LETTERS
PUBLISHED ONLINE: 27 MAY 2012 | DOI: 10.1038/NCLIMATE1547
nature climate change

The polarizing impact of science literacy and numeracy on perceived climate change risks

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Seeming public apathy over climate change is often attributed to a deficit in comprehension. The public knows too little science, it is claimed, to understand the evidence or avoid being misled[1]. Widespread limits on technical reasoning aggravate the problem by forcing citizens to use unreliable cognitive heuristics to assess risk[2]. We conducted a study to test this account and found no support for it. Members of the public with the highest degrees of science literacy and technical reasoning capacity were not the most concerned about climate change. Rather, they were the ones among whom cultural polarization was greatest. This result suggests that public divisions over climate change stem not from the public's incomprehension of science but from a distinctive conflict of interest: between the personal interest individuals have in forming beliefs in line with those held by others with whom they share close ties and the collective one they all share in making use of the best available science to promote common welfare.

The study collected data on the climate-change risk perceptions of a large representative sample of US adults ($N = 1{,}540$). Measures were selected to permit assessment of two competing accounts of public opinion on climate change. One, already adverted to, can be called the science comprehension thesis (SCT). As members of the public do not know what scientists know, or think the way scientists think, they predictably fail to take climate change as seriously as scientists believe they should[3].

The alternative explanation can be referred to as the cultural cognition thesis (CCT). CCT posits that individuals, as a result of a complex of psychological mechanisms, tend to form perceptions of societal risks that cohere with values characteristic of groups with which they identify[4,5]. Whereas SCT emphasizes a conflict between scientists and the public, CCT stresses one between different segments of the public, whose members are motivated to fit their interpretations of scientific evidence to their competing cultural philosophies[6].

Explanations for the public's perceptions of climate change risk can be tested by observational study insofar as such hypotheses imply correlations between concern over climate change and specified individual characteristics[7]. We instructed subjects to rate the seriousness of climate change risk on a scale of 0 (no risk) to 10 (extreme risk), a general risk-concern measure that furnishes a parsimonious focus for such testing[8,9].

SCT asserts, first, that ordinary members of the public underestimate the seriousness of climate change because of the difficulty of the scientific evidence[3]. If this is correct, concern over climate change should be positively correlated with science literacy—that is, concern should increase as people become more science literate.

Second, and even more important, SCT attributes low concern with climate change to limits on the ability of ordinary members of the public to engage in technical reasoning. Recent research in psychology posits two discrete forms of information processing: system 1, which involves rapid visceral judgments that manifest themselves in various decision-making heuristics; and system 2, which requires conscious reflection and calculation[10]. Most members of the public, according to this research, typically employ system 1 reasoning without resorting to more effortful system 2 processing. Although system 1 works well for most daily contingencies, ordinary citizens' predominant reliance on heuristic rather than analytic modes of reasoning is viewed as leading them to underestimate climate change risks, which are remote and abstract compared with a host of more emotionally charged risks (for example, terrorism) that the public is thought to overestimate[2,3].

If this position is correct, one would also expect concern with climate change to be positively correlated with numeracy. Numeracy refers to the capacity of individuals to comprehend and make use of quantitative information[11]. More numerate people are more disposed to use accuracy-enhancing system 2 forms of reasoning and are less vulnerable to system 1 cognitive errors[11,12]. Hence, they should, on this view, form perceptions of climate-change risk less biased towards underestimation.

These predictions were unsupported (Fig. 1). As respondents' science-literacy scores increased, concern with climate change decreased ($r = -0.05$, $P = 0.05$). There was also a negative correlation between numeracy and climate change risk ($r = -0.09$, $P < 0.01$). The differences were small, but nevertheless inconsistent with SCT, which predicts effects with the opposite signs.

CCT also generates a testable prediction. CCT posits that people who subscribe to a hierarchical, individualistic world-view—one that ties authority to conspicuous social rankings and eschews collective interference with the decisions of individuals possessing such authority—tend to be sceptical of environmental risks. Such people intuitively perceive that widespread acceptance of such risks would license restrictions on commerce and industry, forms of behaviour that hierarchical individualists value. In contrast, people who hold an egalitarian, communitarian world-view—one favouring less regimented forms of social organization and greater collective attention to individual needs—tend to be morally suspicious of commerce and industry, to which they attribute social inequity. They therefore find it congenial to believe those forms of behaviour are dangerous and worthy of restriction[4].

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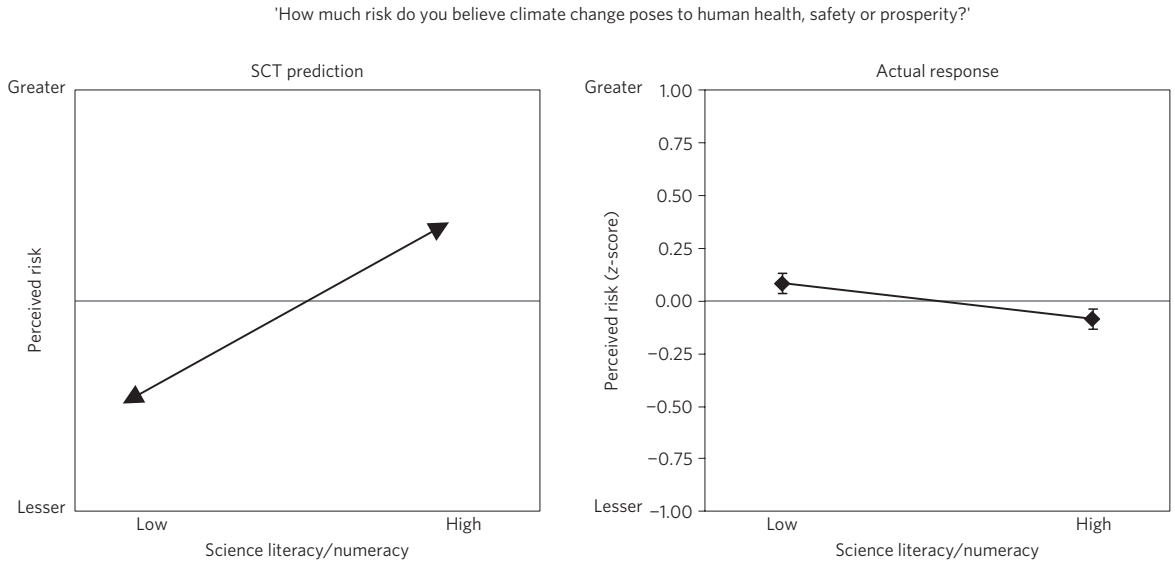

Figure 1 | SCT prediction versus actual impact of science literacy and numeracy on climate change risk perceptions. Contrary to SCT predictions, higher degrees of science literacy and numeracy are associated with a small decrease in the perceived seriousness of climate change risks. Derived from Supplementary Table S4, Model 1. Low and high reflect values set at −1 s.d. and +1 s.d. on the composite Science literacy/numeracy scale (see Supplementary Information). Responses on the 0–10 risk scale ($M = 5.7$, s.d. $= 3.4$) were converted to z-scores to promote ease of interpretation. Confidence intervals reflect the 0.95 level of confidence.

On this view, one would expect egalitarian communitarians to be more concerned than hierarchical individualists with climate change risks.

Our data, consistent with previous studies[6], supported this prediction. Hierarchical individualists (subjects who scored in the top half on both the Hierarchy and Individualism cultural-world-view scales) rated climate change risks significantly lower ($M = 3.15$, s.e.m. $= 0.17$) than did egalitarian communitarians (subjects whose scores placed them in the bottom half; $M = 7.4$, s.e.m. $= 0.13$). Even controlling for scientific literacy and numeracy (as reflected in the composite scale Science literacy/numeracy; see Supplementary Information), both Hierarchy ($b = -0.46$, $P < 0.01$) and Individualism ($b = -0.30$, $P < 0.01$) predicted less concern over climate change (Supplementary Table S4).

These findings were consistent, too, with previous ones showing that climate change has become highly politicized[13,14]. Cultural-world-view and political-orientation measures are modestly correlated. Nevertheless, the impact that cultural world-views has on climate change risk perceptions cannot be reduced to partisanship. The mean hierarchical individualist in our sample was an Independent who leans Republican and is slightly conservative; the mean egalitarian communitarian was also an Independent, but one who leans Democrat and is slightly liberal (Supplementary Fig. S4). The difference between their respective perceptions of climate change risk, however, significantly exceeded what political-orientation measures alone would predict for individuals who identify themselves as conservative Republicans and liberal Democrats (Supplementary Fig. S5).

The finding that cultural world-views explain more variance than science literacy and numeracy, however, does not by itself demonstrate that SCT is less supportable than CCT. SCT asserts not merely that members of the public lack scientific knowledge but also that they lack the habits of mind needed to assimilate it, and are thus constrained to rely on fallible heuristic alternatives. Proponents of this bounded-rationality position treat cultural cognition—the conforming of beliefs to the ones that predominate within one's group—as simply one of the unreliable system 1 heuristics used to compensate for the inability to assess scientific information in a dispassionate, analytical manner[15].

This claim generates another testable prediction. If cultural cognition is merely a heuristic substitute for scientific knowledge and system 2 reasoning, reliance on it should be lowest among those individuals whose scientific knowledge and system 2 reasoning capacity are highest. SCT thus implies that as science literacy and numeracy increase, the scepticism over climate change associated with a hierarchical individualistic world-view should lessen and the gap between people with hierarchical individualistic world-views and those with egalitarian communitarian ones should diminish.

However, this SCT prediction, too, was unsupported. Among egalitarian communitarians, science literacy and numeracy (as reflected in the composite scale Science literacy/numeracy) showed a small positive correlation with concern about climate change risks ($r = 0.08$, $P = 0.03$). In contrast, among hierarchical individualists, Science literacy/numeracy is negatively correlated with concern ($r = -0.12$, $P = 0.03$). Hence, polarization actually becomes larger, not smaller, as science literacy and numeracy increase (Fig. 2 and Supplementary Table S4 and Fig. S3). As the contribution that culture makes to disagreement grows as science literacy and numeracy increase, it is not plausible to view cultural cognition as a heuristic substitute for the knowledge or capacities that SCT views the public as lacking.

To test the generality of this conclusion, we also analysed subjects' perceptions of nuclear-power risks. Egalitarian communitarians and hierarchical individualists were again polarized. Moreover, here, too, the gap between subjects with these outlooks became larger, not smaller as scientific literacy and numeracy increased (Supplementary Table S5 and Fig. S3). Extending research that casts doubt on the knowledge-deficit explanation[16] for public controversy over climate-change and other environmental risks, these findings suggest that bounded rationality is an unsatisfactory explanation as well.

On the contrary, our findings could be viewed as evidence of how remarkably well-equipped ordinary individuals are to discern which stances towards scientific information secure their personal interests. We will elaborate on this interpretation, which we offer as our own best provisional understanding of the results of this and related studies, but which we also believe warrants corroboration by experimental testing. We stress, too, that as consequential as

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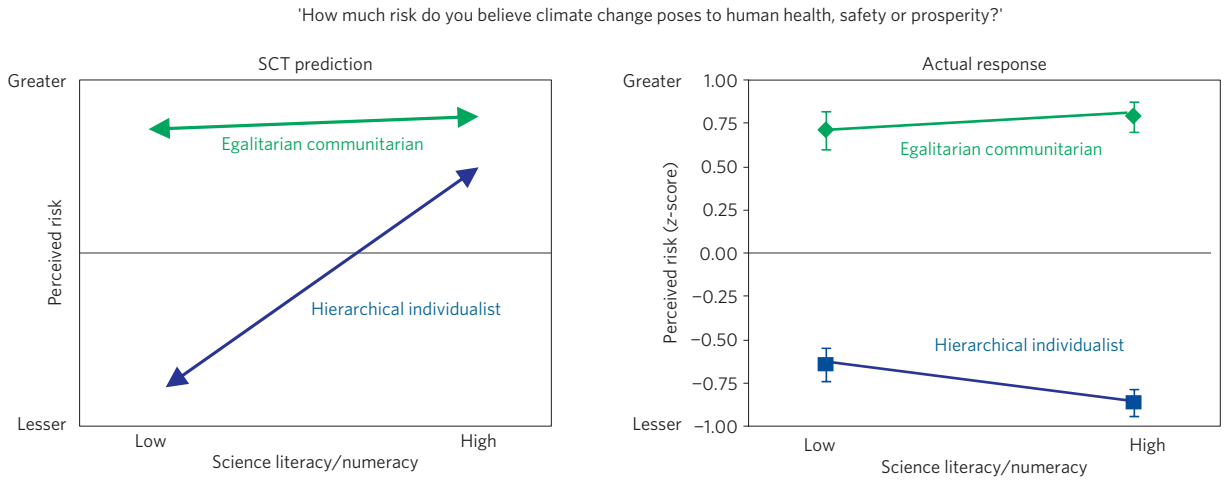

Figure 2 | SCT prediction versus actual impact of the interaction between science literacy and numeracy, on the one hand, and cultural world-views, on the other. Contrary to SCT's predictions, highly science-literate and numerate hierarchical individualists are more sceptical, not less, of climate change risks. Estimated risk-perception scores derived from Supplementary Table S4, Model 3. Hierarchical individualist and egalitarian communitarian reflect values set, respectively, at +1 s.d. and −1 s.d. on both the Hierarchy and Individualism cultural-world-view scale predictors. Low and high reflect values set at −1 and +1 s.d. on the Science literacy/numeracy scale. Responses on the 0–10 risk scale ($M = 5.7$, s.d. $= 3.4$) were converted to z-scores to promote ease of interpretation. Confidence intervals reflect the 0.95 level of confidence.

cultural cognition is for disagreement over climate change, it does not imply the irrelevance of other, more general impediments to public engagement with climate-change science, including trust in communicators and the affective attenuation of risks seen by many as remote in time and place[17].

For the ordinary individual, the most consequential effect of his beliefs about climate change is likely to be on his relations with his peers[18]. A hierarchical individualist who expresses anxiety about climate change might well be shunned by his co-workers at an oil refinery in Oklahoma City. A similar fate will probably befall the egalitarian communitarian English professor who reveals to colleagues in Boston that she thinks the scientific consensus on climate change is a hoax. At the same time, neither the beliefs an ordinary person forms about scientific evidence nor any actions he takes—as a consumer, say, or democratic voter—will by itself aggravate or mitigate the dangers of climate change. On his own, he is just not consequential enough to matter[19]. Given how much the ordinary individual depends on peers for support—material and emotional—and how little impact his beliefs have on the physical environment, he would probably be best off if he formed risk perceptions that minimized any danger of estrangement from his community.

A long-established body of work examining motivated cognition[20] supports this conjecture. Both to avoid dissonance and to secure their group standing, individuals unconsciously seek out and credit information supportive of "self-defining . . . values [and] attitudes"[21], such as the shared world-views featured in the study of cultural cognition[22]. The predictive power of cultural world-views implies that the average member of the public performs these tasks quite proficiently.

Our data, consistent with that observed in other settings[23], suggest that those with the highest degree of science literacy and numeracy perform such tasks even more discerningly. Fitting information to identity-defining commitments makes demands on all manner of cognition—including both system 1 and system 2 reasoning[19,20]. For ordinary citizens, the reward for acquiring greater scientific knowledge and more reliable technical-reasoning capacities is a greater facility to discover and use—or explain away—evidence relating to their groups' positions.

Even if cultural cognition serves the personal interests of individuals, this form of reasoning can have a highly negative impact on collective decision making. What guides individual risk perception, on this account, is not the truth of those beliefs but rather their congruence with individuals' cultural commitments. As a result, if beliefs about a societal risk such as climate change come to bear meanings congenial to some cultural outlooks but hostile to others, individuals motivated to adopt culturally congruent risk perceptions will fail to converge, or at least fail to converge as rapidly as they should, on scientific information essential to their common interests in health and prosperity. Although it is effectively costless for any individual to form a perception of climate-change risk that is wrong but culturally congenial, it is very harmful to collective welfare for individuals in aggregate to form beliefs this way.

One aim of science communication, we submit, should be to dispel this tragedy of the risk-perception commons[24]. A communication strategy that focuses only on transmission of sound scientific information, our results suggest, is unlikely to do that. As worthwhile as it would be, simply improving the clarity of scientific information will not dispel public conflict so long as the climate-change debate continues to feature cultural meanings that divide citizens of opposing world-views.

It does not follow, however, that nothing can be done to promote constructive and informed public deliberations. As citizens understandably tend to conform their beliefs about societal risk to beliefs that predominate among their peers, communicators should endeavor to create a deliberative climate in which accepting the best available science does not threaten any group's values. Effective strategies include use of culturally diverse communicators, whose affinity with different communities enhances their credibility, and information-framing techniques that invest policy solutions with resonances congenial to diverse groups[22]. Perfecting such techniques through a new science of science communication is a public good of singular importance[25].

Methods

Study subjects consisted of a nationally representative general population sample of 1,540 US citizens who participated in the study through the online testing facilities of Knowledge Networks (http://www.knowledgenetworks.com/). Knowledge Networks is a public opinion research firm with offices located throughout the US. It maintains an active respondent pool of some 50,000 adults who are recruited to participate in online surveys and experiments administered on behalf of academic and governmental researchers and private businesses. Its recruitment and sampling methods assure a diverse sample that is demographically representative of the US population.

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We measured respondents' values using scales associated with studies of the cultural theory of risk[4,5]. The first, Hierarchy–Egalitarianism (Hierarchy), consists of agree–disagree items that indicate attitudes towards social orderings that connect authority to stratified social roles (for example, 'We need to markedly reduce inequalities between the rich and the poor, whites and people of colour, and men and women'). Items from the second scale, Individualism–Communitarianism (Individualism), express attitudes towards social orderings in which the individual is expected to secure his or her own well-being without assistance or interference from society versus ones in which society is obliged and empowered to secure collective welfare in the face of competing individual interests (for example, 'Government should put limits on the choices individuals can make so they do not get in the way of what is good for society').

We measured respondents' science literacy with National Science Foundation's (NSF) Science and Engineering Indicators[26]. Focused on physics and biology (for example, 'Electrons are smaller than atoms [true/false]'; 'Antibiotics kill viruses as well as bacteria [true/false]'), the NSF Indicators are widely used as an index of public comprehension of basic science[27].

We measured subjects' numeracy—their capacity to comprehend and use quantitative information—with fourteen mathematical word problems[11,28,29] (for example, 'A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?'). We combined responses to the NSF Indicators and the numeracy questions into a composite scale ($\alpha = 0.85$), labelled Science literacy/numeracy, to avoid collinearity in multivariate analyses of their association with respondents' risk perceptions[30].

Those risk perceptions were measured with items labelled GWRISK and NUKERISK, which asked respondents to indicate 'How much risk' they believed 'climate change' and 'nuclear power,' respectively, 'pose[] to human health, safety or prosperity' on a 0 (no risk) to 10 (extreme risk) scale. Risk-perception items that conform to this format are known to elicit responses that correlate highly with ones targeted at more specific factual beliefs about the hazards of putative risk sources and are thus routinely used as a parsimonious focus for analysis of variance in risk perceptions[8,9].

Study hypotheses were tested by ordinary least-squares linear regression (Supplementary Tables S4 and S5). Predictors included the cultural-world-view scales, Science literacy/numeracy and appropriate cross-product interaction terms. To promote visual comprehension of the variance associated with various predictors, responses to GWRISK ($M = 5.7$, s.d. $= 3.4$) and NUKERISK ($M = 6.1$, s.d. $= 3.0$) were transformed into z-scores.

Full item wording for all measures and the multivariate regression outputs are reported in the Supplementary Information.

Received 29 November 2011; accepted 24 April 2012; published online 27 May 2012

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Acknowledgements

Research for this paper was financially supported by the National Science Foundation, Grant SES 0922714.

Author contributions

D.M.K., E.P., M.W. and L.L.O. contributed to all aspects of the paper, including study design, statistical analysis and writing and revisions. P.S., D.B. and G.M. contributed to the design of the study, to substantive analysis of the results and to revisions of the paper.

Additional information

The authors declare no competing financial interests. Supplementary information accompanies this paper on www.nature.com/natureclimatechange. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to D.M.K.

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