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Knowledge as a driver of public perceptions about climate change reassessed

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It is intuitive to assume that concern about climate change should be preceded by knowledge about its effects[1,2]. However, recent research suggests that knowledge about climate change has only a limited effect on shaping concern about climate change[3–6]. Our view is that this counterintuitive finding is a function of how knowledge is typically measured in studies about climate change. We find that if it is measured in a domain-specific and multidimensional way, knowledge is indeed an important driver of concern about climate change—even when we control for human values. Likewise, different dimensions of knowledge play different roles in shaping concern about climate change. To illustrate these findings, we present the results from a survey deployed across six culturally and politically diverse countries. Higher levels of knowledge about the causes of climate change were related to a heightened concern. However, higher levels of knowledge about the physical characteristics of climate change had either a negative or no significant effect on concern. Efforts aimed at improving public knowledge about climate change are therefore not the lost cause that some researchers claim they may be.

As a cognitive perspective of risk perception and an important prerequisite to facilitate behaviour change[7], the extent to which knowledge about climate change can explain and predict public perception of this risk has been investigated in many previous studies[5,6,8–11]. Most research, however, measured knowledge about climate change using a single, self-assessed scale. A problem with subjective, self-assessed knowledge measures is that they possess low validity, because people often report more knowledge than they actually have[7,12]. Likewise, measuring knowledge about complex topics with a single scale may fail to sufficiently reflect the varied nature of underlying knowledge[13,14]. As a result, it becomes difficult to study the effect of different types of knowledge on public concern about climate change[8,10,15].

We assume here that salient information, as well as beliefs about climate change, form individuals' attitudes—and also risk perception—about this issue. These attitudes and perceptions may, in turn, influence intentions, which may result in more climate-friendly behaviours or higher levels of acceptance for climate-friendly policies (as suggested in the theory of planned behaviour)[16,17]. We acknowledge, however, that climate change is a highly complex phenomenon; it is a function of multiple causes, presents different physical characteristics and consequences that lead to a wide range of risks, and its management may involve a wide range of adaptation and mitigation alternatives. For this reason, we see it as crucial that studies of public knowledge about climate change focus on its different aspects, specifically its physical characteristics, as well as its causes and consequences. These three different types of knowledge have been found to be directly related to concern about climate change in previous studies[14,18].

Likewise, it is also critical that measures of knowledge account for respondents' proficiency; in other words, the assessment of knowledge must use scales that clearly and consistently differentiate between those people with less knowledge and those people with more. We therefore posit that a multidimensional and more accurate scale to account for knowledge about climate change will lead to more informative predictions about climate change risk perceptions. If we are correct, researchers will be better able to determine which dimensions of knowledge shape public concern about climate change, and which dimensions are less relevant in this respect.

Another prominent driver of risk perceptions regarding climate change is human values. Various theories about values and worldviews have been proposed to explain people's risk perception. Examples are cultural theory[19] and cultural cognition[20], the theory of values[21] and the values–beliefs–norms theory[22]. Value orientations are akin to the guiding principles in people's lives[21], whereas worldviews reflect people's orientations towards different societal arrangements[23]. These two value measures have been applied alternatively to explain humans' concern about a wide range of environmental issues[18,24].

Three broad value orientations have been found to be important in the formation of perceptions regarding environmental risks: egoistic values, socio-altruistic values and biospheric values[24]. Egoism refers to one's degree of self-interest, altruism to considering and being concerned about the welfare of others and biospherism to one's view of the importance of nature and the environment around them. In particular biospheric values appear positively correlated with risk perceptions about climate change[25]. Also, people with hierarchical and individualistic worldviews—that is, those who identify with a strong belief in the importance of authority and self-reliance—have been observed to demonstrate lower levels of concern about climate change when compared with individuals who identify more strongly with egalitarian and communitarian values[4].

Some research in which both knowledge and human values were related to perceptions of climate change has led to a counterintuitive view compared with the aforementioned theory about the role of knowledge in the development of public concern about climate change[4]. In this work, general scientific knowledge appeared not to be a robust predictor of perceived climate change risks; instead, risk perceptions were found to be more heavily influenced by cultural worldviews. These are thought-provoking ideas and results. We could not help but wonder, however, if the manner in which knowledge was being measured in these studies contributes to these findings. To be clear, we agree that human values may influence both perceptions and behaviours[18]. However, we are sceptical about

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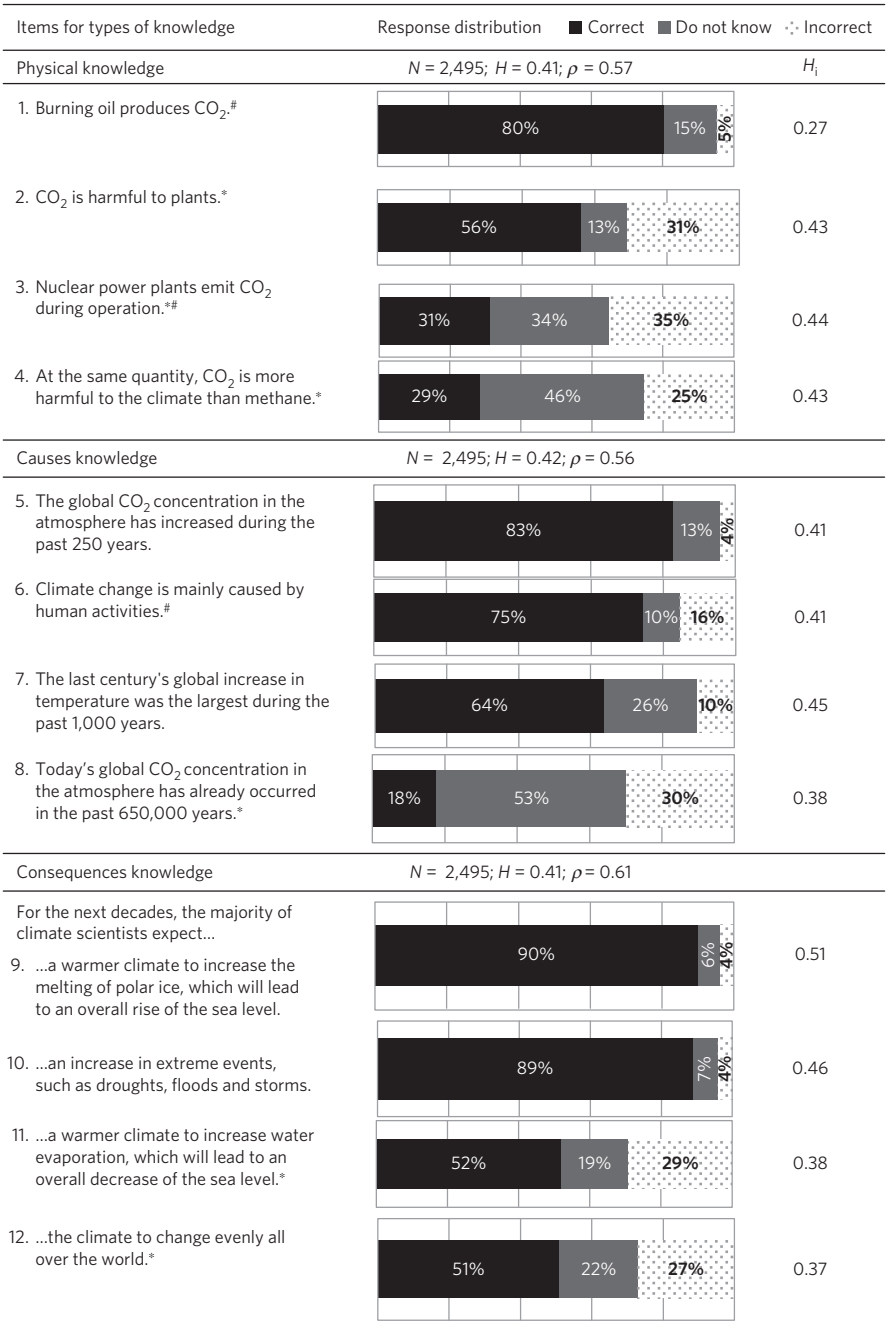

Figure 1 | The items used to assess three kinds of knowledge concerning climate change, their response distributions and scalabilities (H_i), and Loevinger's scalability coefficient (H) and reliability (ρ) of the scales. *Item was reverse coded. #Item was adjusted or newly developed with respect to ref. 14.

their ability to trump public knowledge—particularly about climate change specifically—in such a profound way[26].

With this as backdrop, the present study examined the extent to which knowledge about climate change relates to concern about climate change. We agree with others[25,27] that a broad array of value orientations should be investigated to ascertain their influence on perceptions of climate change, and that systematic differences between values are best measured between countries (versus between individuals)[28]. We therefore chose to investigate people's value orientations (that is, altruism, biospherism and egoism) in the current cross-country study on concern about climate change, and compared results across six countries: Canada, China, Germany, Switzerland, the UK and the US.

We deployed an online survey in these six countries between November and December 2014 ($N = 2{,}495$). A demographically weighted probability sample was used in the US and Canada, and quota samples were used in the other four countries, with gender and age as quota variables. The survey sought to establish respondents' climate-change-related knowledge; biospheric, altruistic and egoistic value orientations; level of concern regarding climate change; and a subset of demographic variables (age, gender and education level). We used three knowledge scales that addressed three aspects of climate change: the causes of climate change, the physical characteristics of climate change and the consequences of climate change. Each knowledge scale consisted of four items that were adopted from previous studies[14,18] (Fig. 1). In addition, we conducted an online study in Switzerland in September 2015 ($N = 336$) to confirm the main results of the cross-country study and to examine the added value of self-assessed knowledge and of the cultural worldviews scales (individualism–communitarianism,

Table 1 | Regression analyses on public concern about climate change.

	Canada		China		Germany		Switzerland		UK		US	
	B	95% CI	*B*	95% CI	*B*	95% CI	*B*	95% CI	*B*	95% CI	*B*	95% CI
Gender†	−0.19	[−0.40, 0.03]	−0.10	[−0.26, 0.07]	−0.32**	[−0.52, −0.13]	−0.08	[−0.27, 0.12]	−0.29**	[−0.48, −0.10]	−0.14	[−0.37, 0.09]
Age	−0.05	[−0.13, 0.02]	−0.04	[−0.10, 0.02]	−0.06	[−0.13, 0.01]	−0.02	[−0.08, 0.05]	−0.12**	[−0.19, −0.04]	−0.06	[−0.14, 0.22]
Low education‡	0.66*	[0.10, 1.22]	0.12	[−0.23, 0.47]	0.02	[−0.23, 0.26]	−0.03	[−0.39, 0.34]	−0.08	[−0.59, 0.42]	0.42	[−0.13, 0.97]
Middle education‡	0.26*	[0.02, 0.49]	−0.13	[−0.31, 0.05]	0.07	[−0.17, 0.30]	0.00	[−0.21, 0.22]	0.15	[−0.06, 0.36]	0.07	[−0.16, 0.31]
Egoistic values	0.13*	[0.02, 0.23]	0.01	[−0.07, 0.09]	0.01	[−0.09, 0.11]	0.02	[−0.07, 0.12]	0.10*	[0.00, 0.20]	0.05	[−0.06, 0.16]
Altruistic values	0.15	[−0.02, 0.31]	0.03	[−0.11, 0.17]	−0.05	[−0.19, 0.08]	0.10	[−0.04, 0.24]	0.05	[−0.08, 0.18]	0.06	[−0.10, 0.21]
Biospheric values	0.38***	[0.22, 0.55]	0.33***	[0.20, 0.47]	0.46***	[0.33, 0.59]	0.28***	[0.14, 0.42]	0.56***	[0.42, 0.69]	0.47***	[0.31, 0.63]
Physical knowledge	−0.92***	[−1.32, −0.51]	−0.27	[−0.63, 0.09]	−0.43*	[−0.78, −0.07]	−0.61**	[−0.95, −0.26]	−0.23	[−0.53, 0.08]	−0.67**	[−1.08, −0.25]
Causes knowledge	1.34***	[0.93, 1.75]	0.53*	[0.12, 0.94]	1.08***	[0.72, 1.44]	1.35***	[0.98, 1.71]	1.22***	[0.86, 1.58]	1.56***	[1.15, 1.98]
Consequences knowledge	0.37	[−0.06, 0.80]	0.08	[−0.33, 0.48]	0.56*	[0.12, 1.01]	0.96***	[0.56, 1.37]	0.60**	[0.22, 0.98]	0.96***	[0.53, 1.39]
R^2	0.35		0.22		0.30		0.35		0.46		0.43	
F(df1, df2)	22.55*** (10, 415)		10.35*** (10, 378)		17.07*** (10, 399)		20.42*** (10, 382)		30.75*** (10, 368)		31.05*** (10, 412)	

For each of the six countries, a separate analysis was conducted. *B* is the unstandardized regression coefficient. 95% CI is the 95% confidence interval for B. *F* is the result of the statistical *F*-test, which is the ratio of average variability explained by the model compared to the average variability unexplained by the model. df1 and df2 are two different degrees of freedom. df1 indicates the number of predictors and df2 indicates the number of included participants minus the number of predictors and minus one. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$. †Dummy variable: 0 = female, 1 = male. ‡Dummy variable with high education as reference group. Low education indicates that the highest degree participants received is below high school (including no education, primary school, secondary school, middle school and some high school in different countries). Middle education indicates that the participants have completed high school but have not yet received a university degree (including high school, vocational school, college and some university). High education indicates that the participants have received a university degree or higher (including a Bachelors, Masters and PhD).

hierarchy–egalitarianism) in explaining concern about climate change (see Supplementary Information).

In the cross-country study, respondents seemed to be reasonably well informed about climate change. For example, approximately 49% of all participants could correctly identify the physical characteristics of climate change, 60% correctly answered all questions about the causes of climate change and 70% of respondents could correctly identify the consequences of climate change (Fig. 1; also see Supplementary Information for a more detailed description of the knowledge scale and the results from it).

We performed multiple regression analyses to examine the impacts of demographics, knowledge and value orientations on concern about climate change in each country (Table 1). Overall, only a few demographic variables were significantly related to public concern about climate change, and only in some of the countries. Specifically, women were found to have more concern than men in Germany and in the UK. In the UK, older adults tended to be less concerned about climate change compared with younger people. Respondents who identified with stronger biospheric value orientations were found to be more concerned about climate change across the six countries. Identifying with egoistic and altruistic values, by contrast, was not significantly related to concern about climate change in most of the countries. It might be because the influence of climate change on individuals or humanity in general is not as significant as its influence on ecosystem and biosphere.

Moreover, knowledge about the causes of climate change was correlated with higher levels of concern about climate change in all countries. This may be because human activities are related to the causes of climate change, which make people feel responsible and, hence, more concerned about climate change. Higher levels of knowledge about the consequences of climate change were linked to heightened concern about climate change in most of the countries. Knowledge about the consequences of climate change may remind people about the severe damage of climate change, and therefore makes the respondents more concerned about it. In addition, knowledge about the physical characteristics of climate change tended to dampen public concern. The result suggests that certain misbeliefs—for example, about the properties of CO_2—may lead to increased concern about climate change. Different knowledge domains may, therefore, have different effects on people's attitudes towards climate change.

Further, in the additional Swiss study, we conducted two hierarchical regression analyses to investigate the additional impact of cultural worldviews and self-assessed knowledge, respectively, on concern about climate change (in addition to the effect of value orientations and objective knowledge, which used the same regression model as in the cross-country study; see Supplementary Information, Model 2). Individualism had a small but significant effect on concern about climate change, whereas hierarchical worldviews did not significantly explain concern about climate change (see Supplementary Information, Model 3[a]). Self-assessed knowledge was not related to concern about climate change (Supplementary Information, Model 3[b]). These results from the additional Swiss study seem to reinforce our findings about the impact of knowledge on concern about climate change in our multinational study, after controlling for cultural worldviews and for value orientations.

In our research, by comparing countries with different cultural backgrounds and political systems, we provide strong evidence that domain-specific and multidimensional measured knowledge about climate change is an important predictor of cross-national public concern even when we control for different value orientations. Importantly, our results show that not all dimensions of knowledge are important for public concern about climate change, and different types of knowledge have different influences on public concern. Knowledge about the causes of climate change is significantly related

to public perceptions about climate change risks, whereas physical knowledge either was not significantly related—or was negatively related—to concern about climate change. This particular result helps to account for why other studies have not found a significant relationship between knowledge and public concerns about climate change, and why they have concluded that the latter is instead more tightly linked to values[4,5].

Further, our findings also reveal that it is worthwhile for researchers to carefully develop and test domain-specific knowledge scales when studying a wide array of risks, including climate change. Specific knowledge about climate change significantly contributes to explaining public perceptions of climate change in addition to value orientations. Our results also show that an objective measure of knowledge appears more qualified than a subjective measure to explain climate change concern.

Our findings further suggest that public education and risk communication efforts regarding climate change may not be the lost cause that some researchers (and some policymakers) assume they are. The emphasis on the causes (versus the physical and consequential dimensions) of climate change should be encouraged in risk education and communication, whereas an emphasis on the physical characteristics about climate change might backfire (leading to dampened public risk perceptions about climate change). Moreover, risk communication of this type should not disregard the importance of individual values. Information that is respectful of biospheric values may be especially important, because people who identify strongly with them tend to demonstrate greater concern about climate change in all the countries we surveyed. Thus, if communication and education are based on carefully curated materials, messages and dialogues that do not violate individual values, public education and risk communication may lead to greater concern about climate change.

To conclude, the results from this study support efforts by scientists and activists who are attempting to present and communicate their information about climate change as a means of raising public awareness and concern. On the basis of our findings, they should continue their efforts, but with an emphasis on the causes of climate change. This, in turn, may help people—and, hopefully, policymakers—to better address the risks and consequences of climate change, and to gain support for mitigation policies.

Methods

Methods and any associated references are available in the online version of the paper.

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Author contributions

All authors contributed to the design, data collection and written presentation for the research reported here. In addition, J.S., V.H.M.V. and M.S. organized and managed the data collection in China, Germany, Switzerland and the UK and J.A. coordinated data collection in Canada and the US. J.S. was primarily responsible for data analysis and for the first complete draft of this manuscript.

Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to J.S.

Competing financial interests

The authors declare no competing financial interests.

Methods

Cross-country survey. *Data collection.* Data of our cross-country study were collected through an online survey deployed between November and December 2014 in six countries (Canada, China, Germany, the German speaking part of Switzerland, the UK, and the US; $N = 2{,}495$). Internet panels from commercial companies were used for recruiting study participants (Germany, Switzerland and the UK: Respondi AG; China: InterfaceASIA Holden; Canada and the US: Insightrix Research). The targeted sample size was 400 adults (over the age of 20) in each country, and respondents were remunerated for their participation. Data from respondents who did not complete the survey, or whose overall survey response time was less than half of the median response time for all participants, were excluded from the analysis.

Gender and age were used as quota variables, and the six samples did not significantly differ with respect to them. After data cleaning, the overall sample was 51.3% female ($n = 1{,}279$) and 48.7% male ($n = 1{,}216$), and respondents were roughly evenly distributed over five age categories: 20–29 years old, 30–39 years old, 40–49 years old, 50–59 years old and 60 years old or above. Respondents in the 20–29-year-old category constituted the smallest portion of the overall sample (17.9%, $n = 446$), whereas respondents over the age of 60 accounted for the largest (22.1%, $n = 551$). In terms of respondents' education level, the largest group had a high school degree but not yet a university degree (53.2%, $n = 1{,}328$), whereas only 243 respondents (9.7%) did not finish high school (see Supplementary Information; Supplementary Table 1 for the demographic breakdown by country).

Instrument development. The knowledge scale used in this research was initially developed in ref. 14. We focused our attention on three dimensions: knowledge about the physical characteristics of climate change, about the causes and about the consequences of climate change. A few items in the original knowledge scales were replaced by new items to optimize the content of the three dimensions of knowledge (see Fig. 1). We selected a subsample of four items from each of the original knowledge scales based on the items' qualities, and on their contributions on public concern about climate change reported in previous studies[14,18]. This resulted in a total of 12 items (Fig. 1).

In the cross-country study, we measured respondents' value orientations by using the egoism, altruism and biospherism scales from ref. 29 (see Supplementary Information; Supplementary Table 2). We chose to investigate value orientations and not cultural worldviews in our cross-country survey because the former are universally valid whereas the latter is strongly linked to the US political system[10]. We therefore would have had to adapt the cultural worldview items in each country so that they would make sense to its sample and it would not have been possible to compare the different worldview scales between countries.

The questions dealing with respondents' concern about climate change were also selected from the previous studies[14,18] (see Supplementary Information; Supplementary Table 3). The survey was initially developed in English, translated into each language and then translated back into English (by the co-authors and by our survey partners in each country) to ensure the correct interpretation of all items.

Data analysis. The scalability of the knowledge scales was determined using Mokken scale analysis[30,31]. Mokken scale analysis is based on an assumption of double monotonicity: first, items that are answered correctly by people with little knowledge about climate change should also be answered correctly by people with extensive knowledge, and second, respondents who are able to correctly answer difficult questions should also be able to correctly answer the objectively easier items. Scalability was measured using the Loevinger scalability coefficient, H, for the entire scale, and by calculating H_i for each item; as such, H indicates the extent to which participants can be accurately ordered by the suggested items, and H_i indicates the degree to which each item could be accurately ordered by the respondents. It is generally accepted that $H \geq 0.40$ and a reliability of $\rho \geq 0.60$ suggest a scale with a sufficiently high scalability factor and good reliability. Further, the findings that a Mokken scale can be constructed, and that the H_{ij} coefficients are moderately correlated, are much better support for the reliability and homogeneity of multidimensional scales than the results of a factor analysis[31] (see the Supplementary Section 2 for a more detailed explanation of the Mokken scale analysis; also see Fig. 1). The Mokken scale analyses were conducted in the software program MSP5 for Windows[30].

To test the extent to which the knowledge scales—in addition to value orientations—are related to concern about climate change, we conducted a linear regression analysis for each country using respondents' concern about climate change as a dependent variable. We included demographic variables (age, gender and education level), the three value orientations (egoism, altruism and biospherism), and the three types of knowledge (physical characteristics, causes and consequences of climate change) as independent variables. Interactions between the three value orientations and the three types of knowledge were not included in the regression analyses. We did not do this, because we had no hypotheses about which value orientation would mediate which type of knowledge. Consequently, we would have had to include nine interaction terms in each of the six regression analyses, and the probability that we found at least one significant interaction among these 54 by chance would be large.

Additional Swiss survey. In the additional online study among a Swiss sample, the same Internet panel was used to recruit a new sample ($N = 336$), with age and gender as quota variables. The sample had 49.7% females ($n = 167$) and 50.3% males ($n = 168$), the youngest participants of the sample are 20 years old and the oldest are 78 years old. The average age of the sample was 44 years (s.d. = 13.91), which was slightly younger than the Swiss adult population[32].

The same items were used to assess concern about climate change, objective knowledge, and value orientations as in the cross-country survey. In addition, items to measure self-assessed knowledge and cultural worldviews were included.

We measured the participants' cultural worldviews by adopting the 12-item scale from ref. 4 (egoism–communitarianism, hierarchy–egalitarianism) and slightly changed the items to better fit the Swiss society. All items were assessed on six-point Likert scales ranging from 1 ('strongly disagree') to 6 ('strongly agree'). Participants were also asked to assess their level of knowledge about climate change on a six-point scale ranging between 'very low knowledge' and 'very high knowledge' (see Supplementary Sections 1.2–1.4).

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