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DOI
10.1016/j.jenvp.2022.101865

Publication date
2022

Document Version
Final published version

Published in
Journal of Environmental Psychology

Journal of Environmental Psychology 83 (2022) 101865

Contents lists available at ScienceDirect

Journal of Environmental Psychology

journal homepage: www.elsevier.com/locate/jep

Truth over identity? Cultural cognition weakly replicates across 23 countries

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ARTICLE INFO

Handling Editor: Mark Ferguson

Keywords:
Cultural cognition
Climate change
Political ideology
Cultural worldviews
Conceptual replication
Open science

ABSTRACT

Political and cultural polarisation are leading explanations for climate change denial and inactions as seen in the Cultural Cognition Thesis (CCT). In this view, individuals hold positions on contested issues to conform to their ideological groups: people ascribe to certain beliefs, not to express what they know but to show their group identity. We present a conceptual test of the CCT using high-quality cross-national data from 21 European countries, Russia, and Israel (total $N = 44{,}378$). Climate change concern was correlated with identification with the political left ($rs = 0.04$–0.13), egalitarianism ($rs = 0.04$–0.13) and communitarianism ($rs = 0.01$–0.07), but in a broad definition cultural cognition was a weak predictor of climate change beliefs ($R^2 = 3.82\%$), policy preferences ($R^2 = 2.09\%$), and actions ($R^2 = 0.62\%$). Moreover, climate change polarisation was not greatest among the highly educated as predicted by the CCT. Education was positively associated with climate beliefs ($rs = 0.07$–0.17), irrespective of political affiliation. Non-linear regressions indicated little evidence that the CCT's predictions held better for more extreme ideological groups. These results suggest cultural cognition may not be central to thoughts about climate change in Europe.

1. Introduction

Climate change denial is often explained by people having insufficient access to scientific information, lacking education, discounting future risks, feeling hopeless, and perceiving low behavioural control (Gifford, 2011; Pinker, 2018). However, a growing body of research argues that political polarisation is the root cause of climate change inaction (de Witt et al., 2016; Hart & Nisbett, 2012; Kahan et al., 2012, 2017; Krosnick et al., 2014; Kunkle & Monroe, 2019; Newman et al., 2018). Proponents of this Cultural Cognition Thesis (CCT) assert that cultural and political values "supply a self-conscious partisan motivation" for public opinions (Kahan, 2008, p. 415). In other words, "values are cognitive[ly] prior to facts" on contested issues such as climate change, migration, and abortion (Kahan & Braman, 2006, p. 171). The CCT suggests that societal disagreements on climate change do not originate from a lack of education or low scientific literacy, but rather from the conflict between opposing cultural and political worldviews. In this conception, people perceive the world in ways that strengthen and protect only their values and social coalitions (Douglas & Wildavsky, 1982; Jost, 2006; Kalmoe, 2020). That is, "people endorse whichever position reinforces their connection to others with whom they share important ties" (Kahan, 2010, p. 296).

The physical science is plain: climate change will have major consequences for humanity and the earth's ecosystems (Ferguson et al., 2016; Hsiang et al., 2013; IPCC, 2022). However, according to CCT, individuals' beliefs are determined by ideologies instead of such facts. In 2018 in the United States, 27% of Republicans saw climate change as a danger to society, compared to 83% of Democrats (Fagan & Huang, 2019). Proponents of the CCT argue that in this age of unprecedented access to knowledge, wide gaps in belief result from identity-protective cognition (Campbell et al., 1960; Mercier & Sperber, 2011; Wood & Porter, 2019). The CCT suggests that people avoid adopting factual and scientifically supported beliefs, not just because these contradict their group's ideological standpoint, but rather because their interpretation of beliefs such as human-caused climate change are "derive[d] from their cultural worldviews" (Kahan & Braman, 2006, p. 150). That is, climate change positions stem from people's motivation to reinforce their "cultural way of life" (Kahan, 2012, p. 3).

An alternative perspective states that communicating the scientific consensus could increase climate change beliefs and actions across the entire political spectrum (Deryugina & Shurchkov, 2016; Goldberg, van der Linden, Leiserowitz, & Maibach, 2019; Myers et al., 2015; van der

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https://doi.org/10.1016/j.jenvp.2022.101865
Received 23 July 2021; Received in revised form 6 June 2022; Accepted 9 August 2022
Available online 15 August 2022

Linden et al., 2017). According to this view, facts could neutralise the perceptual effects of polarisation, and perceptions of factual beliefs and scientific consensus would not be moderated by ideology (van der Linden, 2021; van Stekelenburg et al., 2022). In a representative U.K. sample ($N = 808$), political affiliation explained 1.3% of the variance in climate change risk perception, whereas norms and biospheric values explained 34.4% (van der Linden, 2015). In addition, these authors observed several theoretical and methodological issues with CCT, leading up to the critiques that the CCT may (a) conflate political ideology, worldviews, and cultural norms, (b) not be representative, as it primarily relies on extremely polarised political groups in the U.S., and (c) not cohere with the finding that education and scientific literacy, irrespective of identity, can adjust beliefs towards the consensus (Goldberg et al., 2019b; Persson et al., 2021; van der Linden, 2016a; van der Linden et al., 2017).

The value of the CCT in predicting climate change perception and attitudes is still unclear and this has led to calls for further evaluation (Johnson & Swedlow, 2021; van der Linden, 2016a; Xue et al., 2014). Our pre-registered study tests to what extent political ideology, cultural values, and education explain variability in climate change beliefs, policy preferences, and actions across 21 European countries, Russia, and Israel.

2. Identity and the politics of climate change

2.1. The Cultural Cognition Thesis

Proponents of the CCT observe that the public debate in the 21st century has been subjected to a "maelstrom of irrationality" (Pinker, 2018, p. 355), despite unprecedented science literacy. From climate change scepticism and political conspiracy theories to vaccination hesitancy, such anti-science developments are traditionally attributed to either the public's incomprehension of science or the inaccessibility of scientific sources (Kahan, 2010; Murray, 2019). However, Reynolds et al. (2010; $N = 248$) observed that climate change knowledge is equivalent in believers and non-believers (see also Kahan, 2015). Accordingly, the CCT argues that if people can believe in climate change without understanding the science, then knowledge may not be the primary basis of climate opinions. Therefore, lacking comprehension would not be the main cause of disagreements on climate change (Hart & Nisbet, 2012; Shtulman, 2006).

Instead, the CCT proposes that this public division on climate change is caused by a conflict of interest between two dimensions of cultural cognition (Kahan et al., 2012, 2017). The first dimension *grid* represents political values, where hierarchic right-wing beliefs contrast with leftist egalitarianism (Kahan et al., 2012). The second dimension *group* encompasses cultural values between individualism and communitarianism (Kahan et al., 2012). In a representative survey in the U.S. ($N = 1,540$), traditionalists, who have a strong authority orientation and aversion to collective interference with individual decisions, were sceptical of the role of humans in environmental degradation (Kahan et al., 2012). In contrast, communitarians, who promote solidarity over competitiveness and are less in favour of hierarchical organisation of society, supported climate change mitigation. These results were further replicated when controlling for education and science literacy, indicating that attitudes on climate change convey ideological values rather than scientific appraisals (Pinker, 2018). The CCT predicts that people are psychologically predisposed towards assimilating and processing information in an identity-congruent manner (Hart & Nisbet, 2012; Kahan & Corbin, 2016). Kahan et al. (2017) demonstrated that even the most open-minded political conservatives use their numeracy and reasoning capacities selectively: people with the highest cognitive proficiency were most likely to interpret the scientific research in a way that was consistent with—and therefore benefited—their beliefs and political identity (representative survey in the U.S., $N = 1,600$: Kahan & Corbin, 2016: for background information see Ballew et al., 2020; McCright & Dunlap, 2011). That is, "members of the public with the highest degrees of science literacy and technical reasoning capacity" may generally not be "the most concerned about climate change". Rather, they are "the ones among whom cultural polarisation (..) [is] greatest" (Kahan et al., 2012, p. 2: see also Kellstedt et al., 2008).

Consequently, the CCT suggests that science communication, rather than being a positive force for general consensus, could produce a boomerang effect (Hart & Nisbet, 2012), thereby furthering polarisation and reinforcing people's "cultural predispositions" (Kahan, Jenkins--Smith, & Braman, 2011; on polarisation see also van der Maas et al., 2020). Individuals "extensively (..) [rely] on cultural meanings in forming perceptions of risk" (Kahan et al., 2015, p. 192), with identity-protective cognition mechanisms ensuring that the facts, independent of content, increase the extremity of the group's position. On politically contentious issues such as climate change, the public debate would regress into a partisan contest: "people affirm or deny certain beliefs to express not what they know, but what they are" (Pinker, 2018, p. 713).

Beyond the "subconscious influence" (Kahan, 2008, p. 413) of political and cultural values on attitudes, this entwinement of beliefs and identity has consequences for the behaviour of those whose identity indicates a position on climate change. That is, people may behave in ways such as to harness the symbols of their values (Brick & van der Linden, 2018). People may resist social change and actions promoting environmental sustainability in part because it signals being part of a group with an unwanted identity (Bashir et al., 2013; Brick & van der Linden, 2018), which would be consistent with the CCT. In three correlational studies in the U.S. (total $N = 1,126$), Brick at al. (2017) showed that people decreased their highly visible pro-environmental behaviour when it communicated an unwanted identity, in the "brown-to-keep-down" effect. Crucially, non-environmentalists still engaged in pro-environmental behaviours that were less visible and therefore may have fewer reputational consequences.

2.2. A critique of the Cultural Cognition Thesis

Over the last decade, the Cultural Cognition Thesis won substantial support in the media and the public mind (Kalmoe, 2020). However, its primacy has also been criticised (Goldberg et al., 2019b; Schmidt & Betsch, 2019; van der Linden, 2016a, 2019; Wood & Porter, 2019). Do climate change beliefs have "nothing to do with science, and everything to do with ideology and identity" (Hayhoe, 2021, p. 135)?

In a comprehensive study (U.K., $N = 808$), van der Linden (2015) described climate change risk perception as a function of three psychological processes: cognitive factors (e.g., knowledge), experiential processing (e.g., affect), and socio-cultural influences (e.g., caring for the biosphere and non-human animals). While political ideology only predicted 1.4% of climate change risk perception, affect (21%), biospheric values (12%), descriptive and prescriptive norms (22%), and knowledge (9%) all predicted more (sum ≈ 66%; van der Linden, 2015). Also in contrast with CCT's central claim, after Brick et al. (2017) accounted for behaviour difficulty and visibility, political ideology did not predict self-reported pro-environmental behaviours.

In a 25-country study ($N = 5,323$), Hornsey et al. (2018) found that outside of the U.S. the relationship between ideology and climate scepticism was relatively weak, with little evidence that conservative values predispose people to reject global warming as a fact: $r(205) = 0.44$ in the U.S., and mean $r(4,063) = 0.09$ across all 25 countries. Americans may therefore seem to evaluate and interpret climate science through the lenses of their ideological worldviews, yet Goldberg et al. (2019a; total $N = 16,168$) found that their climate change beliefs were not determined by such deep-seated values but rather by pluralistic ignorance. Hence, although Republicans who perceived a lot of ambivalence in society had lower pro-environment beliefs than Democrats, this belief-gap decreased for those aware of the scientific consensus on climate change (Goldberg et al., 2019a). In sum, political ideology does

not appear central to environmental beliefs, in contrast with the CCT (Brick et al., 2017; Goldberg et al., 2019a; van der Linden, 2015).

It is also possible that the CCT's cultural versus information dichotomy could lead to underestimating the effectiveness of science communication (Persson et al., 2015; van der Linden et al., 2017). Wood and Porter (2019) looked for the CCT's predicted backfire effect in four experiments in the U.S. encompassing 36 topics (total $N = 10{,}100$). In all but one of the topics, conservatives adjusted their opinion towards the consensus, demonstrating that they considered and adhered to information that contradicted their group's views. These adjustments were even made when the issues were politically contentious, such as weapons of mass destruction in Iraq, immigration, and climate change (Wood & Porter, 2019), which suggests that people's perception of societal developments and their beliefs "about the empirical consequences of (..) policies" might not be derived from their "cultural commitments" (Kahan & Braman, 2006, p. 150).

Another piece of suggestive evidence that may contradict CCT predictions is that education is positively associated with pro-climate change beliefs (64-country study, Ns = 102,720: Czarnek et al., 2021). Critically, although left–right identification moderated the effects of education on climate change beliefs, right-wing values did not reverse the positive effects of education. These findings suggest that neither education nor messages on the scientific consensus cause psychological reactance. On the contrary, both kinds of knowledge appear to counter or even refute climate change denial for individuals across the ideological spectrum (Schmid & Betsch, 2019; van der Linden et al., 2019; Wood & Porter, 2019).

3. The present research

To better understand the psychological correlates of climate change attitudes and actions, several studies have pressed for a more holistic approach towards the politics of climate change (Goldberg et al., 2019a; Schmidt & Betsch, 2019; van der Linden 2016a; van der Linden et al., 2017; Wood & Porter, 2019). The main objective of the current study is to evaluate the Cultural Cognition Thesis and test to what extent political and cultural identity explain climate change beliefs, policy preferences, and actions in 21 European countries, Israel, and Russia.

The current multi-country sample ($N = 44{,}378$) from Round 8 of the European Social Survey (ESS; 2016) provided high-quality cross-national data and allowed for a comprehensive empirical and conceptual test of the predictions of the CCT in a wide range of political contexts. As shown by Hornsey et al. (2016), most research on the CCT has been limited to the Anglo-Saxon world (i.e., U.S., Australia, and U.K.). Because climate change is highly politicised in these countries and often seen as a source of public conflict (Baer & Burgmann, 2012; Mildenberger & Tingley, 2019), the CCT might specifically explain why specific English-speaking groups with opposing conceptions of the role of government become more polarised on public and science issues (van der Linden, 2015). Second, researchers critiquing the CCT often operationalized cultural identity as either political affiliation or cultural world values. This is not ideal since Kahan (2002, 2015) demonstrated that both concepts are necessary to measure cultural cognition. Here, cultural identity is operationalized using both dimensions.

Third, the few studies that incorporated both dimensions such as Hornsey et al.'s (2018) 25-country survey provided initial evidence for the weak relationship between (ideological) worldviews and climate change attitudes. However, they did not include related measures such as policy preferences and pro-environmental actions, nor explore the role of education and ideological extremity in the CCT's predictions. Therefore, the aim of the current study is to test to what extent cultural cognition (i.e., political identification and cultural world values) explain the variability in climate-related opinions and behaviours across 23 countries.

3.1. Hypotheses

If polarisation is the root of climate change scepticism as Kahan et al. (2012, 2015, 2017) argue, then:

Hypothesis 1. identification with the political left, communitarianism, and egalitarianism will be positively associated with more climate change beliefs (H1.1), policy preferences (H1.2), and actions (H1.3).

Hypothesis 2. political ideology and cultural worldviews will predict lower climate change beliefs (H2.1), policy preferences (H2.2), and actions (H2.3).

Hypothesis 3. political extremity will be associated with a larger difference in climate change beliefs between the left and the right (H3).

Furthermore, the CCT suggests that people use their cognitive proficiency to articulate ideas and perceive the world in ways that strengthen and protect their social coalition:

Hypothesis 4. education will moderate the relationship between political ideology and climate change beliefs (H4.1), with the highly educated political right having the lowest beliefs, and the highly educated political left having the highest beliefs (H4.2).

4. Method

4.1. Pre-registration

This study was pre-registered at the Open Science Framework (OSF; Nosek & Lakens, 2014) prior to analysis. The pre-registration included the 2016 European Social Survey data (ESS8), the theoretical background of the CCT, the hypotheses, the statistical manipulations, and the analytical plan: https://doi.org/10.17605/OSF.IO/2F6QS.

4.2. Data and participants

The data was retrieved from Wave 8 of the European Social Survey (ESS, 2016) conducted between August 2016 and December 2017. The face-to-face interviews provided high-quality, multistage probabilistic national samples ($N = 44{,}378$) with 47.2% male and 52.8% female respondents, and ages from 15 to 85 years, $M = 49.1$, $SD = 18.6$ (see Table S1 in Supplement for the sample sizes, ages, and gender balance for the individual countries). The countries were Austria, Belgium, Switzerland, Czech Republic, Germany, Estonia, Finland, France, Hungary, Iceland, Ireland, Israel, Italy, Lithuania, Netherlands, Norway, Poland, Portugal, Russia, Spain, Slovenia, Sweden, and the U.K.

4.3. Measures

4.3.1. Predictors

Political ideology. Participants rated their political outlook from 0 (*left*) to 10 (*right*) (McCright & Dunlap, 2011; McCright et al., 2016).

Cultural worldviews. The pre-registered composites of the four cultural worldview constructs were not internally consistent (Cronbach's α's < 0.60). Drawing on Douglas and Wildavsky (1982) and Kahan et al. (2012), we constructed two exploratory composites with z-scored items. To create the *grid* dimension, the hierarchy-egalitarianism index (5 items) surveyed how much the respondents favoured traditional stratifications in society over the removal of barriers to equality (Cronbach's $\alpha = 0.66$, McDonald's $\omega = 0.73$). To explore the *group* dimension, the individualism-communitarianism index (3 items) measured how much the respondents favoured collective solidarity over competitiveness (Cronbach's $\alpha = 0.66$, McDonald's $\omega = 0.66$). See Table 1 for the full item text.

The item-component correlations (range = 0.40–0.83) indicated good discrimination (Hair et al., 2010), yet the internal consistency of

Table 1
Cultural Worldviews in the ESS (two dimensions).

Index	Items	Item-component correlation
Hierarchy – Egalitarianism	Rated 1 (*agree strongly*) to 5 (*disagree strongly*):	
	1. Men should have more rights to a job than women when jobs are scarce	.53
	2. Most unemployed people do not really try to find a job	.40
	3. Gays and lesbians are free to live life as they wish [reversed]	.62
	Rated 1 (*worse place to live*) to 5 (*better place to live*):	
	4. Immigrants make the country a worse or better place to live	.81
	Rated 1 (*cultural life undermined*) to 5 (*cultural life enriched*):	
	5. Country's cultural life is undermined or enriched by immigrants	.83
Individualism – Communitarianism	Rated 1 (*very much like me*) to 5 (*not like me at all*):	
	1. Important to help people and care for others well-being [reversed]	.75
	2. Important to understand different people [reversed]	.78
	3. Important that people are treated equally and have equal opportunities [reversed]	.78

the cultural world values scales was low albeit acceptable (Creswell, 2010; Nunnally & Bernstein, 1994). Because of the relatively low reliabilities, we added two robustness checks for the key analyses in the Supplement: (a) a cultural cognition item pool without assuming an internal structure, and (b) four single-item measures for the individual constructs based on the pre-registration (see Table 2).

Environmental values. Environmental identities and values appear positively associated with pro-environmental beliefs and actions (Brick et al., 2017; Matsuba & Pratt, 2013; Ziegler, 2017). Participants responded to what extent the following statement applied to them: "Important to care for nature and environment". Reverse coded responses ranged from 1 (*not like me at all*) to 6 (*very much like me*).

Education. Education was used to approximate scientific knowledge and numeracy (i.e., cognitive proficiency), as education is one of the strongest predictors of civic science literacy (Kahan et al., 2017; Miller, 2016; van der Linden, 2016). Participants reported their highest level of education (scale from 1 to 27), with the re-coded scale based on the International Standard Classification of Education ranging from 1 (*no formal education*) to 7 (*Master's degree or above*).

Socio-demographic control variables. Age, gender (1 = male), and household income were included as control variables based on negative associations with climate beliefs (Hornsey et al., 2018; Poortinga, Whitmarsh, Steg, Böhm, & Fisher, 2019; van der Linden, 2015). Religious beliefs might be positively related to climate change attitudes and behaviours (Eom et al., 2021; Morrison et al., 2015; Posas, 2007; Schuldt et al., 2017), so respondents also reported their religious tendencies: "*Regardless of whether you belong to a particular religion, how religious are you?*" Responses ranged from 1 (*not at all religious*) to 10 (*very religious*).

4.3.2. Dependent measures

Climate change beliefs. Four items measured belief, perceived risk, and concern about anthropogenic climate change, e.g., "Do you think that the world's climate is changing?", rated from 1 (*definitely not changing*) to 4 (*definitely changing*). The four items were pre-registered as two components, but based on high intercorrelations were z-scored and combined into a single composite (Cronbach's $\alpha = 0.61$, McDonald's $\omega = 0.61$), with item-component correlations ranging from 0.65 to 0.73. See the Supplement for all items.

Climate change policy preferences. The ESS (2016) included three items on policy preferences. When combined, these created a composite with Cronbach's $\alpha = 0.50$. Due to this low reliability, we selected only the item with the highest item-component correlation ($r = 0.73$). Respondents were asked how much they would favour subsidising renewable energy to reduce climate change. The reverse coded responses ranged from 1 (*strongly against*) to 5 (*strongly in favour*), with higher values indicating support for climate mitigation.

Climate change actions. Respondents reported how often they engaged in activities to reduce their energy use in their daily lives from 1 (*never*) to 6 (*always*).

4.4. Analytic plan

All hypothesis tests used unweighted data and all analyses were performed with pairwise deletion of missing data. The study had three levels of analysis. First, linear regressions modelled the relationship between cultural cognition (i.e., political ideology and cultural world values) with climate change beliefs, policy preferences, and actions. The explanatory value of cultural cognition and environmental identity was contrasted using Pratts' (1987) formula of partitioning explained variance. Second, linear and non-linear regressions explored the effects of ideological extremity on climate change beliefs. Third, a moderation model tested whether the relationship between political ideology and belief differed across education.

Using Bonferroni correction, alpha (α) was set to .004 to decrease false positives due to multiple comparisons (the correction was calculated with an α of 0.05 divided by 14 tests). Given the large sample size ($N = 44{,}378$), significance may not however be sufficient evidence for the predictions of the CCT that people's climate change attitudes are "derived" from their "cultural predispositions" (Kahan, Wittlin, et al., 2011, p. 26); for more on sufficient evidence, see (Hentschke & Stüttgen, 2011; Rosnow & Rosenthal, 1996). These effects should also be medium-to-large to support the claim that "values are cognitively prior to facts" (Kahan & Braman, 2006, p. 171). These effect sizes can be evaluated according to their practical significance in relation to previous research (for further work on the comparative standards for evaluating the relative importance of predictors, see Baguley, 2009; Blanton &

Table 2
Cultural worldviews in the ESS (Single items as robustness checks for CCT constructs).

Constructs	Items	Rotated item-component correlation
1. Hierarchy	Important to follow traditions and customs	.88
2. Egalitarianism	Governments should reduce differences in levels of income	.77
3. Individualism	Important to make own decisions and to be free	.82
4. Communitarianism	Important that people are treated equally and have equal opportunities	.82

Note. The four items were selected based on the highest (varimax) rotated item-component correlation. See Supplement for the item scales.

Jaccard, 2006; Kazdin, 1999; Pek & Flora, 2018; Schäfer & Schwarz, 2019). In a meta-analysis of 25 polls and 171 academic studies across 56 nations, key predictors of climate change beliefs had correlations as strong as 0.25 (biospheric values), 0.34 (experience of local weather change), 0.35 (perceived scientific consensus), 37 (trust in scientists), and 0.49 (environmental concern) (Hornsey et al., 2016). If cultural predispositions are central to climate change positions, we expect moderate-to-large effect sizes. All inferential tests marked "exploratory" were not pre-registered, and all deviations are listed in the Supplement.

5. Results

5.1. Descriptives and correlations

Table 3 presents the means, standard deviations, and partial correlations (*ns* > 29,700). Partial correlations show that climate belief was positively associated with education (r = 0.12), egalitarianism (r = 0.06), communitarianism (r = 0.03), and environmental values (r = 0.23), and climate belief was negatively correlated with right-wing political ideology (r = -.13), all *ps* < .001. Furthermore, policy preferences and actions showed similar, slightly weaker associations with these predictors. See the Supplement for the zero-order correlations (Table S1) and consistent findings from the robustness checks with the pooled CCT items and the 4 single CCT items (Tables S2–3).

5.2. Hypothesis 1: Direction of the relationship between CCT and climate change variables

If societal disagreements on climate change originate from the conflict between opposing cultural and political worldviews (Kahan et al., 2012, 2015, 2017), then identification with the political left, communitarianism, and egalitarianism will be positively associated with climate change beliefs (*H1.1*), policy preferences (*H1.2*), and actions (*H1.3*). Three multiple linear regressions (Table 4) tested these claims. All regression coefficients were standardised.

Model 1 explained 14% of the variance in climate change beliefs, F(9, 28,522) = 511, p < .001. Higher beliefs in climate change were predicted by more education (β = 0.03, p < .001) and identifying with egalitarian (β = 0.13, p < .001), communitarian (β = 0.07, p < .001), and environmental values (β = 0.22, p < .001). Furthermore, being politically right-wing predicted lower beliefs (β = -.13, p < .001).

Model 2 explained 7% of the variance in policy preferences, F(9, 29,800) = 329, p < .001. Being in favour of subsidising renewable energy to combat climate change was associated with being more educated (β = 0.03, p < .001), egalitarian (β = 0.14, p < .001), communitarian (β = 0.08, p < .001), and identifying more with environmental values (β = 0.12, p < .001). Being political right-wing predicted lower support of renewable subsidies (β = -.04, p < .001).

Model 3 explained 9% of the variance in self-reported climate change actions, F(9, 29,933) = 324.03, p < .001, with environmental values (β = 0.22, p < .001) predicting more personal energy reduction, whilst identification with the political right predicted less (β = -.04, p < .001). Similarly, egalitarianism (β = 0.06) and communitarianism (β = 0.04) predicted more climate change actions (*ps* < .001). The CCT robustness checks with pooled and single items did not meaningfully change these results (see Tables S4–5 in Supplement). Overall, cultural cognition factors were positively associated with climate change beliefs, policy preferences, and actions.

Table 3
Descriptives.

	n	*M*	*SD*	Partial correlations		
				Belief	Policy	Actions
Predictors						
1. Political ideology	38,583	5.16	2.24	−.13*	−.04*	−.04*
2. Hierarchy – Egalitarianism	40,295	0.02	0.65	.12*	.12*	.06*
3. Individualism – Communitarianism	43,143	0.00	0.77	.06*	.06*	.04*
4. Education	44,170	3.77	1.85	.03*	.03*	.03*
5. Environmental values	43,628	4.82	3.11	.21*	.11*	.20*
6. Religiosity	43,984	4.50	3.17	−.01	−.01	.02*
7. Household income	36,445	5.19	2.73	.02*	.03*	−.03*
8. Female	44,378	52.6%	–	−.02*	−.01	−.03*
9. Age	44,232	49.1	18.6	−.12*	−.05*	.10*
Outcomes						
10. Climate change belief	40,230	0.06	0.63	–		
11. Climate change policy preference	42,983	3.94	1.07	.17*	–	
12. Climate change actions	43,836	4.15	1.22	.13*	.05*	–

Note. Partial correlations *$p \leq .004$.

Table 4
Climate change models.

	Model 1 *Beliefs*	Model 2 *Policy preferences*	Model 3 *Actions*
Political ideology (right)	−.13*	−.04*	−.04*
Hierarchy – Egalitarianism	.13*	.14*	.06*
Individualism – Communitarianism	.07*	.08*	.04*
Education	.03*	.03*	.03*
Environmental values	.22*	.12*	.22*
Religiosity	−.00	−.01	.02*
Household income	.02*	−.01	−.03*
Gender	−.01	−.01	−.03*
Age	−.12*	−.05*	.11*
N	28,532	29,810	29,942
R	.37	.26	.30
Adjusted R^2	.14	.07	.09
F	511	239	324

Note. Regression coefficients were standardised. *$p < .004$.

5.3. Hypothesis 2: Magnitude of the relationship between CCT and climate change variables

If "values are cognitively prior to facts" (Kahan & Braman, 2006, p. 171), the magnitude of these effects matter: political ideology and cultural worldviews should predict climate change variables with moderate-to-strong effects. Yet, the regression β-weights cannot be used to judge relative explanatory power (van der Linden, 2015; Xie et al., 2019), as they do not account for relationships between the constructs within the model (Pratt, 1987). To compare the relative importance of the predictors whilst accounting for multicollinearity (Liu et al., 2014; Nimon et al., 2015), we used the adjusted Method for.

Partitioning of Explained Variance, with the variables standardised β-weights multiplied by the partial correlations (ρ) with the dependent measures.

$$R^2 \approx \sum_j \beta_j * r_{partial\ j} \quad (1)$$

Table 5 shows the variance explained by the three models. Environmental values (4.5%) were the strongest relative predictor of climate change beliefs, with political ideology and cultural values (sum = 3.8%) contributing less. In contrast, cultural cognition measures (sum = 2.1%) explained more variance in policy preferences than environmental values (1.2%). Finally, where environmental values explained 4.4% of the variance in actions, cultural cognition factors (sum = 0.6%) contributed less. The CCT robustness checks did not significantly change these results (see Tables S6–7 in Supplement).

Across 21 European countries, Russia and Israel, there was relatively low value of the Cultural Cognition Thesis in predicting climate change beliefs (*r*s = 0.07, 0.13, and -.13), policy preferences (*r*s = 0.01, 0.13, and -.06), and actions (*r*s = 0.06, 0.04, and -.04). As transnational

Table 5
Relative importance of the cultural cognition thesis.

	Variance Explained (%)		
	Beliefs	Policy preferences	Actions
Socio-demographics			
Age	1.36% *	0.24% *	1.09% *
Gender	0.02%	0.01%	0.08% *
Household income	0.06% *	0.12% *	0.07% *
Education	0.07% *	0.06% *	0.07% *
Religiosity	0.00%	0.01% *	0.05% *
Subtotal	1.49%	0.43%	1.36%
Environmental values	4.47% *	1.24% *	4.36% *
Cultural cognition			
Individualism – Communitarianism	0.51% *	0.16% *	0.32% *
Hierarchy – Egalitarianism	1.65% *	1.69% *	0.14% *
Political ideology	1.69% *	0.33% *	0.16% *
Subtotal	3.82%	2.09%	0.62%

Note. The overall explained variances are slightly lower than the Adjusted R^2 in Table 4 due to partial correlations in the equation. *$p \leq .004$.

models, these results provide a clear pan-European picture of climate change scepticism for separate political and cultural groups (for a segmentation by climate change beliefs across Europe, see Kácha et al., 2022). However, one-level regressions cannot account for possible hierarchies within the ESS sample (i.e., respondents may be nested within a cross-classification of countries; Tabachnick et al., 2007).

Yet, the intraclass correlation coefficients produced by multilevel models for beliefs ($ICC^a = 0.023$ and $ICC^b = 0.026$), policy-preferences ($ICC^a = 0.022$ and $ICC^b = 0.025$), and actions ($ICC^a = 0.022$ and $ICC^b = 0.026$) were below the standard threshold of 0.05 (Heck, 2001; Heck et al., 2013; Rabe-Hesketh & Skrondal, 2008).[1] This demonstrates that more than 97% of the variance in the three climate change measures were predicted by individual variance rather than country variance, and suggests that there is little clustering (i.e., little intra-country correlation). The pan-European, single-level model was therefore the parsimonious solution and was used in all further analyses. To explore individual country statistics, see the Supplement Tables S8–10 for descriptives of the countries and Tables S11–15 for the value of the CCT in explaining climate change measures.

5.4. *Hypothesis 3: Relationship between ideological extremity and beliefs*

Perhaps only a fraction of people are real ideologues. Indeed, Kalmoe (2020, p. 772) asserts that only 20–30% of citizens have "polar, coherent, stable and potent ideological orientations". Similarly, those who hold more extreme political views have stronger and often more extreme convictions than moderates (N = 5,812; Zwicker et al., 2020: for further research on political extremity, see also Toner et al., 2013; van Prooijen & Krouwel, 2017). Accordingly, the predictions of the CCT for political ideology and cultural world values may hold better in polarised groups or other contrasts by ideology.

To test these effects of ideological extremity (*H3*), we compared linear, quadratic, and cubic predictors to evaluate how climate change beliefs vary across the political spectrum (see Table 7). In step 1, Model 4 (only linear regression) showed that political ideology explained 2.8% of the variance in climate change beliefs, $F(1, 35{,}677) = 1{,}064.45$, $p < .001$, with a Residual Standard Error (MSE) of 0.63. The negative relationship ($\beta = -.17$, $p < .001$) indicates that respondents on the political right reported lower beliefs in climate change. However, the association between political ideology and climate change beliefs was not as straightforward as this linear relationship might suggest (see the violin-

[1] Superscript [a] denotes the ICC of the intercept-only (i.e., null) model and [b] denotes the conditional (i.e., full) model.

Table 6
Linear and non-linear models predicting climate change beliefs.

N = 35,677	Model 4 *Linear*	Model 5 *Quadratic*	Model 6 *Quadratic & Cubic*
Political ideology (right)	−.17*	−.31*	.00
Political ideology^2	–	.15*	−.68*
Political ideology^3	–	–	.54*
R	.17	.17	.18
Adjusted R^2	.03	.03	.03
Std. Error of the Estimate	.63	.63	.62
F	1,046	560	400

Note. Regression coefficients were standardised. *$p < .004$.

Table 7
Education moderated the relationship between ideology and climate change belief.

N = 35.535	Model 7 (coefficient)	*SE*	*p*	Bootstrapped LLCI (95%)
Political Ideology (right)	−.02*	.003	.00	[-.03, −.02]
Education	.06*	.004	.00	[.06, .07]
Political Ideology x Education	−.01*	.001	.00	[-.01, −.01]
R	.20			
Adjusted R	.04			
MSE	.39			
F	447			

Note. Regression coefficients were standardised. Political ideology was measured on a scale from 0 to 10 and education on a scale from 1 to 7. *$p < .004$.

plots in Fig. S1 in Supplement for a visualization). In step 2 (Model 5), we included a quadratic function to explore this apparent non-linear relationship. Although the inclusion of this function did not improve the model fit (MSE = 0.63), the quadratic function was significant, $\beta = 0.15$, $F(2, 35{,}677) = 560$, $p < .001$). Finally, in step 3 (Model 6), the cubic function slightly improved the model, $F(3, 35{,}677) = 400$, $p < .001$, MSE = 0.62. The inclusion of all variables as covariates did not change the direction nor significance of these results (see Table S16 in the Supplement).

As shown in Fig. 1, ideologues held more polarising climate change beliefs than moderates. Yet, the growth in differences decays towards the ends of the political spectrum, and the practical differences between the left and the right remains small. With average differences staying within 0.40 standard deviations from the mean in Europe, Russia, and Israel (see for overlapping density plots also Fig. S2 in the Supplement), political ideology was therefore limited in explanatory power even as a non-linear predictor. Since the relationship between political ideology and climate change beliefs shows non-linearity, we explored the effects of extreme values for cultural worldviews on beliefs. To test the differences between cultural ideologues and moderates, six curve-estimation regressions (see Tables S17 and S19 in the Supplement) were run using the same steps described in Table 6. Egalitarianism ($\beta = .18$, $p < .001$), in conjunction with its quadratic ($\beta = 0.14$, $p < .001$) and cubic ($\beta = 0.03$, $p < .001$) exponents explained 5.7% of the variance in climate change beliefs, $r = 0.24$, $F(3, 37{,}516) = 754.38$, $p < .001$, MSE = 0.62. Similarly, communitarianism ($\beta = 0.23$, $p < .001$) and its quadratic function ($\beta = 0.04$, $p < .001$) explained 4.7% of the variance in beliefs, $r = 0.22$, $F(3, 39{,}434) = 961.76$, $p < .001$, MSE = 0.62. The cubic exponent was not significant ($\beta = 0.01$, $p = .65$). The inclusion of all variables of this study as covariates rendered the cubic function for egalitarianism ($\beta = 0.02$, $p = .03$) non-significant, all other results did not change in direction nor significance (see Tables S18 and S20 in the Supplement).

As shown in Fig. 2, those who identified with egalitarian and communitarian values reported higher beliefs in climate change compared to the grand mean in Europe, Russia, and Israel. However, the

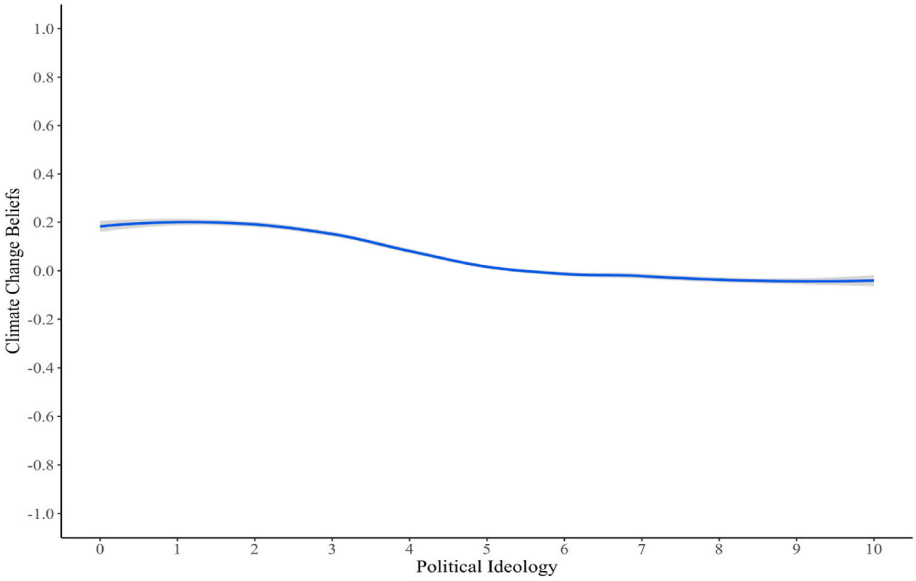

Fig. 1. Non-linear relationship between ideology and climate change beliefs.
Note. Exploratory non-linear regression shows the association between climate change beliefs (z-scored) and political ideology from left-wing (0) to right-wing (10) in Europe, Russia, and Israel.

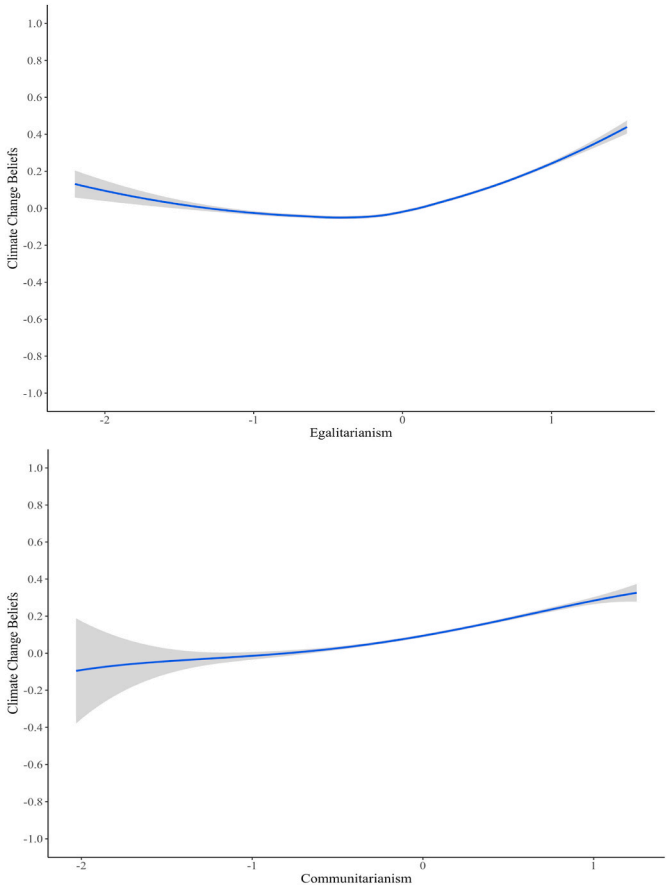

Fig. 2. Non-linear relationship between cultural world views and climate change beliefs.
Note. Exploratory non-linear regressions describe the association between mean climate change beliefs (z-scored) and mean cultural worldviews (z-scored) in Europe, Russia, and Israel.

non-linear relationship suggests that more extreme identification with hierarchical values (i.e., the converse of egalitarianism) did not predict lower climate beliefs: although hierarchical values predicted less belief in climate change, more extreme convictions were associated with slightly more belief.

5.5. *Hypothesis 4: is education a moderator?*

The Cultural Cognition Thesis also predicts that people use their cognitive proficiency to articulate ideas and perceive the world in ways that strengthen and protect their social coalition. In parallel, proponents of the CCT argue that cultural cognition factors are most predictive for the highly educated groups (Kahan et al., 2012). If so, low climate change beliefs are expected for the highly educated on the political right, and high beliefs for the highly educated on the political left (*H4*).

Table 7 shows that the relationship between political ideology and climate change beliefs was moderated by education ($B = -.01$, $p < .001$). The direction of the moderation remained negative and significant after including all other variables as covariates (see Table S21 in the Supplement). To explore the direction of this effect, Fig. 3 visualised the interaction between ideology and education.

Contrasts revealed that ideology affected beliefs for all three levels of education, with low ($t(8,117) = 11.60$, $p < .001$; $r = 0.09$), middle ($t(12,904) = 30.24$, $p < .001$; $r = 0.12$) and high education ($t(14,511) = 23.83$, $p < .001$; $r = 0.16$). Independent of the education level, identifying with left-wing rather than right-wing politics was associated with slightly greater climate change beliefs.

However, education also positively predicted beliefs, with high education predicting higher beliefs compared to middle ($t(31,051) = 17.87$, $p < .001$; $r = 0.10$) and low education ($t(19,058) = 16.23$, $p < .001$; $r = 0.12$). In contrast with the CCT's prediction, those who were higher educated reported more belief in climate change independent of their political identification (see Table 8). In sum, although the association between education and beliefs varied across the political spectrum ($rs = 0.07–0.17$), the direction of education's correcting mechanism remained positive.

6. Discussion

We tested the relative importance of cultural cognition as a predictor

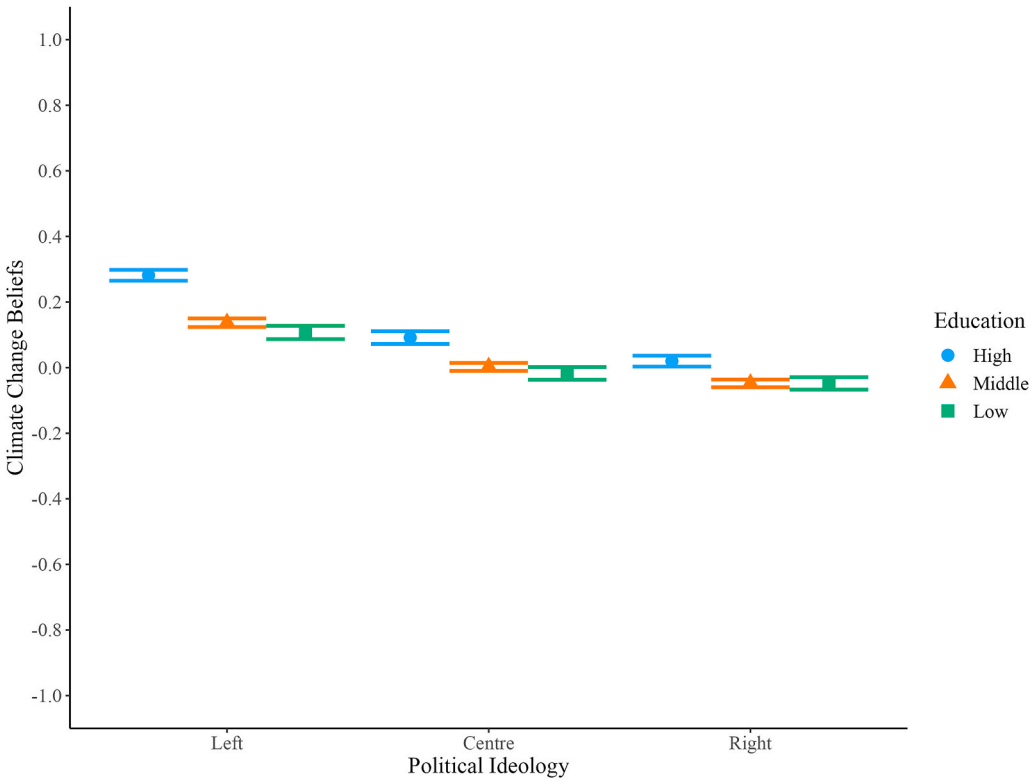

Fig. 3. Moderation-effect of education on the relation between ideology and beliefs.
Note. Climate change beliefs were z-scored. For clarity, education and political ideology were each segmented into three groups, with (a) high education (education values 1–2; N = 10,339), middle education (3–5; N = 23,059) and low education (6–7; N = 10,773), and ideology into (b) left (0–4; N = 11,964), centre (5; N = 12,389) and right (6–10; N = 14,230). The error bars are very small and indicate 95% CIs.

Table 8
Education moderated the relationship between ideology and belief.

	Political ideology		
	Left	Centre	Right
Education			
High	.28	.09	.02
Middle	.14	.00	−.05
Low	.11	−.02	−.05
Significant comparisons			
High vs middle			
MD [bootstrapped 95% CI]	.14 [.12, .17]	.09 [.06, .12]	.07 [.05, .09]
T(df)	$t(8{,}900) = 13.45$	$t(8{,}851) = 6.71$	$t(10{,}320) = 6.52$
r	.15	.09	.07
High vs low			
MD [bootstrapped 95% CI	.17 [.15, .20]	.11 [.08, .14]	.07 [.04, .09]
T(df)	$t(5{,}728) = 13.22$	$t(5{,}048) = 7.76$	$t(6{,}052) = 5.21$
r	.17	.11	.07

Note. Climate change beliefs is the dependent variable (z-scored mean). Comparisons are included if $p < .004$, with MD = mean difference and r = effect size.

of climate change beliefs, policy preferences, and actions across Europe, Russia, and Israel. We evaluated how much political ideology and cultural worldviews predicted beliefs, policy preferences, and actions in representative samples of 21 European countries, Russia, and Israel.

Previous research by Kahan et al. (2012, 2015, 2017) argued that political ideology and cultural worldviews are the root cause of climate change polarisation and inaction. The current findings are not consistent with this claim. Identification with the political left, egalitarianism and communitarianism were positively but weakly associated with climate change positions. In its broadest definition, cultural cognition only weakly predicted climate change beliefs, policy preferences, and actions. Compared to key predictors such as biospheric values, experience of local weather change, perceived scientific consensus, trust in scientists, and the New Environmental Paradigm as shown in the Hornsey et al. (2016) meta-analysis, and environmental values in the current study, the predictive utility of the CCT factors appears relatively small.

Prior literature argued that the CCT's predictions are also contingent on ideological extremity and educational level. Kalmoe (2020) hypothesised that the predictiveness of political ideology is conditional on its extremity, with the gap in beliefs between the left and right increasing towards the extremes on the political spectrum. However, since climate change beliefs varied very little in Europe, Russia, and Israel, political ideology was limited in explanatory power even as a non-linear predictor. Relatedly, the effects of cultural world values were inconsistent and contradictory across its modalities. These findings suggest that the CCT had only modest contributions across Europe and in ideologically polarised European groups.

Finally, education moderated the effect of ideology on climate change beliefs. Although the differences in beliefs between the different levels of education were more prominent on the left, the positive relationship between education and climate change beliefs persisted across the entire political spectrum. Hence, contrary to Kahan et al.'s (2012,

2017) prediction of spreading interactions, higher education did not magnify the extremity of the climate change position of the political right in the current sample. In contrast, higher educated individuals identifying with the extreme right were more prone to believe in climate change than their less-educated political peers. One explanation could be that right-wing identifiers may not have used their cognitive proficiency to interpret the climate change developments in ways that would benefit their political group. Another explanation would be that not believing in climate change would not have benefited their political identity. Either way, education seemed to neutralise the perceptual effects of political polarisation. For further work on the effect of education, see also (Deryugina & Shurchkov, 2016; Goldberg et al., 2019a; Myers et al., 2015; van der Linden et al., 2017).

In sum, cultural cognition appeared to have poor predictive validity in Europe, Russia, and Israel. Although political and cultural identity were associated with environmental scepticism, it was not sufficient to know someone's ideological group to predict their perspective on climate change.

6.1. Limitations and strengths

The large sample and multiple countries provided a unique test of cultural cognition across cultures with high power and representativeness. To our knowledge, this is also the first study that systematically evaluates the CCT's predictions in their broadest definition with analyses including both the direction and the magnitude of the effects of the cultural cognition factors, and the role of ideological extremity and motivated cognition. These findings therefore advance a growing body of literature assessing the role of cultural cognition in climate change scepticism (i.e., Fielding & Hornsey, 2016; Goldberg et al., 2019a; Johnson et al., 2020; Kunkle & Monroe, 2019; Libarkin et al., 2018; Newman et al., 2018; Oltedal et al., 2004; Persson et al., 2015; van der Linden, 2016; Xue et al., 2014; Xue et al., 2016).

One concern with this study is the temporal and inter-cultural generalizability of the conclusions. Global concern and knowledge of climate change has risen sharply since the ESS8 was conducted (Bell et al., 2021) and climate scepticism varies substantially across social and geographical landscapes (Leiserowitz et al., 2021; Wolf & Moser, 2011). However, to this date, the ESS8 was the newest and most conceptually inclusive open-source dataset on climate change attitudes and actions. It would be helpful to extend this research by testing the reliability of these findings over time and the generalizability to non-Western cultures.

A second concern was that country-level variation might obscure the above tests of individual-level CCT variables. This issue was tested in exploratory multilevel analyses, which showed that very little variance in the climate change outcomes was predicted by country-level variance, below the threshold for trivial intra-country correlations (Heck, 2001). Furthermore, both the direction and range of the results in the individual country analyses (see Supplement Tables S11–15) were aligned with the aggregate conclusions, which suggests that the overall findings are representative of the politics of climate change across Europe, Russia, and Israel. Finally, Verschoor, Albers, Poortinga, Böhm, and Steg (2020) have shown that the network structure of ESS8 climate change scepticism items are very similar and robust across the countries, thereby corroborating the pan-European approach. For further work on the homogeneity of the relationships between countries, see also Bhushan et al. (2019) and De Groot and Steg (2007).

Third, it is difficult to infer causation from correlational designs. We are therefore "unable to disentangle the extent to which the ideologies are causing scepticism, scepticism is causing the ideologies or (as seems likely) they influence each other in a dynamic fashion" (Hornsey et al., 2018, p. 619). To investigate to what extent political and cultural values cause climate change scepticism, we recommend future studies use experimental and longitudinal designs.

Fourth, secondary data restrict the operationalizations of key constructs and can worsen conceptual coverage. This is one explanation for the low but acceptable reliability of the CCT scales: these low reliabilities could be obscuring true correlations with CCT factors. However, the robustness checks, e.g., replacing the composites with the single face-valid items and pooled items (see Supplement), supported the main findings and the partial correlations of the single item CCT variables with the individual climate change belief items were also consistent (see Table S22 in Supplement).

Finally, this study cannot tell if the original findings, under the exact same conditions are true. We have, however, explored "the existence of a concept (..) using a different paradigm" (Roetger, 2012, p.1). A central benefit of conceptual replication is that ideas are the unit of analysis rather than effects (Crandall & Sherman, 2016: for the difference between both, see also Derksen & Morawski, 2022). Consequently, by using diverse tests of CCT hypotheses this current study investigated the generalizability of the underlying mechanisms. As such, we retained the CCT constructs whilst formulating "different operationalization for them" (Hudson, 2021, p. 4), thereby offering insights into the conditions under which the theory may or may not hold.

6.2. Future directions

The results suggest that cultural identity is not a central predictor of climate change scepticism. It is still unclear what 'cultural' means in 'cultural cognition' (van der Linden, 2016a). Rather than trying to fit people from different countries into clear-cut cultural dimensions debated between researchers, we suggest studying the influence of diverse social orientations, norms, and political values on climate change scepticism (Price et al., 2014; Sjöberg, 1998). Further studies could also contrast different operationalisations of cultural cognition, including moving beyond political and economic affiliations to alternative identities such as environmentalism (Brick et al., 2017; Kahn, 2002; Matsuba & Pratt, 2013).

Second, dichotomization of complex dimensions is another theoretical concern. For example, the left-right political division has been widely used in political science, psychology, and sociology (Castles & Mair, 1984), although there can be considerable intra-personal and between-country variance in the associations with the 'left' and 'right' concepts (Bauer et al., 2017; King et al., 2004). Furthermore, literature in political psychology is increasingly separating the left-right political ideology into two dimensions: one centred around economic values, including social welfare, inequality and taxes, and another focussed on social issues, such as law and order, immigration, and minority rights (de Wit, 2021; Feldman & Johnston, 2014; Jahn, 2011). Although both these facets were explicitly represented in our cultural worldview composites, current studies on the CCT have not yet adapted to the changes in the 21st century political landscape, such as the fusion of economic liberalism and social conservatism (de Wit, 2021; Wheatley, 2015). The lack of equivalence and the diverse effects of these developments across the globe may help explain why most of the evidence for the CCT has been found in the U.S. In this sense, the CCT might be a theory specific to the U.S. (van der Linden, 2016a), precisely due to the cultural variation in understanding of the ideological and cultural scales.

Third, even though cultural cognition researchers have focused on the relationship between identity and self-reported pro-climate behaviour, there has been surprisingly little empirical research on the role of political and cultural ideologies in actual impacts on the environment. A recent article by Moser and Kleinhückelkotten (2018) posits that even pro-environmental values are typically only associated with actions providing small ecological benefits. Consequently, they argue that ecological footprints are largely determined by environmental damage and are best predicted by income: while intentional climate change mitigation actions may rise with education, so do emissions. Studying politics of climate change also means better understanding how income may affect relationships among cultural cognition, pro-climate behaviours and their impacts, and environmental damage (Attari, 2014; Kormos & Gifford, 2014; Nisbett & Wilson, 1977). Fourth, it would be

informative to explore how high-impact mitigation actions could be promoted to those who identify with right-wing, hierarchic, or individualistic values. Impactful changes that help reduce carbon emissions (e.g., reducing flying or preferring a plant-based diet; Wynes & Nicholas, 2017) and public actions are often highly visible, which increases the salience of these ideological values, thereby potentially decreasing people's inclination to perform meaningful pro-environmental behaviours (Brick et al., 2017). Rather than essentializing differences between diverse political and cultural groups on climate change, a promising practical approach might be to frame climate change mitigation in terms of outcomes each group find most important (e.g., economic competitiveness, innovation and conservation) and to de-emphasize stereotypical associations with environmental behaviours (Bain et al., 2012; Bashir et al., 2013; Feygina, Jost, & Goldsmith, 2010). A last key question for future research on climate change beliefs is which identities influence the formation and sustainment of environmental values. Though left-right political affiliation and cultural worldviews have value, it is crucial to extend both the theoretical and societal focus to other identifiers, such as those based on socio-demographics, trust, the status-quo, democratic commitment, civic engagement, and environmental norms (Feygina, Goldsmith, & Jost, 2010; Halman & Luijkx, 2006; Lee et al., 2015; Lewis et al., 2019; Tam & Chan, 2018). In order to stimulate people to believe in climate change and to act accordingly, both in private and in public, future studies should go beyond the conventional ideological frames and explore ways in which different social identities could be harnessed to help enhance environmental concern.

6.3. Conclusion

Even though political identity may seem like the guiding principle of public debate, these results showed that ideology and cultural values are relatively weak predictors of climate change beliefs, policy preferences, and actions in Europe, Russia, and Israel. In contrast with the Cultural Cognition Thesis, education mitigated the effects of political polarisation. Like all complex social phenomena, climate attitudes and actions are multi-determined (van der Linden, 2016b) and can be analysed using diverse political, sociological, and psychological perspectives.

Data availability

All data is publicly available at https://www.europeansocialsurvey.org/data/download.html?r=8.

Financial disclosure/funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Contributor roles taxonomy

HP: Conceptualization Pre-registration Data curation Formal analysis Investigation Validation Visualization Writing-original draft Methodology Writing-review and editing *SG* Methodology Data analysis peer review/verification Writing-review and editing *TB* Data analysis peer review/verification Methodology Writing-review and editing *CB* Conceptualization Data analysis peer review/verification Methodology Project administration Supervision. *Note.* See https://www.casrai.org/credit.html for the details and definitions of each role.

Declaration of competing interest

The authors declared no potential competing interests with respect to the authorship and/or publication of this article.

Acknowledgements

We thank Ondřej Kácha for his input on the methods and statistical.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2022.101865.

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