ATTACHMENT 2

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PERSPECTIVE

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The role of social and decision sciences in communicating uncertain climate risks

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A major challenge facing climate scientists is explaining to non-specialists the risks and uncertainties surrounding potential changes over the coming years, decades and centuries. Although there are many guidelines for climate communication, there is little empirical evidence of their efficacy, whether for dispassionately explaining the science or for persuading people to act in more sustainable ways. Moreover, climate communication faces new challenges as assessments of climate-related changes confront uncertainty more explicitly and adopt risk-based approaches to evaluating impacts. Given its critical importance, public understanding of climate science deserves the strongest possible communications science to convey the practical implications of large, complex, uncertain physical, biological and social processes. Here, we identify the communications science that is needed to meet this challenge and the ambitious, interdisciplinary initiative that its effective application to climate science requires.

In many nations, much of the public has long recognized the potential gravity of climate change[1,2]. Nonetheless, few citizens or political leaders understand the underlying science well enough to evaluate climate-related proposals and controversies. As a result, it is hard for political leaders to generate and sustain broad public support for ambitious climate policies[3] or for citizens to take effective personal action[4]. Conversely, it is relatively easy for a vocal, partisan minority to sow confusion, hoping to justify delay and inaction by amplifying uncertainties[5,6]. Without basic scientific knowledge, lay people struggle to distinguish legitimate scepticism, which all sciences welcome[7], from radical scepticism, an unwillingness to accept any evidence that might disprove the claims in question. Even those who see little merit in recent attacks on climate science, such as the 2009 controversy regarding e-mails obtained from the University of East Anglia's Climatic Research Unit and posted on the Internet[8,9], must wonder why they went so far and what they mean for the future[10] (Fig. 1).

These controversies may, in fact, have limited effects[11,12]. So far, few institutions have been as trusted as science[13,14]. The public knows scientists primarily from positive contexts, such as classrooms, news reports of breakthroughs and the many ways that science has improved their lives. Indeed, the recent stories drew such attention precisely because they depicted some scientists as violating society's expectation of independent, competent, trustworthy behaviour[15], untainted by politics. One sign of public faith in science is that even those who criticize climate science on ideological grounds use science-like language, seeking to reject the conclusions of specific scientists rather than the idea of climate science.

As painful as these attacks may be, they should not lead climate scientists to conclude that communication is hopeless. Doing so would represent what psychologists call the 'spotlight effect', exaggerating how much attention others pay to our actions. For better and worse, most people do not think about science all that much. It would be equally tragic if the attacks goaded scientists into becoming polemicists, a role that would undermine their credibility by making science seem like less trusted professions, such as the media and politics[13].

Climate scientists bear a heavy burden: potentially, the fate of the world lies partly in their hands. Fortunately, they also have some of the strongest evidence ever assembled regarding a global environmental risk. All but the most adamant critics acknowledge that global-scale climate changes have occurred before (for example, the Dansgaard–Oeschger events of the last glacial[16]) and might occur again. Where critics and mainstream scientists disagree is in their inferences about the scale and sources of the recent warming and their predictions about the impacts of continued anthropogenic climate forcing.

Realizing the practical value of climate-related research means ensuring that diverse policymakers and the public understand the risks and uncertainties relevant to the decisions that each faces. Promoting such understanding is unlikely to be a sufficient condition for individuals or societies to respond effectively to the risks posed by climate change, as a range of well-documented political[3]

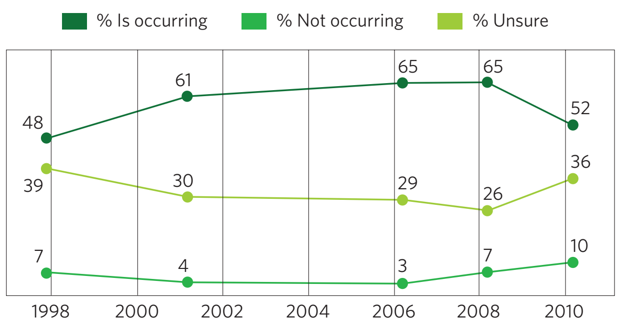

Figure 1 | Shifting public opinion. Opinion polling in America shows how people became more sure that climate scientists believed in global warming over the period 1998–2006. But more recently views are less certain, a phenomenon also seen in Britain and Europe. The reasons for this recent trend are complex and probably include a response to politicization of climate policy, as well as the impacts of the East Anglia e-mails controversy. The question asked which one of the following statements do you think is most accurate — most scientists believe that global warming is occurring, most scientists believe that global warming is not occurring, or most scientists are unsure about whether global warming is occurring or not? Data from Gallup.

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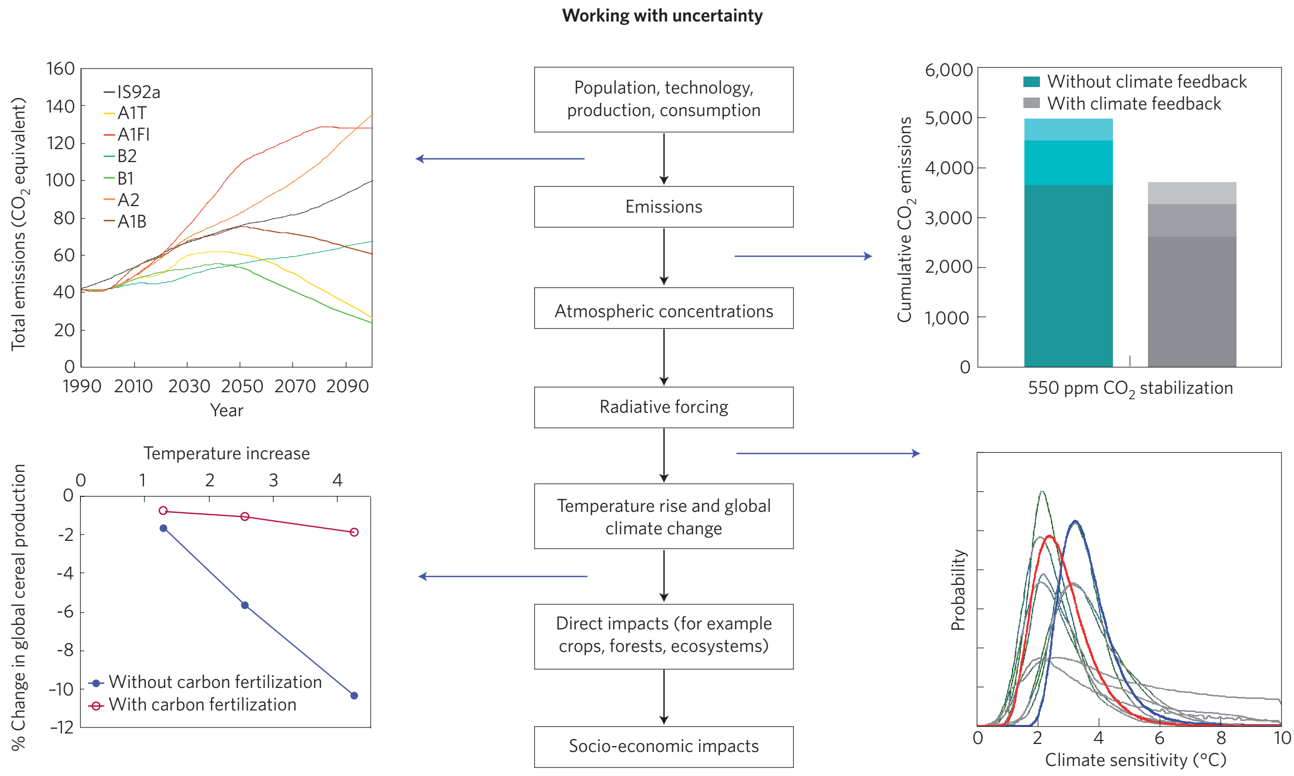

Figure 2 | Sources of uncertainty in climate assessments. The centre column shows schematically the causal chain leading from the anthropogenic sources of climate change to their impacts. The four charts show estimates for different effects in that chain, linked (by arrows) to causal factors that introduce uncertainty into these estimates. In the top-left chart, different assumptions about future human activities lead to different estimates of total emissions. The other three charts show uncertainties in cumulative emissions depending on uncertainty about climate feedback (top right), climate sensitivity depending on uncertainty about radiative forcing (bottom right), and change in global cereal production depending on uncertainty in temperature rise and carbon fertilization (bottom left). Interactions between elements in the chain also create further significant uncertainties. Reproduced with permission from ref. 27, © 2006 Cambridge Univ. Press.

and psychological[4] barriers to action will also need to be addressed. However, such understanding is a necessary condition for action. In this Perspective we offer a proposal on applying the best available communications science to convey the best available climate science. The execution of this task will require sustained interdisciplinary collaboration between natural, social and decision scientists. Here we characterize the communication challenge posed by the scope, complexity and uncertainty of climate science, sketch the communications science available for this task and put forward a strategic approach to climate science communication, including the institutional support needed to sustain it.

Risk, uncertainty and climate decision-making

Uncertainty in climate systems. Climate scientists face many uncertainties. They progress by developing greater understanding of those uncertainties, with inquiries that sometimes reveal new sources of uncertainty[17,18]. However, their own communications about those uncertainties are very different from the ones needed by lay people and policymakers. Indeed, scientists' very familiarity with the issues can impede their ability to communicate with people outside their field, to the point that even excellent scientists can be poor communicators.

The climate system involves interactions among many moving parts, with uncertainties arising in both structuring climate models[19] and assessing their parameters and relationships[20] (Fig. 2). The systems involving climate drivers and impacts are more complicated still, and are unfamiliar to most non-scientists. Some are inherently unintuitive, such as the nonlinear relationships between emissions and atmospheric concentrations of greenhouse gases, between those concentrations and radiative forcing, and between mean global temperature changes and regional impacts. Unless scientists can convey the nature of these processes, others may over- or underestimate the definitiveness of their claims; either accepting them on faith or rejecting them outright. These uncertainties are likely to grow, as climate science extends to incorporate the socio-economic processes that drive climate changes and determine their impacts[21]. Depending on how they are communicated, these complications may further fuel fatalistic acceptance of climate-related changes (on the grounds that people and society cannot change their ways), or alternatively may highlight the fact that people, by their decisions and actions, do ultimately have the ability to avert dangerous climate change.

In addition to its unfamiliar subject matter, much climate science relies on simulation modelling that is an unfamiliar form of inference not just for lay people but even for scientists whose disciplines use observational methods. Unless the logic of that modelling is conveyed, people may discount its conclusions. Communicating the value of climate modelling thus requires confronting such apparent contradictions as the fact that increasing a model's complexity — by adding the behaviour of clouds, people or ecosystem feedbacks, for example — may actually increase the uncertainty in climate projections. Atmospheric scientist Kevin Trenberth of the US National Centre for Atmospheric Research in Boulder, Colorado, has explicitly warned[22] that unless such seemingly paradoxical results are communicated carefully, the more complex modelling being used in climate simulations for the upcoming fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) may confuse both the public and decision-makers, thereby reducing their willingness to act.

The discourse of scientists can be a further source of confusion. For example, scientists do not normally repeat facts that are widely accepted among them, focusing instead on the uncertainties that pose the most challenging problems. As a result, lay observers can get an exaggerated sense of scientific uncertainty and controversy, unless a special effort is made to remind them of the broad areas of scientific agreement[23]. Even that may fail unless it is made clear how 'scientific consensus' (as represented in the IPCC process for assimilating and deliberating evidence) differs from that in everyday life.

Reframing policy through risk and uncertainty. The first three IPCC assessments avoided formal expressions of uncertainty, using instead scenario-based projections of possible futures. The fourth IPCC assessment[24], though, assigns explicit likelihoods (typically Bayesian assessments of probability distributions) when assessing the weight of evidence. Behavioural research has found that lay people can often extract the information that they need from clear numeric expressions of uncertainty, but that they struggle with the ambiguity of verbal quantifiers, such as 'unlikely' or 'probable'[25]. However, whether the IPCC's specific communications have succeeded is an empirical question whose answer requires rigorous research. At least one study suggests that the IPCC has not done as well as it would have wished[26].

The UK government's Stern review on the economics of climate change[27] argued for framing climate decisions in terms of the costs, risks and uncertainties of different options, as does a recent study from the US National Academies[28]. That perspective shifts the debate from whether there is anthropogenic warming to what gambles we should take with our world[29]. The former frame requires meeting an ill-defined standard of proof for demonstrating anthropogenic warming, before taking any action. The latter frame requires analysing the expected costs and benefits of different actions. The former frame leads to deliberation, the latter to decision-making.

The conclusions of these analyses ultimately depend on how decision-makers value the expected risks and benefits that are revealed[30]. For example, some critics of the Stern review argue that its discount rate was too low, relative to standard economic practice[31], thereby overweighting future outcomes. Other critics argue that its discount rate is too high, as is any non-zero discount rate when catastrophic consequences are possible[32]. Value judgements also arise in relation to many other aspects of these analyses, such as how to treat uncertain projections of the economic costs of mitigation or of the benefits of increased energy efficiency. Yet, however intense these debates, they still involve choices among options and might therefore lead to actions that avoid 'dangerous climate change', the goal enshrined in the 1992 United Nations Framework Convention on Climate Change[18,33,34]. In contrast, debates about evidence *per se* — such as whether there is anthropogenic climate change — can be interminable, as there will always be uncertainties to forestall decision-making.

Planning for climate adaptation necessarily requires comparison of decision options, each with its own uncertainties about the 'when, where and how' of climate impacts. For example, the UK's infrastructure planning process has 50–100-year time horizons for renewing the Thames flood-barrier scheme (Fig. 3)[35]. As a result, it must consider, among other factors, the uncertain evidence predicting that over that period the UK is likely to experience sea-level rise, more frequent summer hot spells, reduced summer rainfall in the south and east, and much wetter and stormier winter weather overall. That evidence led the UK Climate Impacts Programme scenarios for 2009 to incorporate probabilistic projections of regional impacts while acknowledging the difficulties in downscaling global projections to provide such regional forecasts (Fig. 4)[36]. In these cases, the usefulness of climate science depends on how effectively the analytical results can be communicated and how relevant they are to decision-makers.

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Figure 3 | The existing Thames flood-protection barrier at Greenwich, East London, UK. Conceived after the 1953 flooding and associated fatalities in eastern England there are now concerns about its ability to protect London from any increased risks associated with climate change, and in particular rising sea levels and future storm surges. This has led to an extensive risk assessment and appraisal of the options for its renewal or replacement, for the period up to 2070 and beyond.

The science of communication

Climate scientists' struggles in communicating with the non-specialist audience are typical of the challenges that arise with any policy question having significant technical content, whether it be nuclear power[37,38], genetically modified crops[39] or nanotechnology[40]. Over the past 40 years, social and decision science research has addressed these challenges across a broad front. This body of research has identified basic processes guiding risk perceptions and has applied that knowledge to facilitating informed choices involving complex, uncertain and contested science[41,42]. Studies focused on lay perceptions of climate change echo these general patterns with some unique specifics. For example, in western countries most people are concerned about the problem, although few make it a top priority[2,43]. Most have fragmentary mental models that are more complete for the consequences of climate change than for its causes[44,45]. Whatever their beliefs, most people find climate change psychologically distant, as something that will affect other people in other places and times[1,46]. Although they generally understand the broad outlines of climate change, people can be confused by the uncertain signals sent by extreme weather events. People with different cultural values may have different beliefs[47,48], yet still act similarly (for example, both concerned individuals and critics are more likely than disinterested people to adopt energy-saving practices[49]). In addition, many lay people ascribe primary responsibility for dealing with climate change to national governments and other powerful organizations and agents[11,50], concluding, quite sensibly, that climate change is too big a problem for them to tackle as individuals alone. In turn, many governments fear punishment by citizens at the ballot box if they propose overly radical actions[3], leading to a collective failure to act on the part of both governments and individuals.

Research in social and decision science has identified several key lessons that are especially relevant to communicating climate science. The first is that 'risk' can be defined in different ways, by both analysts and lay people[51], depending on how they value the outcomes at stake[52]. For example, some people care primarily about threats to human life; others care about the economy or the environment as well, and need different risk estimates. When concern focuses on human life, some people care about the age of those at peril; others do not. Depending on which of these two positions decision-makers take, they will need different estimates: expected chance of premature death for those in the first group; expected

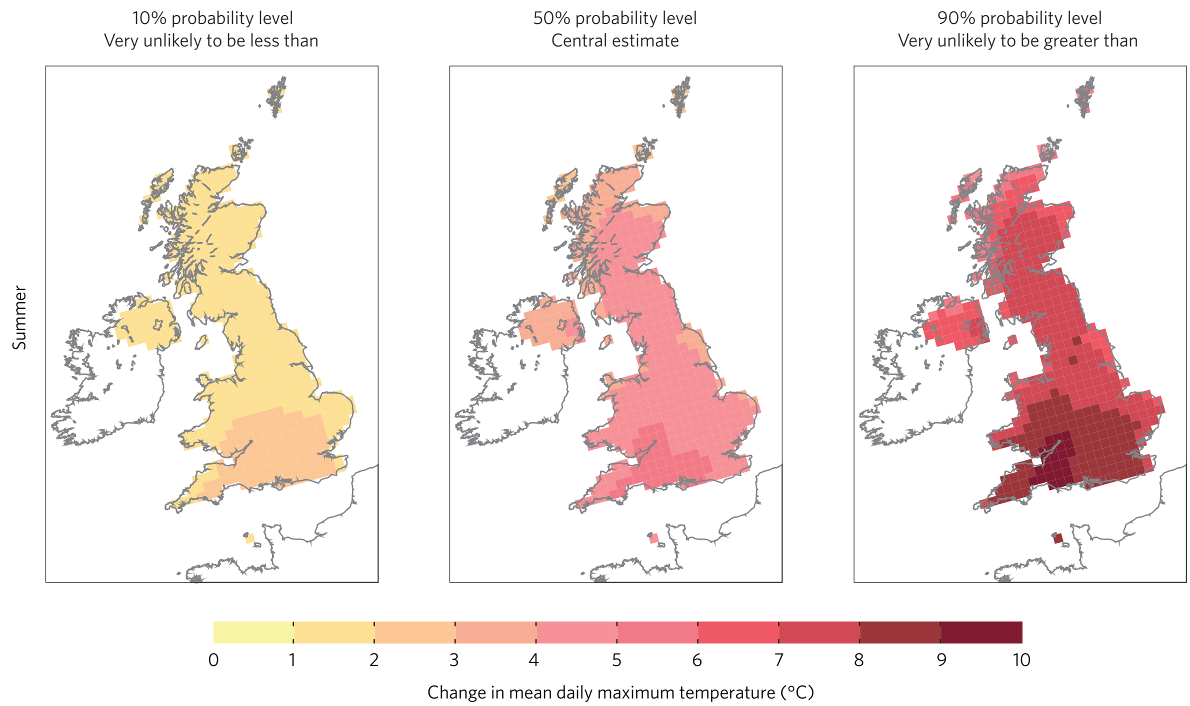

Figure 4 | The recent UK climate projections in 2009 use probability assessments to represent the modelling uncertainty for a range of variables and with a grid resolution of 25 km². The figures show 10, 50 and 90% probability levels respectively for changes to the mean daily maximum temperature in summer across the United Kingdom by 2080 and under a medium emissions scenario. Hence, within the constraints of the modelling, at the 10% level it is very unlikely (equivalent to a 10% probability) that the temperature will be less than that shown at any particular location. Reproduced with permission from ref. 70, © UK 2009 Climate Projections .

life years lost for those in the second. Proponents of environmental justice need to know which groups bear the risks and which get the benefits of proposed policies. Some people need to know the extent to which risks are voluntary, controllable, uncertain, irreversible and catastrophic[53]. Unless they receive the information that they need, people must guess at it, reading between the lines of scientists' statements and controversies.

But understanding risk requires more than just knowing risk estimates. People also need cognitive representations[41] (or 'mental models') of the processes creating and controlling the risks, and thus causing uncertainty about them. For example, they may need to know how warmer oceans affect tropical storms, marine phytoplankton and winter precipitation, or how rising atmospheric carbon dioxide levels lead to increased ocean acidification. Knowledge of such processes allows people to follow public debates and grasp the rationale for alternative policies. It protects (or 'inoculates') them from being 'blind-sided' by unfamiliar facts or perspectives. It affords them the warranted feelings of self-efficacy needed before acting.

Recent advances in behavioural and decision science also tell us that emotion is an integral part of our thinking, perceptions and behaviour, and can be essential for making well-judged decisions[54,55]. Although it can cloud judgment[48,56], emotion can provide cues valuable to evaluating evidence and the people who provide it. Emotion creates the abiding commitments needed to sustain action on difficult problems, such as climate change. It motivates climate scientists, as well as their audiences and critics[57]. Clear, respectful messages can reduce the destructive emotions of impatience, frustration and anger, and appropriately framed emotional appeals can motivate action, given the right supporting conditions[58] (in particular a sense of personal vulnerability, viable ways to act, feelings of personal control and the support of others).

Finally, social processes can amplify or attenuate perceptions of risk[59]. Sometimes those processes undermine lay understanding, as with interest groups' disinformation campaigns. Sometimes they create trust between lay and expert communities, as with well-designed public consultations. At their very best, they create effective social oversight and governance structures[60]. At their worst, they subordinate science to ideology[5,48].

Of course, information alone will not ensure wise climate-related decisions. Social scientists have documented a range of structural, political and economic barriers to strong action affecting both institutions[3] and individuals[4]. Moreover, as noted above, for some partisans science-like arguments are just a means to political or economic ends. Well-informed individuals can rationally do nothing if they see no viable actions. Well-informed collectives can be paralysed when they realize that their members have conflicting goals. Resolving such impasses requires applying climate science to the creation of better options. Whatever the barriers might be, scientists' obligation is to provide the information that is necessary, if not sufficient, for informed choices. Having fulfilled this minimum condition, they are free to weigh in as ordinary citizens, with their own personal votes on how to make the difficult choices that climate science has identified. They might find it easier to make their case if good science communication has expanded the range of reasoned discourse.

These research results, and others like them, belie the simple behavioural theory underlying the 'deficit model' of the public understanding of science, which assumes that simply teaching more science will bring lay behaviour into line with scientists' expectations. Although the limits to this model are well documented[61,62], it has such strong intuitive appeal that communication must explicitly adopt an alternative strategy if it is to respect audiences' values, feelings and need for dialogue and engagement[42,63]. Here we offer such a strategy.

A strategic approach to climate communication

Strategic listening. Climate science has always taken a long-term integrated approach. The communication of that science must

Box 1 | Expertise needed for effective communication of climate science to aid climate-related decision-making.

- Subject-matter experts who can represent the latest science on topics that matter to their audiences. Those scientists might include climatologists, ecologists, economists, engineers, physicists or others, as the decisions require.
- Decision scientists who can identify the most relevant aspects of that science and summarize it concisely, including its uncertainties and controversies.
- Social and communications scientists who can assess the public's beliefs and values, propose evidence-based designs for communication content and processes, and evaluate their performance.
- Programme designers who can orchestrate the process, so that mutually respectful consultations occur, messages are properly delivered and policymakers hear their various publics.

be just as strategic in its analysis, design, implementation and evaluation. Like climate systems, human systems involve the complex, uncertain interaction of many processes. As a result, even the best-designed communications, based on the strongest social and decision science, require rigorous implementation and empirical evaluation to determine how effective they are. Yet, despite the critical importance of climate-change communication, such evaluations are remarkably rare. Instead, most communications rely on intuitive notions of what to say and how to say it.

Unfortunately, people often have flawed intuitions regarding how well they communicate, typically exaggerating their success. In ordinary conversation, people receive feedback, allowing them to refine imperfect communications. Scientists, though, often have little direct contact with the public. As a result, they cannot tell how well they are doing or how to do better. Without evidence to moor them, science communication can lurch from one well-intended initiative to the next. A scientific approach to communicating science requires the systematic feedback provided by empirical evaluation.

In this strategy, social and decision science research provides connections that scientists normally lack. Its methods (for example surveys, interviews and moderated deliberations) can be seen as surrogate conversations, conducted by researchers on behalf of climate scientists, to establish which outcomes matter to different people, which options they have for attempting to realize their goals and what additional knowledge they need[63,64]. The decision science approach takes an 'inside view', letting decision-makers' needs determine the content of communications, rather than just relaying the messages that scientists think are important. With some decisions, research might find that people already know enough about the relevant climate science, but need to know more about risks to prized ecosystems or about the viability of cap-and-trade schemes. Research might find that people know enough about the facts of a decision, but are uncertain how to make the hard trade-offs that it requires (for example between risks to the present generation and to future ones). If so, then people do not need more facts but more perspectives, helping them to think about what the decision means to them and the outcomes that they value. There is no way to know what information people need without doing research that begins by listening to them.

Such listening protects against simplistic solutions to complex problems. For example, if scientists conclude that uncertainty means paralysis, they may avoid discussing it. However, if lay people know that climate risks involve complex, uncertain processes, they may resent being patronized with overly certain accounts. British readers may remember the promise that British beef was completely safe to eat at a time when the evidence regarding the transfer of BSE (bovine spongiform encephalopathy) to humans was not yet settled. US readers may remember their government's assurances that flying was completely safe when it lifted the ban imposed after the September 11 attacks in 2001, even though such terrorist threats were only just beginning to be understood. With contested science, uncertainties eventually emerge. Scientists can protect themselves by being the first to acknowledge the uncertainties in their work. Those admissions need not encourage paralysis if the results are framed as illuminating the relative risks of action and inaction rather than as inviting delays until they are completely resolved.

Strategic listening also protects scientists from confusing ignorance with incompetence. When lay people misunderstand some aspect of science, it may be that they are incapable of grasping it. However, the science may also have been poorly explained or seemed too irrelevant to master. Not knowing facts that are second nature to scientists does not, by itself, provide grounds for writing off the lay public. Doing so runs the risk of souring scientists' relations with non-scientists, who will sense the lack of respect. By dismissing non-scientists, experts also forgo the chance to fill the gaps in their fragmentary mental models. For example, lay people often confuse healthy lawns with healthy ecosystems, think that turning thermostats past the set point will make homes heat up faster and believe that the ozone hole is a cause of global warming[44]. The flaws in these beliefs are not hard to explain, once research has identified them. Indeed, such research has helped to reduce the prevalence of the last of these misconceptions[2].

Strategic listening can also assess the cumulative impact of the diverse messages on a topic. For example, it could determine when a flood of uncoordinated climate-related recommendations produces inaction ("I'll wait until the experts sort things out"), a symbolic act or two ("because you can't do everything") or sweeping lifestyle changes ("I hadn't realized the scope of the problem"). It could determine when messages about adaptation discourage mitigation by making the future seem tolerable, or encourage it by making the risks more real. Or it could focus messages on the few actions most worth doing, hoping to encourage a cascade of effective actions—sometimes called 'behavioural spillover'[65].

A strategic communication perspective will find that there is no single simple recipe for climate communication[66]. At the individual level, even the strongest social and decision science produces only better best guesses about how to formulate messages. As a result, empirical testing is always needed. At the society level, people with different goals and knowledge will have different needs to hear and be heard. For example, energy conservation programmes that motivate some people fail with others who hold similar political values, while motivating people with different values[49]. Changes in the science, the economy and politics may bring different issues to the fore, requiring communications to evolve. As a result, continued listening is needed.

Strategic organization. Communications worthy of climate change will require sustained contributions from cross-disciplinary teams, working within an institutional framework that provides support for their efforts. Such teams would include, at minimum, climate and other experts, decision scientists, social and communications specialists, and programme designers (Box 1). Once assembled, these teams must be coordinated so that experts stay focused on their aspect of the communication process. For example, subject-matter experts should edit for fact, not style; they should also check that social scientists have not garbled the facts when trying to make them clearer. That coordination must maintain a rhetorical stance of non-persuasive communication[67], trusting the evidence to speak for itself, without spin or colouring. Although there is an important place for persuasive communication, encouraging individual behaviours and public policies, it must be distinct, lest scientists come to be seen as inept politicians. If climate scientists passionately offer dispassionate accounts of the evidence, it will preserve their uniquely trusted social position and avoid the advocacy that most are ill-suited to pursue by disposition, experience and training.

Creating such teams will require an organization with unique capabilities, as yet absent in the climate change arena. It must nurture the sustained interactions needed to build trust among disciplines unaccustomed to collaboration. It must maintain public trust by faithfully representing the science and its attendant uncertainties and controversies. Such a commitment to candour is routinely found in academic institutions, but often without a core commitment to practical and collaborative research. Transcending academic norms requires 'boundary organizations', chartered both to conduct basic science and to translate its results into decision-relevant terms[68,69]. It requires the resources to support research, design and evaluation services for all scientists hoping to communicate their work. It requires the stature needed for those scientists to value its services. And it requires the staying power needed to develop new research methods and career paths, allowing its collaborators to pursue the basic research topics that it identifies. Having such capabilities should reduce the risk of unwarranted controversies and provide evidence-based responses to them.

Models for such interdisciplinary 'big science' might include the RAND Corporation (in the US) and the International Institute for Applied Systems Analysis (in Austria). In the UK, the Tyndall Centre for Climate Change Research has fostered a ten-year collaboration between climate and social scientists, although without a major focus on communication and decision-making research. In the US, the National Center for Atmospheric Research has made similar efforts. Each of these institutions performs publication-quality research on applied problems, using analytical methods to integrate diverse data, while contributing critical expertise to address policy problems. Each provides an environment that attracts scientists for individual projects, short stays and careers. Each has leadership willing and able to redeploy resources from over-represented disciplines to under-represented ones. Although smaller, more distributed models might be envisaged[28], the science of communicating science has become so important that it requires equivalent institutions, properly funded and staffed.

Conclusion

Many climate scientists are understandably frustrated by the limited response to what they see as the greatest threat facing our planet. One impulsive response to a seemingly recalcitrant public is a big advertising campaign. However, unless founded on sound social and decision science principles and accompanied by rigorous empirical evaluation, such efforts have little chance of sustained success. Moreover, each communication failure makes future success less likely, by eroding both the public's trust in the experts, who seem not to know their needs, and the experts' trust in the public, which seems unable to understand the issues. Given the gravity and the complexity of climate-related decisions, we need a new model of science communication, with new collaborations among the sciences at both the national and the international level.

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Author contributions

N.P. and B.F. contributed equally to the formulation and writing of the manuscript.

Additional information

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