (NFC), that is, the extent to which people are inclined towards cognitive effort (e.g., 'I prefer to do something that challenges my thinking abilities rather than something that requires little thought'; Cacioppo & Petty, 1982). Five items assess people's Faith in Intuition (FI), that is, the extent to which people rely on intuition and experience to make decisions (e.g., 'I believe in trusting my hunches'; Epstein et al., 1992). Participants answered NFC (Cronbach's $\alpha = .77$) and FI (Cronbach's $\alpha = .90$) using a 5-point scale ranging from 1 (Completely False) to 5 (Completely True). A composite score for each of the dimensions was then calculated. A high score on the NFC scale indicates stronger engagement and enjoyment of cognitive activities and analytical thinking. A high score on the FI scale indicates stronger engagement and enjoyment of intuitive thinking.

Following the same rationale as in Study 1, to avoid collinearity, we transformed CRT, NFC, and FI (reversed) into a ratio score, and we combined the three measures into an analytic cognitive style score (Cronbach's $\alpha = .75$).

Climate Change Knowledge and Confidence: To assess people's climate change literacy, we relied on the questionnaire proposed by Tobler et al. (2012). The original version captures five dimensions. With regard to our purpose, we included 19 items from only three dimensions: 7 items for General and Causal knowledge dimension (e.g., "The global CO₂ concentration in the atmosphere has increased during the past 250 years" [True/False]), 6

items for Physical knowledge (e.g., “At the same quantity, CO₂ is more harmful to the climate than methane” [True/False]), and 6 items for Consequence knowledge (e.g., “For the next few decades, the majority of climate scientists expect a warmer climate to increase the melting of polar ice, which will lead to an overall rise of the sea level” [True/False]). Participants scored 1 point per correct answer and a composite performance score was calculated (out of 19).

After answering each question, participants were instructed to indicate the extent to which they were confident that the response they just provided was the correct one, using a scale ranging from 0 (Not at all confident) to 100 (Totally confident)². Overconfidence levels were calculated as the difference between the average confidence level and the proportion of correct answers for each participant. An average confidence level higher than the proportion of correct answers indicates overconfidence, while an average confidence level lower than the proportion of correct answers indicates underconfidence (a difference of 0 indicates no confidence bias).

General Knowledge and Confidence: To assess participants’ general knowledge, we used the measure proposed by Ilieva et al. (2018). The measure consists of 18 questions about general knowledge and participants have to decide between three options which is the correct one (e.g., “What artistic movement does Anacreontics belong to? » [Response options: **Rococo**; Romanticism; Realism]). Similar to the climate change literacy task, after answering each

² Some scholars use a confidence scale ranging from 33% (guess) to 100% (totally sure) when participants have to find the correct answer among 3 proposed options. However, because lay people are not necessarily comfortable with probabilities, and because we are interested in their subjective perception, we decided to range our confidence scale between 0 and 100. For the sake of completeness, we nevertheless reanalyzed our data excluding confidence ratings below 33%. The results were straightforwardly the same as when all the confidence ratings were included in the analyses.

question, participants were instructed to indicate the extent to which they were confident in their answer, using a scale ranging from 0 (Not at all confident) to 100 (Totally confident).

Results

We computed Pearson's r correlations and multiple linear regressions models. Including knowledge levels and overconfidence together made us suspect suppressor effects on the general knowledge variable (for which r is nonsignificant and negative, but with a beta following multiple linear regressions significant and positive) and the climate change overconfidence (for which r is significant and positive, but with a beta following multiple linear regressions significant and negative). Because suppressor effects are hardly interpretable, we present two models enabling clearer interpretations, one which includes the knowledge variables (see Table 2a), one which includes the overconfidence variables (see Table 2b).

Analytic cognitive style was found to be an independent predictor of climate change skepticism ($\beta = -0.13$). Importantly, in regard to our current purpose, climate change knowledge was the stronger, negative predictor of climate change skepticism ($\beta = -0.41$): people with greater knowledge about climate change were less skeptical about climate change (note that this predictor was also significant, of the same sign, and was found to be the strongest predictor when explored using all the variables in a single model). Overconfidence, both at the general and specific level, although significantly associated with climate change skepticism in the bivariate correlations, did not survive the inclusion of the other variables, just as was the case for numeracy.

Table 2a. Semi-partial correlations and multiple regression results using climate change skepticism as the criterion (including general and climate change knowledge; Study 2).

Predictor	<i>b</i>	<i>b</i> 95% CI [LL, UL]	<i>beta</i>	<i>beta</i> 95% CI [LL, UL]	<i>sr</i> ²	<i>sr</i> ² 95% CI [LL, UL]	<i>r</i>	Fit
(Intercept)	5.47**	[4.55, 6.39]						
Age	0.01**	[0.01, 0.02]	0.16	[0.08, 0.25]	.03	[-.00, .05]	.10	
Gender	-0.53**	[-0.74, -0.31]	-0.22	[-0.31, -0.13]	.04	[.01, .08]	-.17**	
Education	0.03	[-0.03, 0.09]	0.05	[-0.04, 0.14]	.00	[-.01, .01]	.01	
Numeracy	-0.09	[-0.39, 0.21]	-0.03	[-0.14, 0.07]	.00	[-.00, .01]	-.19**	
Analytic cognitive style	-1.11*	[-2.01, -0.20]	-0.13	[-0.24, -0.02]	.01	[-.01, .03]	-.24**	
General Knowledge	0.02	[-0.02, 0.07]	0.05	[-0.04, 0.14]	.00	[-.01, .01]	-.03	
Climate Change Knowledge	-0.20**	[-0.24, -0.15]	-0.41	[-0.51, -0.31]	.13	[.07, .19]	-.43**	
								$R^2 = .266^{**}$ 95% CI[.18,.32]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. *sr*² represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively.

* indicates $p < .05$. ** indicates $p < .01$.

Table 2b. Semi-partial correlations and multiple regression results using climate change skepticism as the criterion (including general and climate change overconfidence; Study 2).

Predictor	<i>b</i>	<i>b</i> 95% CI [LL, UL]	<i>beta</i>	<i>beta</i> 95% CI [LL, UL]	<i>sr</i> ²	<i>sr</i> ² 95% CI [LL, UL]	<i>r</i>	Fit
(Intercept)	3.96**	[3.13, 4.78]						
Age	0.01**	[0.00, 0.02]	0.14	[0.05, 0.24]	.02	[-.01, .05]	.10	
Gender	-0.56**	[-0.80, -0.32]	-0.23	[-0.33, -0.13]	.05	[.01, .09]	-.17**	
Education	0.01	[-0.05, 0.08]	0.02	[-0.08, 0.12]	.00	[-.00, .00]	.01	
Numeracy	-0.27	[-0.59, 0.05]	-0.09	[-0.21, 0.02]	.01	[-.01, .02]	-.19**	
Analytic cognitive style	-2.10**	[-3.05, -1.14]	-0.25	[-0.36, -0.14]	.04	[.01, .08]	-.24**	
General overconfidence	0.00	[-0.00, 0.01]	0.05	[-0.06, 0.15]	.00	[-.01, .01]	.14**	
Climate change overconfidence	0.00	[-0.01, 0.01]	0.00	[-0.10, 0.11]	.00	[-.00, .00]	.12*	
								$R^2 = .138^{**}$ 95% CI[.07,.19]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. *sr*² represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively.

* indicates $p < .05$. ** indicates $p < .01$.

The present results suggest that analytic cognitive style and climate change knowledge are two independent negative predictors of climate change. So far, our results confirm one more time that cognitive reflection was a stronger predictor than cognitive ability (measured via numeracy). Of importance is that climate change knowledge was the stronger predictor of climate change skepticism. That is, analytic cognitive style seems not the unique central element predicting skepticism. Interestingly, these results highlight that both the *structure* and the *content* of the cognition are required to depict an acute understanding of the issue. These results go beyond the simple knowledge-deficit account (see Weber and Stern, 2011) or reasoning-deficit account, but stress that the both are critical aspects of climate understanding. Before drawing any further conclusion, we present a third study, whose purpose is twofold: first, it aims to replicate the present results; second, and of importance, it examines the articulation between knowledge/reasoning and political orientation, which has been shown to play an important part in the development of climate change skepticism.

Study 3 Political orientation and climate change skepticism

So far, our studies shed the light on the importance of cognitive reflection and climate change knowledge as leading factors of climate change skepticism. Beyond the implication of the cognitive dimension, there is also evidence that stances on climate change are shaped by political culture (e.g., McCright & Dunlap, 2011a, 2011b; Gromet et al., 2013). Literature on politically motivated reasoning stresses that moral and political attitudes configure information processing and information selection strategy: when evaluating political

arguments, people seem unable to escape the pull of (political) ideology (Bolsen et al., 2015; Jost et al., 2013, Kahan et al., 2013b; Taber & Lodge, 2006). This Identity Protective Cognition (IPC; Kahan, 2015, 2017) reflects people's tendency to selectively favor or dismiss evidence or information in a fashion that is consistent with the beliefs and values which prevail in their own group. Strikingly, critical reasoning aptitudes do not steer ideologically-motivated individuals toward the best possible evidence, unless the latter dovetails with ideological preferences (see Kahan, 2015) ; and this phenomenon is observed on a wide variety of topics (for instance, see Drummond & Fischhoff, 2017; Khanna & Sood, 2018; Washburn & Skitka, 2018). Specifically, it was observed that cognitive sophistication articulates with identity protective cognition in such a manner that the effects of ideology are greater the more cognitively sophisticated participants are (i.e. a polarization effect; see Kahan et al., 2012). The willingness to engage Type 2 processes would make individuals able to deal with complex evidence and supply them with opportunities to form strong (counter) arguments that fit their ideological interests (Kahan, 2013).

Applied to the topic of climate change, IPC would predict a greater acceptance of the existence of climate change among liberals with high cognitive sophistication and, by contrast, greater skepticism among conservatives with high cognitive sophistication. There is evidence that, when it comes to gauging perceived risks associated with climate change, individualistic interests and partisan tribalism prevail, while climate science comprehension and technical reasoning are instrumented to rationalize one's political preconception (Kahan et al., 2012, van der Linden et al., 2018). For instance, people high in critical reasoning and science comprehension were shown to have higher propensity to align their stance with that of their political group regarding the anthropogenic dimension of climate change (Kahan, 2015).

To date, most of the investigations have been devoted to deciphering the reasons for identity-consistent positioning among conservatives. Some findings suggest that, beyond

ideologically-driven disparity in exposure to climate science information (Campbell & kay, 2014) or gap in attitude toward science (Gauchat, 2012), higher prevalence of climate change denialism among conservatives has to do with the fear that potential policy solutions - e.g., restriction on free-market, carbon taxes – conflict with their political values (Campbell & kay, 2014).

Although there is evidence supporting IPC, some data, however, challenge this account, with some studies failing to confirm the predicted interaction effect. For instance, Connor et al. (2020) failed to replicate the Kahan et al. (2017)'s polarization effect using a Western European sample. Experimental manipulations also showed results hardly reconcilable with IPC. For instance, van der Linden et al. (2018) showed that exposing participants to a simple fact about climate change made both liberals and conservatives update their beliefs on the issue in line with the scientific norm.,

In this study, we appraise dispositional cognitive factors, knowledge³, and overconfidence in knowledge, together with political orientation. Two main competing predictions can be made regarding the influence of these variables as a function of political orientation. On the one hand, IPC would allow to conjecture a polarization effect in which high reasoning proficiency, higher level of knowledge, and lower level of knowledge overconfidence would be associated with lower levels of climate change skepticism among liberals but higher levels of skepticism among conservatives. On the other hand, the classic view of analytical thinking would predict that these elements would contribute to abate climate change skepticism irrespective of political partisanship (Pennycook & Rand, 2019; see also McPhetres, & Pennycook, preprint). Overall, the planned exploration will provide

³ We still rely on both the knowledge measures (specific and general) used in Study 2, to provide a further exploration of the effect found by Guy et al., (2014) - i.e., that general knowledge supports political identity in the framework of climate change, whereas specific climate change knowledge is positively associated with the acceptance that climate change is occurring regardless of political orientation.

additional insights in the attempt to disentangle the influence of both cognitive and cultural dimensions.

Method

Sampling rationale: An a priori power analysis was conducted using Gpower (Erdfelder et al., 1996). The analysis indicated that a sample size of 251 would be required to reach a significant effect of our predictors with a power of 95 % and an alpha of 0.05, based on medium effect size (F^2) of 0.10. Based on prior studies, we expected that between hundred and hundred and fifty participants would be discarded from the sample due to attention check failure.

Participants and design: A total of 397 American participants were recruited on the Amazon Mechanical Turk online data collection platform. Among the initial sample, 125 participants did not complete the questionnaire ($N = 82$) and/or failed to correctly answer the attention check question ($N = 84$). They were then removed from any further analysis, leaving a final sample of 272 participants (97 females; $Mean_{age} = 37.6$, $SD_{age} = 12.1$) (see supplementary material S1c for detailed demographic information).

Material:

The climate change skepticism scale (Cronbach's $\alpha = .94$), the cognitive reflection measure (CRT), the cognitive ability measure (Numeracy), the general knowledge (and confidence) and the climate change knowledge (and confidence) measures were the same as the ones used in Study 2. The novelty is the assessment of political orientation. We used the scale used by Pennycook et al. (2020) which consists in the two following statements “on social issues, I am” and “on economic issues, I am” to which participants are instructed to answer using a 5-

point scale ranging from 1 (Strongly liberal) to 5 (Strongly conservative). The questions showed very good reliability ($\alpha = .85$), and a composite mean score was computed.

Results

Before conducting our main analyses, we started by addressing a current worry about the political representativeness of participants recruited on MTurk (e.g., Kahan, 2013; but see Clifford et al., 2015, for a direct assessment; see also Berinsky et al., 2012; Mullinix et al., 2015, for instance, who show that Mturkers are at least -if no more- as representative of the U.S. population as in-person convenience samples). As it is displayed in Figure 1, we observe a widespread distribution, with data not normally distributed ($p < .001$) and negatively skewed (skewness = -0.61), suggesting that conservatives are sufficiently represented to carry out analyses.

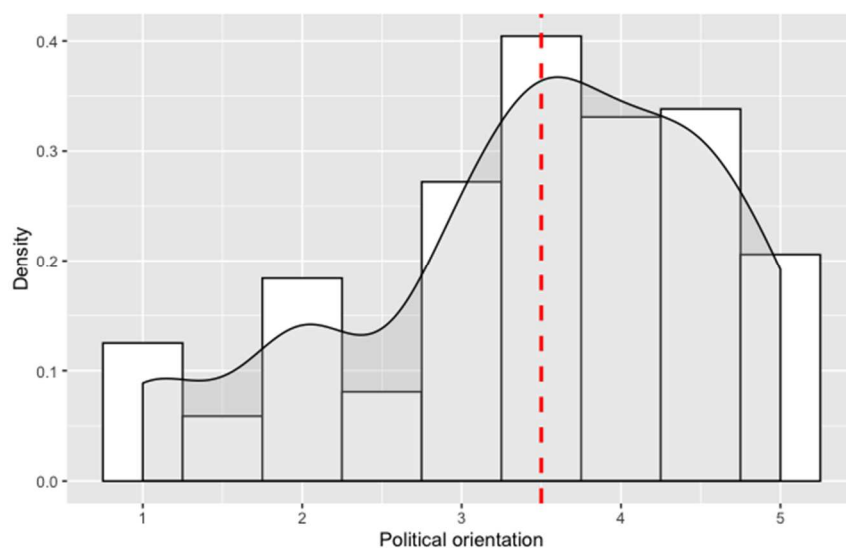


Figure 1. Frequency and density of the sample on the political orientation variable, ranging from 1 (Liberal) to 5 (Conservative) (Study 3).

Similar to Study 2, an initial investigation of the regressed variable including all our variables of interest led us to suspect a suppression effect for the general knowledge variable

(which has a significant and negative correlation coefficient, but a significant and positive beta following multiple linear regressions). Following the same rationale as in Study 2, we present two models, one which includes the knowledge variables (see Table 3a), and one which includes the overconfidence variables (see Table 3b).

CRT ($\beta = -0.17$) and climate change knowledge ($\beta = -0.33$) remained significant negative predictors of climate change skepticism. Overconfidence, both at the general and specific levels, remained significant when including the other variables ($\beta_{\text{general}} = 0.13$; $\beta_{\text{specific}} = 0.27$). Of importance, with regard to our current purpose, is the politics variable, which was found the greater predictor of climate change skepticism ($\beta = 0.36$) with participants more conservative showing the highest levels of climate change skepticism; and it was observed in the two models.

Table 3a. Semi-partial correlations and multiple regression results using climate change skepticism as the criterion (including general and climate change knowledge; Study 3).

Predictor	<i>b</i>	<i>b</i> 95% CI [LL, UL]	<i>beta</i>	<i>beta</i> 95% CI [LL, UL]	<i>sr</i> ²	<i>sr</i> ² 95% CI [LL, UL]	<i>r</i>	Fit
(Intercept)	4.19**	[3.35, 5.04]						
Age	-0.00	[-0.01, 0.01]	-0.00	[-0.09, 0.09]	.00	[-.00, .00]	-.11	
Gender	-0.26**	[-0.43, -0.10]	-0.13	[-0.22, -0.05]	.02	[-.00, .04]	-.16**	
Education	0.06	[-0.01, 0.13]	0.07	[-0.01, 0.16]	.00	[-.01, .02]	.11	
Numeracy	-0.34*	[-0.64, -0.03]	-0.12	[-0.22, -0.01]	.01	[-.01, .02]	-.42**	
CRT	-0.60**	[-0.96, -0.23]	-0.17	[-0.27, -0.07]	.02	[-.00, .04]	-.45**	
General knowledge	-0.02	[-0.49, 0.45]	-0.00	[-0.09, 0.09]	.00	[-.00, .00]	-.14*	
Climate change knowledge	-2.65**	[-3.43, -1.87]	-0.33	[-0.42, -0.23]	.08	[.03, .13]	-.54**	
Politics	0.31**	[0.24, 0.39]	0.36	[0.27, 0.45]	.11	[.06, .17]	.54**	
								$R^2 = .528^{**}$ 95% CI[.43,.58]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. *sr*² represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval,

respectively.

* indicates $p < .05$. ** indicates $p < .01$.

Table 3b. Semi-partial correlations and multiple regression results using climate change skepticism as the criterion (including general and climate change overconfidence; Study 3).

Predictor	<i>b</i>	<i>b</i> 95% CI [LL, UL]	<i>beta</i>	<i>beta</i> 95% CI [LL, UL]	<i>sr</i> ²	<i>sr</i> ² 95% CI [LL, UL]	<i>r</i>	Fit
(Intercept)	2.45**	[1.70, 3.19]						
Age	-0.00	[-0.01, 0.00]	-0.03	[-0.12, 0.06]	.00	[-.00, .01]	-.11	
Gender	-0.21*	[-0.38, -0.04]	-0.10	[-0.19, -0.02]	.01	[-.01, .03]	-.16**	
Education	0.05	[-0.02, 0.12]	0.06	[-0.02, 0.15]	.00	[-.01, .01]	.11	
Numeracy	-0.28	[-0.57, 0.02]	-0.10	[-0.20, 0.01]	.01	[-.01, .02]	-.42**	
CRT	-0.68**	[-1.03, -0.33]	-0.19	[-0.29, -0.09]	.03	[-.00, .05]	-.45**	
General overconfidence	0.01*	[0.00, 0.01]	0.13	[0.02, 0.23]	.01	[-.01, .03]	.45**	
Climate change overconfidence	0.01**	[0.01, 0.02]	0.27	[0.17, 0.37]	.05	[.01, .08]	.56**	
Politics	0.28**	[0.20, 0.36]	0.32	[0.23, 0.41]	.08	[.04, .13]	.54**	
								$R^2 = .538^{**}$ 95% CI[.45,.59]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. *sr*² represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively.

* indicates $p < .05$. ** indicates $p < .01$.

We further tested whether the relationship between our cognitive variables and climate change skepticism varied as a function of political orientation. To this end, we classified participants who scored 1 or 2 on the political orientation scale as Liberals, participants who scored 3 as Moderates, and participants who scored 4 or 5 as Conservatives (see Pennycook et al. (2020). Interaction analyses were performed between the cognitive variables and the political orientation variable (dummy coded). All the interactions, but for the Numeracy × Political orientation, were significant (Table 4; see also Figure 2).

Table 4. Results from the interaction analyses. Political orientation was dummy coded. All the combinations were tested before concluding on non-significant interactions.

	Estimate	SE	<i>t</i>	<i>p</i>	Interaction	Cohens's f^2	(CI 90 %)
CRT x Politics (Moderate)	-0.2897	0.5118	-0.566	0.57			
CRT x Politics (Conservative)	0.9406	0.3799	2.476	0.01*	sig	0.04	0.01-0.08
Numeracy x Politics (Moderate)	0.2748	0.4618	0.595	0.55			
Numeracy x Politics (Conservative)	0.5398	0.3449	1.565	0.12	NS		
General knowledge x Politics (Moderate)	2.0919	0.9480	2.207	0.03*			
General knowledge x Politics (Conservative)	0.6363	0.6961	0.914	0.36	sig	0.02	0.00-0.05
Climate change knowledge x Politics (Moderate)	-0.1680	1.0857	-0.155	0.88			
Climate change knowledge x Politics (Conservative)	2.5590	0.8412	3.042	0.003**	sig	0.04	0.01-0.09
General overconfidence x Politics (Moderate)	0.0233	0.0087	2.658	0.008**			
General overconfidence x Politics (Conservative)	0.0085	0.0079	1.069	0.29	sig	0.04	0.01-0.08
Climate change overconfidence x Politics (Moderate)	0.0029	0.0082	0.350	0.73			
Climate change overconfidence x Politics (Conservative)	-0.0123	0.0057	-2.146	0.03*	sig	0.03	0.00-0.06

Note: * $p < .05$; ** $p < .01$

Simple slopes analyses were performed (all adjusted using Tukey method), testing how much the slope for each of the variables who independently predicted climate change skepticism (cognitive reflection, climate change knowledge, and climate change overconfidence) differed as a function of political orientation (Liberal, Moderate, or Conservative). Regarding CRT, the slope among conservatives was significantly flatter than that of the liberals (estimate = -0.94, SE = 0.38, $t(266) = -2.48$, $p = 0.04$) and the moderates (estimate = -1.23, SE = 0.48, $t(266) = -2.57$, $p = 0.03$), while no difference was observed between liberals and moderates (estimate = 0.29, SE = 0.51, $t(266) = 0.57$, $p = 0.84$). The same pattern of results was observed for climate change knowledge: conservatives significantly differed from moderates (estimate = -2.73, SE = 1.08, $t(266) = -2.52$, $p = 0.02$) and liberals (estimate = -2.56, SE = 0.84, $t(266) = -3.04$, $p = 0.007$), with flatter slopes for the

conservative group, while no difference was observed between liberals and moderates (estimate = 0.17, SE = 1.08, $t(266) = 0.16$, $p = 0.99$. Climate change overconfidence followed the same direction, although the differences did not reach significance (all $ps > .08$). Taken together, these results suggest that the cognitive variables predict significantly less climate change skepticism in conservatives.

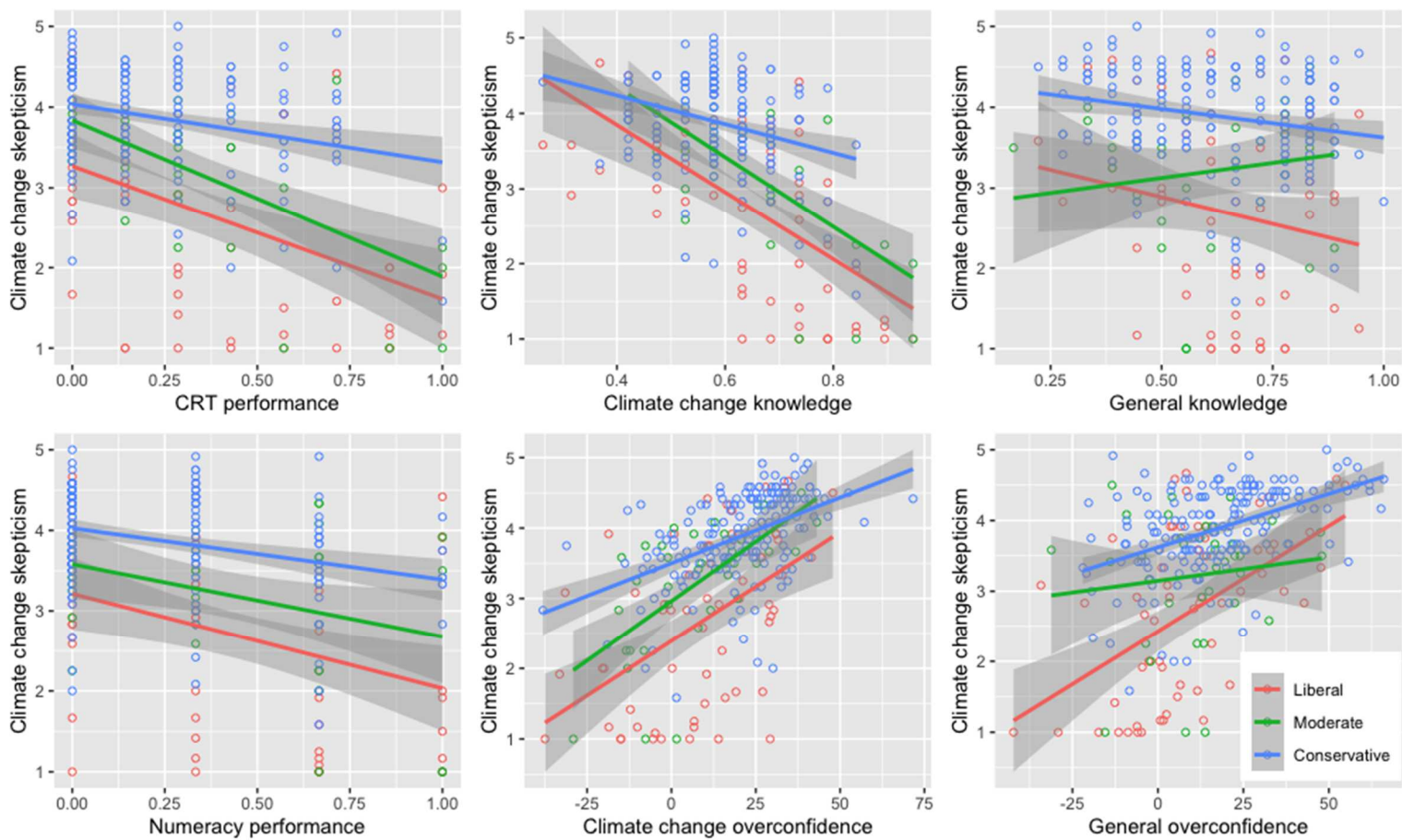


Figure 2. Interaction patterns between Political orientation (Liberals, Moderates, Conservatives) and each of our six main variables in predicting climate change.

General discussion

Despite scientific evidence and consensus, some people remain skeptical about the causes or else the existence of climate change, justifying further investigations of the

underlying psychological processes. We first explored the classic view of analytic thinking, and we observed that people more analytic were less skeptical about climate change than people more intuitive, regardless of their cognitive ability (numeracy) or science literacy (Study 1). Second, we also observed that specific knowledge (here, about climate change) was an independent negative predictor of climate change, together with analytic cognitive style (Study 2). Finally, the influential value of these cognitive variables in explaining climate change skepticism varied according to political orientation (Study 3). Specifically, cognitive reflection, climate change knowledge and specific overconfidence were less associated with the endorsement of climate change skepticism among conservatives than among liberals and moderates (note that these differences were only marginal to nonsignificant for specific overconfidence).

Taken together, these findings support the notion that climate change skepticism can be shaped by people's information-processing style, their amount of knowledge about the topic, and their accuracy in assessing their specific knowledge. Interestingly, classical reasoning proponents argue that analytical thinking is not always sufficient, and that mastering climate models may also be required to accurately understand the anthropogenic underpinning of climate change (see Pennycook & Rand, 2019). Consistent with the conclusions by McPhetres and Pennycook (preprint) about people's beliefs about science, we observed that specific knowledge (here in the domain of climate change) was the best predictor of climate change skepticism. Climate change knowledge was associated with lesser skepticism on the issue, similar to what was observed by Guy et al. (2014). In this respect, reasoning processing and self-insight into the understanding of basic climate science have consequences on beliefs in climate change.

Interestingly, we also observed, in Study 3, that overconfidence in domain-specific knowledge independently predicts climate change skepticism (although that variable did not

survive the inclusion of the other predictors in Study 2). Overall, participants who showed higher levels of epistemic circumspection exhibited lower levels of climate change skepticism. In line with our expectation, aside from cognitive structure and knowledge levels, the metacognitive dimension may be of great importance in the process. Hence, intellectual humility and circumspection could help facilitate the recognition of the complexity of climate science or refrain one from jumping to hasty conclusions.

The present results only partially support IPC and the proposed dynamic between ideological orientation and cognitive factors in the domain of climate change evaluation (see Kahan et al., 2012, Kahan, 2015). Our results showed that both cognitive reflection and the amount of knowledge on the topic negatively predict climate change anti-skepticism in liberals. The predictive value of these variables was significantly weaker in conservatives but remained in the same direction: cognitive reflection and knowledge negatively predict climate change skepticism in conservatives, contrary to what IPC would have suggested (Kahan, 2017). The results reported herein would align with the classical reasoning account, although they do not provide full support for a pure version of this account, at least in this specific context: analytic thinking style prevents both liberals and conservatives from exhibiting climate change skepticism, but this effect is significantly reduced in conservatives, as supported by the interaction effects and the subsequent simple slope analyses.

Reflecting upon the latter results, another perspective may be advocated. The pattern of relationships between the cognitive variables (especially cognitive reflection and domain-specific knowledge about climate) and climate change skepticism in the liberal subsample mirrors that of the conservative subsample, but with a different magnitude. An *asymmetrical conflict account* may help reconcile both the classical reasoning and the IPC perspectives about the effect of analytical thinking on the topic of climate change. According to this perspective, when it comes to reflect about the existence of climate change or its

anthropogenic nature, analytical conservatives could undergo a taxing transaction between their motivation and ability for analytic thinking and their identity-protective mindset. This conflict would not be experienced by analytical liberals because the rational and evidence-based conclusions dovetail with partisan narratives about the issue. If analytical conservatives were to deliberately dismiss the best available scientific evidence in favor of partisan tribalism, we would observe, if not a positive correlation between cognitive reflection/climate knowledge and climate change skepticism (according to an IPC conjecture), at least an absence of correlation. In the same manner, if climate change beliefs were only influenced by analytical reasoning, we would not observe the moderating impact of political orientation. Everything happens as if conservatives who are cognitively equipped to grasp the stake of climate change show attenuated skepticism without completely giving it up. According to this asymmetrical conflict account, the opposite trend may be expected if a scientific consensus was supportive of the conservative worldview. However, things are not as simple as it may appear since conservatives have been shown in the literature to be more concerned by the concept of authority/respect than liberals (Graham et al., 2009). Perhaps, analytical liberals would go through a less demanding conflicting experience. Future research is needed to examine whether such a conflict exists more in conservatives. In addition, it would be interesting to study the narrative and the reasoning of individuals who portray themselves as conservatives but hold a counter-normative stance about the question of climate change. It is reasonable enough to state that among conservatives, some people, with a science background or not, rely on scientific consensus and are convinced that climate change occurs.

Although speculative we acknowledge, another explanation would rely on possible differences in terms of information exposure. On the very topic of climate change, liberals' views fit with the conclusion drawn from climate scientists. As a result, liberal elites do not need to form strong competing arguments against anthropogenic climate change, contrary to

conservative elites. Analytic conservatives, by contrast, may be compelled to consider valid scientific arguments possibly diluted in a whole constellation of (scientific or non scientific) counter-arguments consistent with the conservative view ; what may attenuate conservatives' reliance on the best scientific evidence to such a point that climate skepticism is not totally casted aside. Perhaps, increasing a preferential focus on factual-based information may alleviate skepticism, a view consistent with interventionist studies reversing skeptic attitudes on various scientific issues (McPhetres et al., 2019, Van der Linden et al., 2018).

A limitation in our studies, we advocate, is the correlational nature of our designs, which makes it impossible to test for the directionality of the effects observed. The issue with correlational studies is that it only provides punctual measurements of attitude, beliefs, and cognitive processing. In addition, the specific contents of thoughts that are conducive to skepticism or anti-skepticism, how arguments and counterarguments regarding climate change are dealt with with respect to prior beliefs, or else the content of beliefs that revolve around climate skepticism are not much considered (see Bago, Pennycook, and Rand, preprint). Experimental longitudinal investigations can yield conclusive evidence about the nature of information (corpus of scientific facts) that can cause shifts in beliefs whatever partisanships (see McPhetres et al., 2019, Van der Linden et al., 2018); and there is evidence for it: while correlational studies tend to support identity protective cognition (note that our present results moderate this point), empirical interventions targeting a given topic mitigate prior beliefs in spite of partisan tribalism.

Second, the distribution of ideology (which is negatively skewed, with a greater number of conservatives than liberals) is somewhat unusual according to the studies conducted on Mechanical Turk. For instance, a study targeting the political composition of Mturk samples (Levay et al., 2016) showed that only about 22% of the participants qualified as (slight to extreme) conservatives while liberals accounted for about 58% of the Mturk

sample. We acknowledge that we have no compelling cues explaining this unusual, furthermore considering that some data support demographic stability on Mechanical Turk in the COVID-19 period (see Moss et al., 2020, for instance, although they are silent regarding the political composition of their sample).

An additional limitation refers to the sample size of Study 3 regarding the interaction effects. A sensitivity analysis conducted with a power of .95, an alpha of 0.05, and a sample size of 272 participants for linear multiple regression analyses including the interaction terms indicated that a minimal effect size (f^2) of 0.057 was required. In our study, the obtained effect sizes (f^2) for the interaction terms range from 0.03 to 0.04, suggesting that Study 3 may appear slightly underpowered to confidently claim that the obtained significant interaction terms are probable true positives. On a side note, it is worth noting that a less conservative sensitivity analysis with a standard power of 80 % showed a required minimal effect size of 0.035, suggesting adequate power in this case.

How can one succeed at debiasing climate change skeptics? There is no obvious answer and several propositions and attempts have been made, most that target the intuitive component. In response to the observation that lay people are ready to conform their beliefs to that of their group, a call has recently been made for climate communicators to create a sound climate change message in which scientific information does not threaten groups' values (Kahan et al., 2012), as well as for communicators to make people they want to convince like them (Haidt, 2012). Taking people's difficulty to apprehend climate change into account, other levers have been proposed that rely on climate change nudges (Thaler and Sunstein, 2008). As promising they are, they only show mixed effects to date, the reliance on nudges undermining support for more costly greater impact policies (Hagmann et al., 2019).

We contend that targeting the individuals' intuitive thinking component is not sufficient on its own in the long run, as people's deliberative engagement, in conjunction with

the exposure of factual scientific information, seems to us a *sine qua non* condition to foster the conditions for a march towards informed and sustainable environmental improvement. This suggests that specific levers must actually be targeted. We believe that parallel efforts must be made to promote critical thinking in education and foster intellectual humility (see Pithers, & Soden, 2000). Inoculation framework has proven useful to promote critical thinking in the case of climate change, by providing people with a set of propositions that counter misinformation, and by training them to spot fallacious reasoning (Cook et al., 2017). Intellectual humility, on his side, has been shown to be connected to critical thinking and learning. It qualifies as a worthy and meaningful educational purpose (Baehr, 2016) since people might lack self-insight about the foundation of their opinion and beliefs (Fernbach et al., 2013). In this respect, education can take place everywhere. Encouraging results have been observed through recent popular initiatives in which simple informal dialogues were designed to make people dialectically tackle their questionable beliefs. Inspired by Socrates' maieutic philosophy in which people come to probe the foundation of their opinion, street epistemology (Boghossian, 2014) is a step by step discussion that has proven useful (see also Ranney & Clark, 2016, on the role of learning and instructions on understanding of climate change). Such educational initiatives must target lay people as well as leaders who exert important vertical influence (Druckman & McGrath, 2019). A partisan shift or moderation regarding climate change issues could help reduce potential culture-versus-cognition conflicts among analytical conservatives.

The road to the global acceptance of climate change and human responsibility in the process is full of pitfalls. Maintaining higher educational standards is not a sufficient condition to address the biggest problem humanity has to solve. It is not only the quantity and quality of information that is at stake, but how people process information and practice

intellectual self-defense or epistemic vigilance (Sperber et al., 2010) in a world overwhelmingly filled with fake news and ideological discourses.

Author contributions

The authors contributed equally at all stages of the present research.

Competing interests

The authors declare no competing interests.

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