PREPRINT
Oxford Handbook on the Science of Science Communication

On the Sources of Ordinary Science Knowledge and Extraordinary Science Ignorance

Dan M. Kahan
Yale University

It is impossible to make sense of persistent controversy over certain forms of decision-relevant science without understanding what happens in the much greater number of cases in which members of the public converge on the best available evidence without misadventure. In order to live well—or just to live, period—individuals must make use of much more scientific information than any (including a scientist) is in a position to comprehend or verify. They achieve this feat not by acquiring expertise in the myriad forms of science essential to their well-being but rather by becoming experts at *recognizing* what science knows—at identifying who knows what about what, at distinguishing the currency of genuine scientific understanding from the multiplicity of counterfeit alternatives. A rational form of information processing, their recognition of valid science is guided by recourse to cues that pervade their everyday interactions with other non-experts, whose own behavior convincingly vouches for the reliability of the scientific knowledge on which their own actions depend. Cases of persistent controversy over decision-relevance science don't stem from defects in public science comprehension; they are not a result of the failure of scientists to clearly communicate their own technical knowledge; nor are they convincingly attributable to orchestrated deception, as treacherous as such behavior genuinely is. Rather such disputes are a consequence of one or another form of disruption to the system of conventions that normally enable individuals to recognize valid science despite their inability to understand it. To preempt such disruptions and to repair them when they occur, science must form a complete understanding of the ordinary processes of science recognition, and democratic societies must organize themselves to use what science knows about how ordinary members of the public come to recognize what is known to science.

1. The perils of ignoring the denominator

We live in an age of spectacular public conflict over policy-relevant *facts*. Is the earth heating up—and if so are humans the cause? Will vaccinating schoolgirls against the human papilloma virus promote their health by immunizing them from a cancer-causing sexually transmitted disease—or put their health at risk by lulling them into unprotected sex, thereby exposing them to other STDs and teen pregnancy? Do laws allowing private citizens to carry concealed handguns increase violent crime—or reduce it by enabling potential victims to defend themselves and by deterring violent predation more generally?

Each of these and numerous other factual questions are subject to intense, sustained political contestation. Yet each has also been the subject of extensive empirical investigation. Indeed, *on* each there is scientific consensus by the most reliable measures of such—authoritative pronouncements issued by expert panels charged with aggregating and weighing the extant evidence for the benefit of decision makers, individual and collective (e.g., American Academy of Pediatrics 2012; Intergovernmental Panel on Climate Change 2014; National Resource Council 2004).

The persistence of deep public division on such facts is rightly understood to pose a significant challenge to the prospects for enlightened self-government. Individuals of diverse outlooks can't be expected always to agree on the ends of public policymaking. But if, in the face of voluminous quantities of sound, clearly articulated, and widely disseminated scientific evidence they cannot even agree on the *facts*, how can democratic citizens be expected to identify much less deliberate intelligently over the values-tradeoffs that competing policy responses entail?

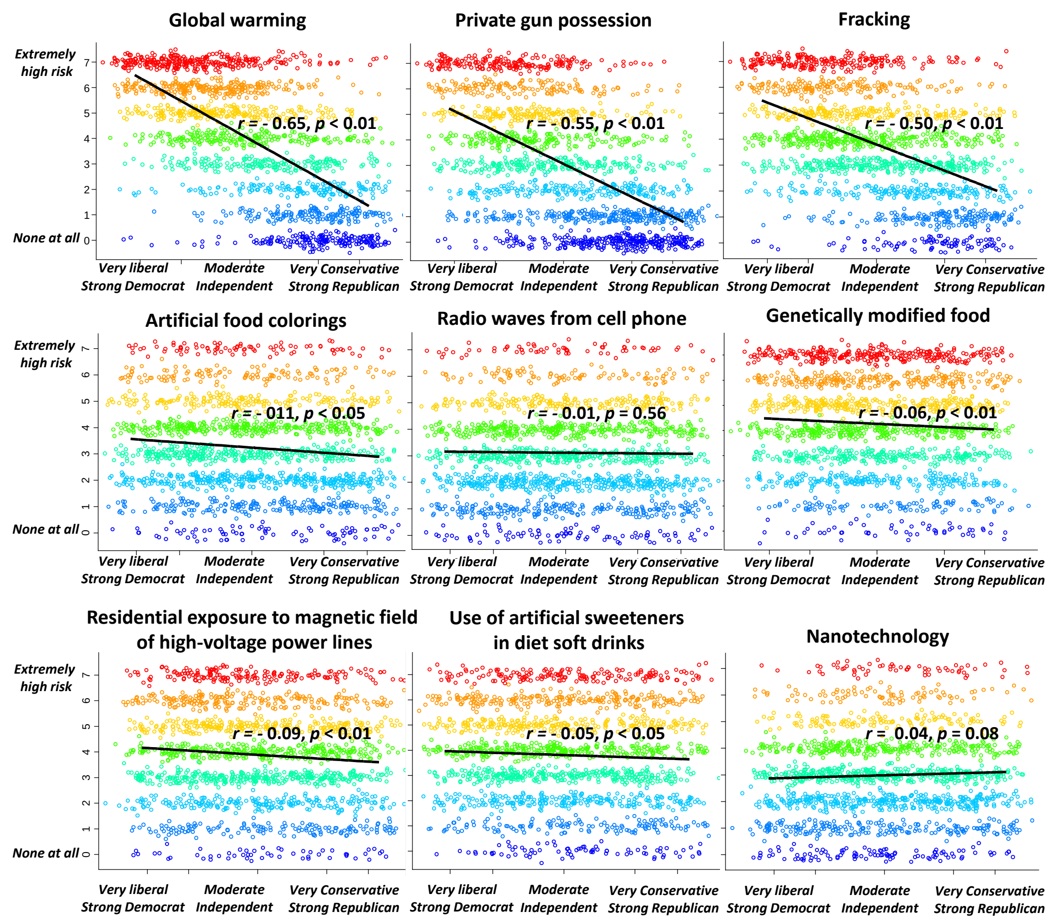

Figure 1. Risks, polarized and not. Scatterplots relate risk perceptions to political outlooks for members of nationally representative sample (N = 1800), April–May 2014. Source: Kahan (2015*b*).

I will refer to the failure of valid scientific evidence to quiet disputes over policy-relevant facts as the *Science Communication Problem*. The stock of empirical studies examining how this state of affairs affects various issues is already ample, and is expanding at an accelerating pace. The central theme of this chapter is that scholarly fixation on such controversies itself is inhibiting both scientific investigation of the source of the Problem and discovery of effective means for counteracting it.

In a narrowly methodological sense, scholarly fixation on controversies that feature the Science Communication Problem involves a form of selecting on the dependent variable. Selecting on the dependent variable occurs when a study design tests a hypothesis with a sample that has been assembled on the basis of criteria that assume the truth of the hypothesis—or that in any case exclude from the sample observations that could well falsify it.

This is a substantial problem in studies that purport to "explain" controversy over a single issue (human-caused climate change, for example) by examining public opinion on that issue alone. But the problem is barely any smaller for studies that purport to explain the Science Communication Problem generally by examining only sets of issues (climate change plus gun control plus nuclear power plus gun control plus the HPV vaccine etc.) that feature it.The simple fact is that the number of issues that actually display the Science Communication Problem is orders of magnitude smaller than the number that do not but plausibly *could*. Diverse members of the public in the U.S. are not divided over the hazards of chronic exposure to power-line magnetic fields; they aren't polarized over pasteurized milk; they aren't split on the carcinogenic effects of artificial sweeteners or food colorings—and so on and so forth (Kahan 2015*b*) (Figure 1). A researcher who studies *only* public opinion on global warming or *only* global warming plus other issues that conspicuously feature the Science Communication Problem will never be able to be confident that any influence she identifies as affecting those issues truly *is* affecting them if she has failed to confirm that those influences are absent in the myriad cases in which diverse members of the public have converged on the best available evidence (or at least converged on something).

But this mistake—one, essentially, of "ignoring the denominator" when looking at issues that feature the science of Science Communication Problem—shouldn't be understood in narrow, methodological terms only. It is in fact symptomatic of something much bigger, much more fundamental: a cultural *science of science communication literacy* deficit. The sorts of explanations for the Science Communication Problem that appear plausible when researchers and others confine their attention *solely* to controversies that feature conspicuous instances of the Science Communication Problem are ones that, to be blunt, reflect widespread and long-standing misunderstandings of the ordinary processes by which the public comes to know what is known by science. Forms of science communication that reflect these misunderstandings are at best ineffectual and at worst highly counter-productive.

Or so I will argue. The remainder of this essay will be divided between efforts to illustrate the sorts of mistakes we are likely to make if we "ignore the denominator" when investigating the Science Communication Problem, the focus of Part 2; and, in Part 3, efforts to furnish a glimpse of the insights into the Problem that can be achieved when researchers examine the sources of ordinary science knowledge—that is, the influences that enable the public to agree about so much of what science knows. Part 4 identifies what juxtaposing ordinary science knowledge and the Science Communication Problem implies about the proper focus for the emerging field of "science of science communication."

2. Four false starts

What makes persistent public disagreement over policy-relevant facts so puzzling is not the scarcity of explanations for this phenomenon; on the contrary, it is the surfeit of them. The number of plausible mechanisms that might account for the Science Communication Problem far exceeds the number that could be true. Separating the true (or more likely to be true) from the merely plausible is the principle mission of empirical research (Watts 2011).

Four plausible explanations for the Science Communication Problem quickly become much less so when we don't make the error of "ignoring the denominator" —or systematically averting our empirical gaze from the almost infinitely large class of cases in which we *don't* see public conflict over decision-relevant science but easily could. I'll call these mistakes the four "False Starts," and give each one its own label:

I. ***"The public is irrational";***
II. ***"First thing we do—let's kill all the scientists";***
III. ***"Welcome to the age of science denial"; and***
IV. ***"The public is being manipulated."***

2.1 . The most plausible—and also most commonly asserted—explanation for the Science Communication Problem is the public's limited capacity to comprehend science. The public is only modestly science literate. About half, we are regularly reminded, understands that the earth orbits the sun in a year as opposed to a day (National Science Foundation 2016); less than a quarter knows that *nitrogen* is the most common gas in the earth's atmosphere (Pew 2013); less than ten percent can make sense of a two-by-two contingency table essential to determining the ratio of true- to false-positives when assessing medical test results (Kahan 2016). So how can members of the public possibly be expected to understand what scientists are saying when scientists try to explain complex issue like climate change or nuclear power?

More importantly still, members of the public don't think the way scientists do. They rely on rapid, intuitive, affect-driven sources of information processing to the exclusion of the deliberate, conscious, analytic ones essential to making appropriate judgments of risk. As a result, they tend to overestimate the magnitude of more emotionally charged calamities (terrorists attacks, e.g.) and discount actuarially more consequential but more temporally or emotionally remote ones (e.g., the impact of human-caused climate change). They also are more likely to rely on defective heuristics, such as crediting the opinions of their peers, a form of reasoning that can trigger self-reinforcing states of polarization (e.g., Marx, Weber et al. 2007; Sunstein 2005, 2007).

The "public irrationality thesis" or PIT, let's call it, *is* plausible. But if we don't ignore the denominator, we'll quickly see that it is indeed a *false start*.

What attending to the denominator allows us to see is how many more instances of the Science Communication Problem we'd expect to see if PIT were the explanation for it. Why aren't members of the public either politically fragmented over, or uniformly anxious about, medical x-rays, for example? The answer cannot be that members of the public are experts on nuclear science; half of them think (or incorrectly guess) that "atoms" are "smaller than electrons" (National Science Foundation 2016). It is also clear that "radiation" generally makes them queasy—an affective response that accounts for widespread fear of nuclear power (e.g., Peters, Burraston & Mertz 2004).

Or how about nanotechnology? Although still routinely applied, the label "emerging technology" clearly no longer fits: the last decade has seen the steady introduction of nanotechnology consumer goods, which now total some *2000* (Vance, Kuiken et al. 2015). One might have imagined (or fretted) that the "grey goo" doomsday scenario popularized by K. Eric Drexler's 1986 book *Engines of Creation* would furnish affectively rich soil for growing public risk perceptions. But environmental activists have been trying to cultivate such fears for over a decade (e.g., "Green Goo: Nanotechnology Comes Alive" 2003) with zero success. The reason isn't that the public has been inoculated with valid scientific information on nanotechnology, over 75% of Americans—a proportion that has not moved in over a decade—says that it knows little or nothing about it (Liang, Ho et al. 2015).

2.2. A related false start blames scientists. If despite the clarity of the evidence, members of the public aren't converging on some policy-relevant facts, the reason must be that scientists are failing to convey the evidence clearly enough (e.g., Brownell, Price & Steinman 2013). Or maybe they are speaking *out* too clearly, crossing the line from factfinder to policy advocate in a manner that compromises their credibility (e.g., Tamsin 2013). Or perhaps what is compromising their credibility is how cagily they are hiding their advocacy by implausibly asserting that the facts uniquely determine particular policy outcomes (e.g., Fischoff 2007).

While one can make a compelling normative case for scientists speaking with greater clarity (Olson 2009; Dean 2009) or with less certitude about policy outcomes (Lempert, Groves & Fischbach 2013), the idea that how scientists talk is the cause of the Science Communication Problem is palpably unconvincing (see Atkin and Scheuffele, Chapter X). Again, all one has to do is look at the myriad science issues that don't provoke persistent controversy. How about raw milk (Sci., Media, & Public Res. Group 2016)? Is there some reason to believe biologists have been doing a better job explaining pasteurization than climate scientists have been doing explaining the greenhouse effect? What folksy idioms or tropes did the former use that were so effective in quieting political polarization? Or was it that they just were more genuinely neutral on whether people should drink their milk straight up from the cow's udder?

Here, obviously, I'm relying on a cascade of rhetorical questions in lieu of evidence. But the absence of evidence *is* my evidence. No one has ever thought it worthwhile to construct a statistical model to test whether the difference between public acceptance of, say, the dangers of ozone depletion, on the one hand, and those of human-caused climate change, on the other, correlates with the clarity and policy-neutrality of the National Academy of Sciences' respective reports on those issues (National Research Council 1976, 1982, 2008, 2011); or whether the difference between how readily, and how rapidly, states added the adolescent HBV vaccination to their mandatory school-enrollment immunization schedules, on the one hand, and how persistently they have resisted adoption of the HPV vaccine, on the other (Kahan 2013), correlates with the clarity and policy-neutrality of the American Academy of Pediatrics' endorsements of both (American Academy of Pediatrics 1992, 2007).

Likely no one has because it's clear to the naked ear that what these groups of scientists had to say on the uncontested members of these societal-risk pairs (ozone depletion, the HBV vaccine) was no less obscure and no less opinionated than what they had to say about the contested ones (climate change, the HPV vaccine). But whatever the source of the omission, including only contested cases in the sample and leaving uncontested ones out necessarily defeats any valid inference about how the "obscurity" or "partisanship" of scientists' own words affects the Science Communication Problem.

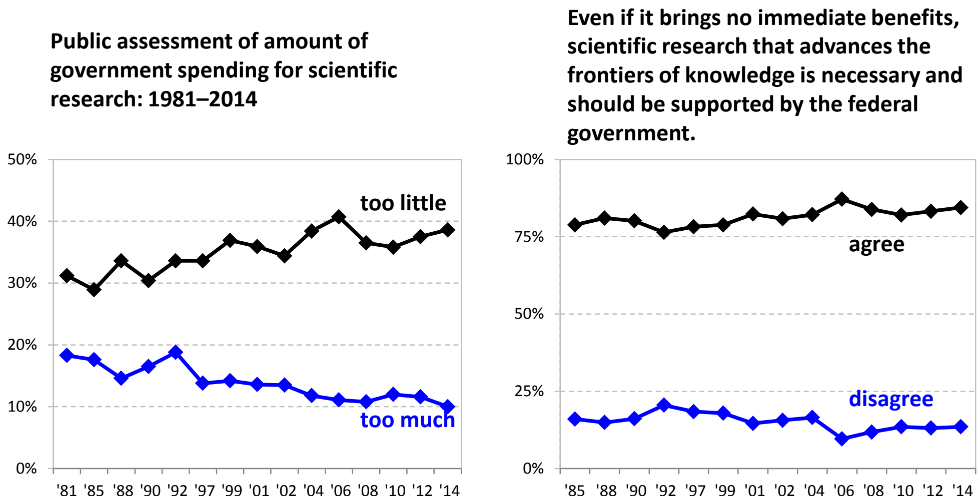

Figure 2. Select NSF Indicators' science attitude items. Source: NSF (2016).

2.3. Another false-start account of the Science Communication Problem attributes it to growing resistance to the authority of science itself. Along with widespread disbelief in evolution, political conflict over global warming or other issues is variously depicted as evidence of either the "anti-science" sensibilities of a particular segment of the public (e.g., Mooney 2012) or of a creeping anti-science strain in American culture generally (e.g., Frank 2013).

Anyone who manages to divert his gaze from the Science Communication Problem is sure to spy evidence massively out of keeping with this account. In its biennial Science Indicators series, for example, the National Science Foundation (2016) includes survey measures that consistently evince effusive degrees of confidence in and support for science (Figure 2). These levels of support do not vary meaningfully across groups defined by their political outlooks or degrees of religiosity (Figure 3). Indeed, the levels of support are so high that it would be impossible for them to harbor practically significant levels of variance across groups of any substantial size. For behavioral validation of these sensibilities, all one has to do is look at the care-free confidence individuals evince in science when making decisions both mundane (the ingestion of a pill to preempt hair loss) and vital (submission to radiation therapy for cancer). Because this evidence is so obvious, it's less likely proponents of the "age of denial" thesis don't see it than that they see it as irrelevant. On this view, confusion over or rejection of the dispositive evidence that science has collected on human-caused climate change or human evolution just *is* evidence of a deficit in the cultural authority of science.

But in that case, what started out as an explanation for the Science Communication Problem has transmuted, ironically, into a piece of evidence-impervious dogma. Is it possible that some influence wholly unrelated to the authority of science accounts for the peculiarly contested status of this collection of issues? The question is now ruled out by definitional fiat.

2.4. Advocates seeking to mislead the public on issues that feature the Science Communication Problem are legion. But this does not in itself establish that orchestrated misinformation campaigns *cause* the problem. Indeed, studies that purport to find causation by focusing on misinformation on climate change or other contested issues furnish textbook examples of selecting on the dependent variable. The excluded observations, again, are other science issues that do *not* fit the profile associated with the Science Communication Problem. The inference that misinformation causes the Problem's signature form of persistent contestation is warranted only if (among other things) examination of relevant cases that lack such contestation reveals the absence of comparable sources of misinformation. If, in contrast, we discover that issues unplagued by the Science Communication Problem are *not* free of the scourge of misinformation, then we will have reason to doubt that misinformation furnishes a satisfactory explanation of why some issues are characterized by this problem.

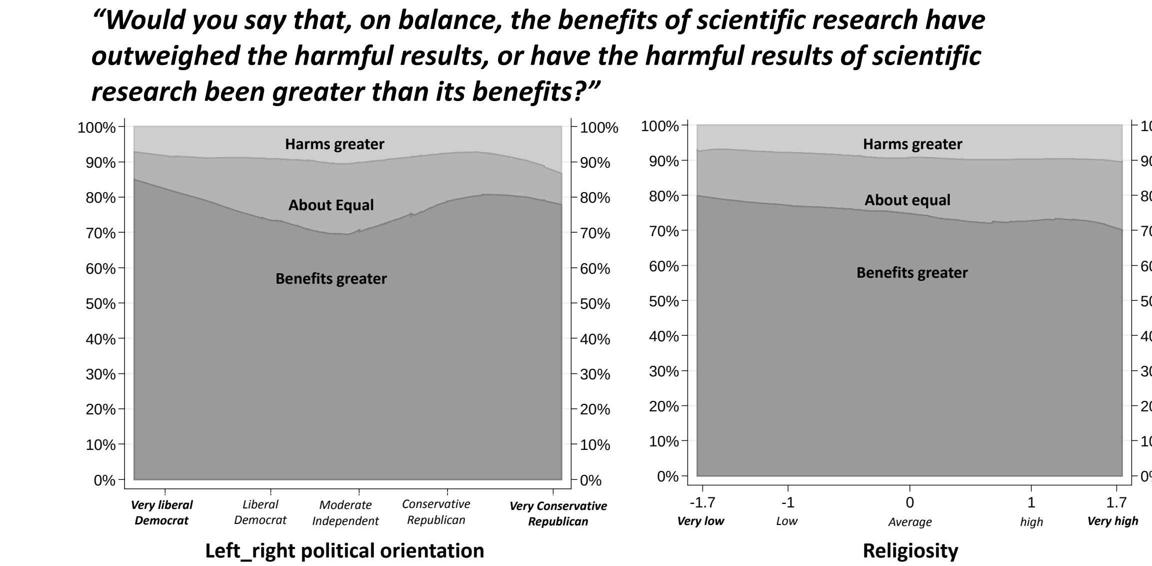

Figure 3. Science attitude by political orientation and religiosity. Source: Original analysis of General Social Survey 2006, 2008, 2010, 2012. *N*'s = 4653 (left_right), 4607 (religiosity). "Left_right" is political outlook scale formed by aggregation of 7-point liberal-conservative ideology and 7-point partisan identification items (α = 0.65). "Religiosity" is standardized score on scale formed by aggregation of self-reported religiosity, frequency of prayer, and church attendance (α = 0.79).

In fact, parties seeking to mislead the public on issues *unaffected* by the Science Communication Problem are legion, too. Likely the most compelling example involves GM foods, which have been repeatedly found to be as safe as their conventionally grown equivalents (National Research Council 2016). Never mind the $25 million that GM labeling proponents spent merely to strike out on public referenda in three politically liberal states— Oregon, Washington, and California, the last of which defeated a labeling initiative in a year in which President Obama crushed his Republican rival Mitt Romney by twenty percentage points (Tims 2014; Chokshi, 2013; Flynn 2012). Forget, too, that the U.S. Congress has now passed into law a federal statute that these groups bitterly fought and that will preempt any further attempts by them to mandate on-package labelling (Bjerga & Keane 2016). Those results have marked only the final step in the long march of futility for GM foes in trying to arouse public concern. After twenty years of persistent agitating, anti-GM groups have not only failed to generate the level of public anxiety that has historically surrounded issues such as nuclear power, toxic waste disposal, and air and water pollution in the U.S.; they have failed to even produce discernable comprehension that GM foods exist *at all*. Less than 50% of the public realizes that GM foods are already on supermarket shelves (in 75% of every food product on sale there, in fact), and only 25% (incredibly!) that they have ever consumed any (Hallman, Cuite & Morin 2013). When specifically asked, bewildered survey respondents say they prefer the issue of whether and how to regulate GM foods simply be left to expert regulators to deal with as those experts see fit (McFadden & Lusk 2016).

Of course, as ample as their efforts to sow confusion have been (e.g. Kloor 2012), supporters of GM food regulation have no doubt spent less to mislead citizens than have, say, opponents of climate change regulation. But the more apt comparison is with the efforts of GM food opponents in Europe, where comparable investments have paid handsome dividends: high levels of anxiety about GM technology in popular opinion, and the regulatory exclusion of GM products from consumer markets (Sato 2007). Manipulating public opinion is not as easy as it looks—or at least not as easy as one might infer if one makes the mistake of examining only cases that feature the Science Communication Problem and ignore all the rest.

Nothing in this account by any means suggests that efforts to mislead the public are never of consequence in cases that feature the Science Communication Problem. But obviously there are other influences that determine *when* misinformation matters and *how much*. Unless one's sample includes a fair representation of issues that *don't* feature the Science Communication Problem, no amount of data collection will help to identify what those influences are.

3. Four theses on ordinary science knowledge

So far I've emphasized how easily one can credit false accounts of the Science Communication Problem if one focuses only on instances of it. I now want to pivot the analysis and offer a glimpse of how much insight can be gained by studying what is going on in the much larger class of cases that evade the Problem's signature form of contestation.

The exposition will be admittedly skeletal. It, too, consists in nothing more than four propositions. These relate to *ordinary science knowledge*—or the normal state of collective convergence by members of the public on what is known by science:

I. ***"Individuals must accept as known more decision relevant science (DRS) than they can possibly understand or verify for themselves";***
II. ***"Individuals acquire the insights of DRS by reliably recognizing it";***
III. ***"Public conflict over DRS is a recognition problem, not a comprehension problem"; and***
IV. ***"The recognition problem reflects a polluted science communication environment."***

Even when the argument is presented in this form, however, I expect it to bear sufficient weight to show that adding empirical muscle to it—by making ordinary science knowledge the focus of scientific conjecture and refutation (Popper 1962*a*)—is the best way to advance the project to understand and to solve the Science Communication Problem.

3.1. The motto of the Royal Society is *Nullius in verba*, which translates literally into "take no one's word for it." But something—namely, any pretense of being a helpful guide to getting the benefits of scientific knowledge—is definitely lost in a translation that literal.

If you aren't vigorously nodding your head, then consider this possibility. You learn next week that you have an endocrinological deficit that can be effectively treated but only if you submit to a regimen of daily medications. You certainly will do enough research to satisfy yourself—to satisfy any reasonable person in your situation—that this recommendation is sound before you undertake such treatment.

But what will you do? Will you carefully read and evaluate all the studies that inform your physician's recommendation? If those studies refer, as they inevitably will, to previous ones the methods of which aren't reproduced in those papers, will you read those, too? If the studies you read refer to concepts with which you aren't familiar, or use methods which you have no current facility, will you enroll in a professional training program to acquire the necessary knowledge and skills? And once you've done that, will you redo the experiments—*all* of them; not just the ones reported in the papers that support the prescribed treatment but also those relied on and extended by them—so you can avoid taking anyone's word on what the results of such studies actually were as well?

Of course not. Because by the time you did those things, you'd be dead. To live well—or just to live—individuals (including scientists) must *accept* much more DRS than they can ever hope to make sense of on their own.

Science's way of knowing involves crediting as true only inferences rationally drawn from observation. This was—still is—a radical alternative to other *ways* of knowing that feature truths revealed by some mystic source to a privileged few, who alone enjoy the authority to certify the veracity of such insights. *That* system is what the founders of the Royal Society had in mind when they boldly formulated their injunction to "take no one's word for it." But it remains the case that to get the benefits of the distinctive, and distinctively penetrating, mode of ascertaining knowledge they devised, we must *take the word* of those who know what's been ascertained by those means—while being sure *not* to take the word of anyone else (Shapin 1994).

3.2. But how exactly does one do that? How do reasonable, reasoning people who need to use science for an important decision but who cannot plausibly figure out for themselves what science knows figure out *who* does know what science knows?

We can rule out one possibility right away: that members of the public figure out who genuinely possesses knowledge of what science knows by evaluating the correctness of what putative experts believe. To do that, members of the public would have to become experts in the relevant domain of knowledge themselves. Again, it is obvious that they lack both the capacity and time to do that.

Instead they have to become experts at *recognizing* valid sources of science. They become expert at that, moreover, in the same way they become expert at recognizing *anything else*: by using a conglomeration of cues, which operate not as necessary and sufficient conditions, but as elements of prototypical representations (e.g., "cat," "advantageous chess position," "ice cream sandwich," "expert") that are summoned to mind by mental processes, largely unconscious, that rapidly assimilate the case at hand to a large inventory of prototypes acquired through experience. In a word (or two words), they use *pattern recognition* (Margolis 1993).

This is equivalent to the answer that Popper gave (in an essay the title, and much more, of which are the inspiration for this one) in answering the near-identical question about how we come to know what is known by science. Popper's target was a cultural trope of sensory empiricism that treated as "scientific knowledge" only what one has observed for oneself. After impaling this view on the speartips of a series of reductios, Popper explains that most things we know"—i.e., know *to be known to science*—"we have learnt by example, by being told." In appraising the conformity of any such piece of information to the qualities that invest it with the status of scientific knowledge, moreover, an individual must rely on "his knowledge of persons, places, things, linguistic usages, social conventions, and so on" (ibid., p. 30). To be sure, powers of critical reasoning play a role. We must calibrate this facility of recognition by "learning how to criticize, how to take and to accept criticism, how to respect truth" (ibid, p. 36), a view Baron (1993) and Keil (2003, 2010, 2012) both develop systematically.

But the *objects* of the resulting power to discern valid science are *not* the qualities that make it valid: those are simply far too "complex," far too "difficult for the average person to understand (Baron, 1993, p, 193). What this faculty attends to instead are the *signifiers* of validity implicit in *informal, everyday social processes* that vouch for the good sense of relying on the relevant information in making important decisions (Keil 2010, 2012). Popper characterizes the aggregation of these processes as "tradition," which he describes as "by far the most important source of our knowledge" (1962*b*, p. 36).

It is worth noting that although Popper here is referring to the process by which ordinary science knowledge is disseminated to nonscientists, there is no reason to think that scientists are any less in need of their own valid-science recognition capacity, or that they acquire or exercise it in a fundamentally different way. Indeed, there is ample reason to think that it couldn't possibly differ from the faculty that members of the public use to recognize valid science (Shapin 1994) aside from its being more finely calibrated to the particular insights and methods needed to be competent in the production of the same (Margolis 1987, 1996).

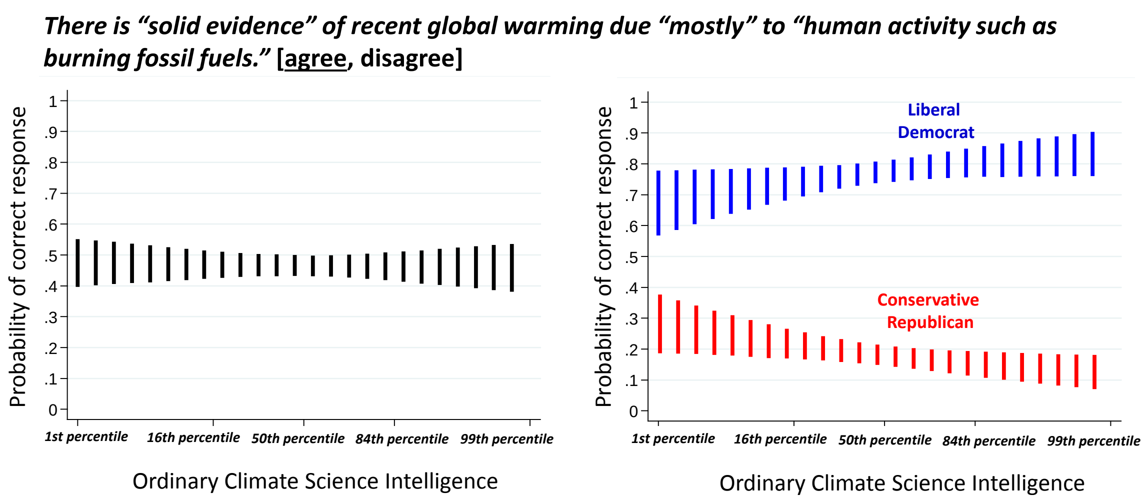

Figure 4. Belief in human-caused climate change in relation to performance on climate science literacy assessment and political outlooks. Source Kahan (2015*a*). *N* = 2000, nationally representative sample. "Ordinary Climate Science Intelligence" is 9-item climate-science literacy test. Scores for "Liberal Democrat" and "Conservative Republican" based on logistic regression model. Colored bars denote 0.95 CIs.

"How do we gain our knowledge about how to analyze data?" ask Andrew Gelman and Keith O'Rourke (2015, pp., 161-2). By "informal heuristic reasoning," they reply, of the sort that enables those immersed in a set of practice to see the correctness of an answer to a problem before, and often without ever being able to give a fully cogent account of, why.

3.3. Now we can start to put things together. The First False Start, PIT, attributes the Science Communication Problem to defects in the public's capacity to understand science. Challenging this position, I noted the absence of contestation over myriad other risk sources about which members of the public know just as little and on which they are no better equipped to analyze data. The Second Thesis posits that where the Science Communication Problem is absent, members of the public converge on the best evidence not by *comprehending* its validity but rather but by *recognizing* it.

If these claims are correct, then we should expect the Science Communication Problem to be one that affects the capacity of the pubic to recognize valid science, not their capacity to comprehend it. That is a proposition easily tested.

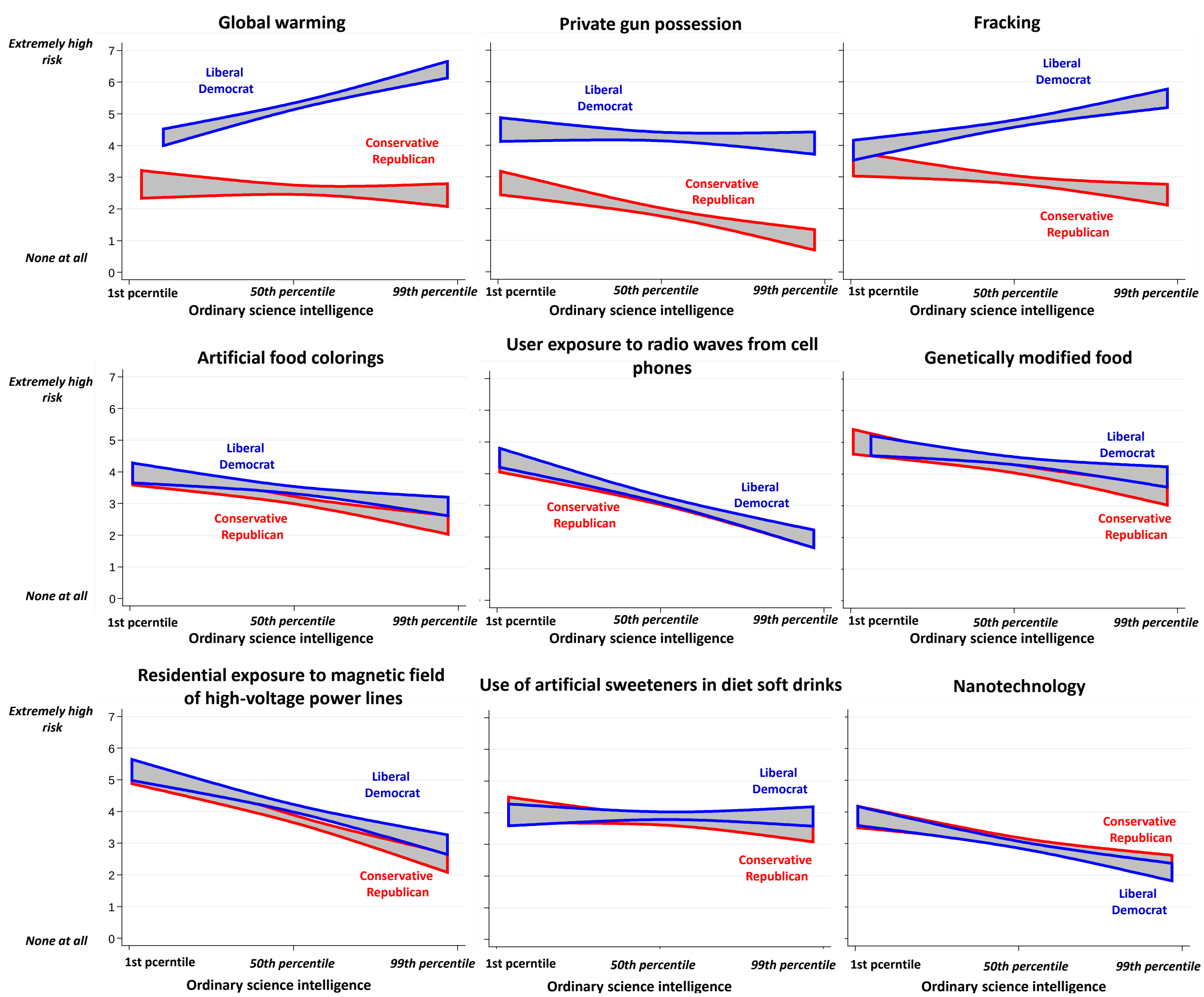

Figure 5. Impact of increased science comprehension on political polarization of select risk items. Source Kahan (2015*a*). *N* = 2000, nationally representative sample. "Ordinary Science Intelligence" is 18-item -science literacy test. Scores for "Liberal Democrat" and "Conservative Republican" based on linear regression model. Colored bars denote 0.95 CIs**.**

The tests that can be performed are two, First, one can examine whether lower degrees of science comprehension predict disagreement on issues affected by the Science Communication Problem.

The answer is no. There is zero correlation, in fact, between belief in human-caused climate change and how individuals perform on a valid "climate science literacy" test (Kahan 2015*a*) (Figure 4). Indeed, political polarization doesn't abate as individuals become more proficient in numeracy, cognitive reflection, and other capacities essential to accurate risk perception increase; on the contrary, it increases (Kahan & Peters 2012; Kahan & Peters et al. 2013; Kahan 2013; Kahan 2015*a*) (Figure 5).

The second test examines the relationship between issues that feature the Science Communication Problem and individuals' apprehension of the indicia of *valid* science. This evidence suggests that disagreement about what evidence counts as valid and what it implies is precisely what accounts for the persistent contestation associated with the Science Communication Problem.

Thus, members of the groups that disagree about key facts on human-caused climate change, nuclear power, and gun control, for example, disagree just as sharply about what scientific consensus *is* on those facts. In addition, if we treat, say, the National Academy of Sciences' expert consensus reports as a benchmark, no group is any more likely than any other to be correct about what scientific consensus is across the run of issues on which contending cultural groups are divided (Kahan, Jenkins-Smith & Braman 2011). This result is contrary, of course, to the Third False Start, which asserts that we've entered an "age of science denial" since it shows that *no group* understands itself to be "rejecting" the weight of scientific opinion on any of the issues featured in the Science Communication Problem. That these groups are forming such unreliable judgments on what scientists' consensus is, however, suggests that something is disabling their members from correctly assessing information about what genuine experts believe on these matters.

That inference has been confirmed experimentally. When evaluating a highly credentialed scientist, individuals of opposing cultural identities will conform their assessment of the expertise of that scientist within the relevant domain to whether he was depicted as supporting or opposing the position that predominates within the subjects' own groups. In other words, rather than treating the view of a particular expert scientist as reason to adjust their assessment of the weight of scientific opinion on the issue at hand (whether human beings are causing global warming; whether laws allow carrying of concealed weapons in public increases or decreases crime; whether nuclear wastes can be safely deposited in deep geologic isolation), study subjects use their current position to determine *what weight* to give the view of any particular scientist (ibid) (Figure 6).

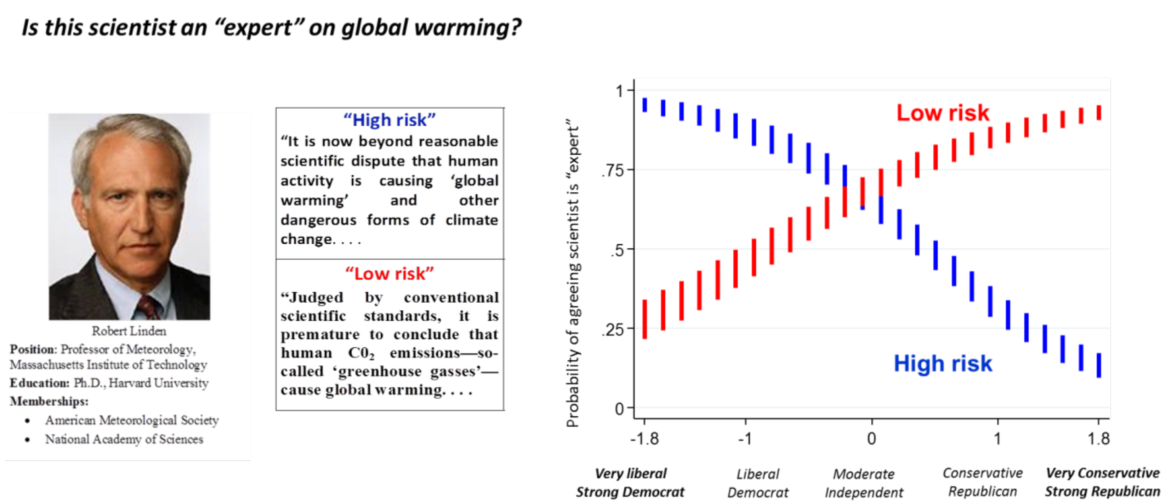

Figure 6. Biased recognition of scientific expertise. Source: Kahan, Jenkin-Smith, Braman (2011). $N = 1336$, nationally representative sample. Based on logistic regression model. Slopes indicate probability of recognizing that featured scientist is an expert within climate-change domain conditional on attributed position and subject political outlook. Colored bars reflect 0.95 confidence intervals.

Note, too, that this style of reasoning dispenses with the need for anyone to engage in misinformation—the fourth False Start—in order to *exploit* the Science Communication Problem. No one is doing anything to misinform the subjects in this study; the subjects are aggressively *misinforming themselves* by selectively crediting or discrediting evidence on what scientists believe in patterns that cohere with the positions associated with their group identities.

That is a style of reasoning in the nature of confirmation bias. When indulged in outside the lab, it will result in the pattern of persistent disagreement about scientific consensus that we observe in the world. It is a pattern of information processing, moreover, that systematically blocks diverse members of the public from giving effect to cues that would otherwise be expected to help them converge in their recognition of who knows what about what.

3.4. The species of pattern recognition that non-expert members of the public normally use to recognize valid science enables them to get the benefit of substantially more scientific insight than any could possibly hope to comprehend. The evidence I described in the last section, however, shows how this critical capacity can be disabled. The final "thesis of ordinary science knowledge" identifies the source of this disablement: *a polluted science communication environment.*

As noted, Popper (1962*b*) attributes the acquisition and exercise of the capacity for science-recognition to immersion in a set of social processes and conventions. When I refer to the *science communication environment*, I mean the sum total of the processes and conventions that enable recognition of valid science in this way (Kahan 2015*b*). Any influence that impairs or impedes the operation of these social practices will degrade the power of free, reasoning citizens to *recognize* valid science, and hence to fully realize its benefits. As a result, we may understand any such influence to be a form of *pollution* in the science communication environment.

The sorts of influences that can generate such disablement are no doubt numerous and diverse. But I will focus on one, which degrades an especially consequential cue of science validity.

Of all the sources of ordinary science knowledge, by far the most significant are individuals' interactions with others with whom they a share *cultural commitments* or basic understanding of the best way to live. The suggestion that direct communication with scientists is more consequential reflects either the First or Second False Start or both: individuals have neither the time nor the capacity to extract information directly from scientists. Much more accessible, and much more readily subject to meaningful interpretation, are words and actions of *other ordinary people*, whose *use* of DRS vouches for their confidence in it as a basis for decision.

Indeed, it vouches as effectively when *nothing* is said about it as it does when something is. Nothing—including a new National Academy of Sciences expert consensus report (National Research Council 2016) that few members of the public will ever recognize exists—will as effectively assure an ordinary person that it is safe to eat GM corn chips as will watching his best friend and his brother-in-law and his officemate *eating them* without giving the matter a second's thought; seeing what these models of normal behavior do is the "all clear" signal that obviates the need for the vast majority of Americans even to bother learning that the corn chips they are eating contain GM foods (Hallman, Cuite & Morin 2013). *Social proof* (Aronson 1999) is the dominant mode of communicating the reliability of decision-relevant science for non-expert members the public.

Of course, ordinary citizens don't interact only with those with whom they share important cultural commitments. But they interact with them much more than they interact with others, for the simple reason that they find their company more congenial and more conducive to all manner of profitable intercourse. They are also less likely to waste time squabbling with these people, and can also *read* them more reliably, distinguishing those who really do know what science knows from those who are only posers. It is perfectly rational, then, for them to consciously seek guidance from those who share their outlooks, and to form unconscious habits of mind that privilege these individuals as sources of guidance on what science knows (Kahan 2015*b*).

This process is admittedly insular, *but it clearly works in the main.* All of the major cultural groups in which this process operate are amply stocked both with members high in science comprehension and with intact social processes for transmitting what they know. No group that lacked these qualities—and that as a result regularly misled its members on the content of valid DRS—would last very long! On issues that *don't* display the profile of the Science Communication Problem, those highest in science proficiency *do* tend to converge on the best available evidence, and no doubt pull the other members of their groups along in their wake (Figure 5).

But such a system is vulnerable to a distinctive pathology: *identity-protective cognition* (IPC). IPC occurs when a policy-relevant fact that admits of empirical inquiry becomes entangled in antagonistic social meanings that transform positions on them into badges of identity in, and loyalty to, competing cultural groups (Kahan 2010, 2012). The cost under those conditions of forming *factually incorrect* beliefs on matters such as whether humans are heating up the earth or whether fracking will exhaust or contaminate drinking water sources is essentially zero: individuals' personal views and actions are not consequential enough to affect the level of risk they face, or the likely adoption of ameliorating (or simply pointless or even perverse) regulatory responses. But given what beliefs on these subjects (correct or incorrect) have come to signify about the kind of person one is—about whose side one is on, in what has become a struggle for status among competing cultural groups—the personal cost of forming the *wrong* ones in relation to one's own cultural identity could be punishingly high (Kahan, Peters et al. 2012).

In such circumstances, individuals can be expected to *use* their reason to form and persist in beliefs that reliably vouch for their group identities *regardless* of whether those beliefs are factually accurate. This conclusion is consistent with numerous studies, observational (Bolsen, Druckman & Cook 2015, 2013; Gollust, LaRussao et al. 2015; Gollust, Dempsey, et al. 2010) and experimental (Kahan, Braman, et al. 2009, 2010), that link IPC to the Science Communication Problem's signature forms of polarization. Indeed, individuals who enjoy the *highest level of proficiency* will display this form of motivated reasoning to the greatest extent, precisely because they will be the most adept at using their reasoning proficiency to secure the interest that they share to form identity-expressive beliefs (Kahan in press).

In sum, the antagonistic social meanings that trigger IPC are a toxic form of pollution in the science communication environment of culturally pluralistic societies. They disable individuals' science-recognition capacities, *not* by diminishing their reason but by *conscripting* it into the service of advancing their group's cause in a demeaning form of cultural status competition. IPC does not *create* the role that social influences play in popular recognition of what science knows. Rather it corrupts them, transforming the role that spontaneous, everyday social interactions play from an engine of convergence on the best available evidence into a relentlessly aggressive agent of public dissensus over what scientific consensus really is.

4. Understanding and protecting the science communication environment

I will conclude by adding to the "four theses of ordinary science knowledge" a fifth:

> ***V. Protecting the science communication environment from contamination is the principal aim of the science of science communication.***

The Fifth Thesis places an analytical capstone atop the arc of the argument this essay has presented. I began by showing that "ignoring the denominator"—fixating on the relatively small number of cases that feature persistent public conflict over policy-relevant facts and ignoring the vastly larger number of ones that feature convergence—predictably generates insupportable explanations of the Science Communication Problem. Next I examined how attending to the dynamics that account for the normality of public convergence on what is known by science generates a much better explanation: the disruption of the everyday social processes productive of the cues that certify the validity of decision relevant science. A research program aimed at managing those influences—at neutralizing the disruptive influence that they exert on the sources of ordinary science knowledge—is ideally calculated to test this theory and thus advance knowledge of how people come to know what is known by science.

But more fundamentally, the Fifth Thesis is intended to summon the energy and focus needed for the science of science communication to perfect enlightened self-government. As Popper (1945) also famously made clear, liberal democracy is the political regime must congenial to the advancement of scientific knowledge. The privileged status it affords individual freedom of thought fuels the engine of scientific conjecture and refutation and removes any bureaucratic impediment to its relentless convergence on truth.

But precisely because the highly diverse citizens of this regime will not submit to a central authority's certification of the truth (*Nullius in verba!*), they face a distinctive epistemic challenge. The problem is *not* the absence of a social system of truth certification; they have one—"tradition"—without which scientific "knowledge would be impossible" (Popper 1962*b*, p. 36). But in a pluralistic liberal regime, there will necessarily be a *plurality of certifiers*—a plurality of communities, bonded by their shared view of the good, whose interactions generate the *multiple* "traditions," immersion in which calibrates the reasoning faculties their members use to recognize valid science. Conflicts among these plural communities of certification, even if rare, are statistically certain to arise as their members' independence of mind and freedom of action continuously enlarge the stock of scientific knowledge at their disposal. The threat IPC poses to the science communication environment is intrinsic to the very conditions that make liberal democratic societies so distinctively fit for producing scientific knowledge.

But this is not an "inherent contradiction" in the constitution of the Liberal Republic of Science. It is just a problem to be solved—with the instrument best suited for solving any problem that threatens the welfare of its citizens: the power that science's distinctive method of disciplined observation and inference confers on human reason. Assuring that the citizens of liberal democratic regimes get the full benefit of the knowledge that their way of life makes possible is what the Science of Science Communication is *for* (Kahan 2015*b*).

References

American Academy of Pediatrics, Committee on Infectious Diseases. Universal hepatitis B immunization. *Pediatrics* 8, 795-800 (1992).

American Academy of Pediatrics. HPV Vaccine Does Not Lead to Increased Sexual Activity (2012), http://tinyurl.com/jrjx37o

American Academy of Pediatrics. Prevention of Human Papillomavirus Infection: Provisional Recommendations for Immunization of Girls and Women With Quadrivalent Human Papillomavirus Vaccine. *Pediatrics* **120**, 666-668 (2007).

Aronson, E. *The Social Animal* (Worth Publishers, New York, N.Y., 1999).

Baron, J. Why Teach Thinking? An Essay. *Applied Psychology* **42**, 191-214 (1993).

Brownell, S.E., Price, J.V. & Steinman, L. Science communication to the general public: why we need to teach undergraduate and graduate students this skill as part of their formal scientific training. *J. Undergraduate Neuroscience Educ.* 12, E6 (2013).

Bjerga, A. & Keane, A.G. Obama REady to Sign Food-Label Bill Consumer Groups Dislike. *Bloomberg.com* (July 13, 2016), available at http://www.bloomberg.com/politics/articles/2016-07-13/obama-ready-to-sign-food-label-bill-consumer-groups-find-suspect

Chokshi, N. Big corporate spending pays off in Washington's genetically modified food fight. Wash. Post (Nov. 6, 2013), https://www.washingtonpost.com/blogs/govbeat/wp/2013/11/06/big-corporate-spending-pays-off-in-washingtons-genetically-modified-food-fight/.

Dean, C. *Am I making myself clear? : a scientist's guide to talking to the public* (Harvard University Press, Cambridge, Mass., 2009).

Doh, J.P. & Guay, T.R. Corporate Social Responsibility, Public Policy, and NGO Activism in Europe and the United States: An Institutional-Stakeholder Perspective. *Journal of Management Studies* 43, 47-73 (2006).

Drexler, K.E. *Engines of creation* (Anchor Press/Doubleday, Garden City, N.Y., 1986).

Edwards, T. Climate scientists must not advocate particular policies. *The Guardian, July* 31 (2013).

Fischhoff, B. Nonpersuasive Communication about Matters of Greatest Urgency: Climate Change. *Environmental Science & Technology* 41, 7204-7208 (2007).

Flynn, D. GM Food Labeling in California Goes Down in Defeat. Food Safety News. (Nov. 7, 2012), at http://www.foodsafetynews.com/2012/11/big-setback-for-right-to-know-about-gm-foods-prop-37-goes-down-in-crushing-defeat/#.V1p5L7srJGr.

Frank, A. Welcome to the age of denial. *N.Y. Times* (Aug. 21, 2013), available at http://www.nytimes.com/2013/08/22/opinion/welcome-to-the-age-of-denial.html?_r=0.

Gelman, A. & O'Rourke, K. Convincing Evidence. in *Roles, Trust, and Reputation in Social Media Knowledge Markets: Theory and Methods* (ed. E. Bertino & A.S. Matei) 161-165 (Springer International Publishing, Cham, 2015).

Gollust, S.E., Dempsey, A.F., Lantz, P.M., Ubel, P.A. & Fowler, E.F. Controversy undermines support for state mandates on the human papillomavirus vaccine. *Health Affair* **29**, 2041-2046 (2010).

Gollust, S.E., LoRusso, S.M., Nagler, R.H. & Fowler, E.F. Understanding the role of the news media in HPV vaccine uptake in the United States: Synthesis and commentary. *Human vaccines & immunotherapeutics*, 1-5 (2015).

"Green Goo: Nanotechnology Comes Alive." *ETCgroup.org* (Feb. 2003), at http://www.etcgroup.org/content/green-goo-nanotechnology-comes-alive.

Hallman, W., Cuite, C. & Morin, X. Public Perceptions of Labeling Genetically Modified Foods. *Rutgers School of Environ. Sci.* Working Paper 2013-2001, available at http://humeco.rutgers.edu/documents_PDF/news/GMlabelingperceptions.pdf.

Kahan, D. Fixing the Communications Failure. *Nature* **463**, 296-297 (2010).

Kahan, D. Why we are poles apart on climate change. *Nature* **488**, 255 (2012).

Kahan, D., Braman, D., Cohen, G., Gastil, J. & Slovic, P. Who Fears the HPV Vaccine, Who Doesn't, and Why? An Experimental Study of the Mechanisms of Cultural Cognition. *Law Human Behav* **34**, 501-516 (2010).

Kahan, D.M. 'Ordinary science intelligence': a science-comprehension measure for study of risk and science communication, with notes on evolution and climate change. *J. Risk Res*, 1-22 (2016).

Kahan, D.M. A Risky Science Communication Environment for Vaccines. *Science* **342**, 53-54 (2013).

Kahan, D.M. Climate-Science Communication and the Measurement Problem. *Advances in Political Psychology* **36**, 1-43 (2015*a*).

Kahan, D.M. Ideology, Motivated Reasoning, and Cognitive Reflection. *Judgment and Decision Making* **8**, 407-424 (2013).

Kahan, D.M. The Politically Motivated Reasoning Paradigm. *Emerging Trends in Social & Behavioral Sciences,* (in press), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2703011

Kahan, D.M. What is the "science of science communication"? *J. Sci. Comm,* 14, 1-12 (2015*b*).

Kahan, D.M., Braman, D., Slovic, P., Gastil, J. & Cohen, G. Cultural Cognition of the Risks and Benefits of Nanotechnology. *Nature Nanotechnology* **4**, 87-91 (2009).

Kahan, D.M., Jenkins-Smith, H. & Braman, D. Cultural Cognition of Scientific Consensus. *J. Risk Res.* **14**, 147-174 (2011).

Kahan, D.M., Peters, E., Dawson, E. & Slovic, P. Motivated Numeracy and Enlightened Self Government. *Cultural Cognition Project Working Paper No. 116* (2013).

Keil, F.C. Folkscience: Coarse interpretations of a complex reality. *Trends in cognitive sciences* **7**, 368-373 (2003).

Keil, F.C. Running on Empty? How Folk Science Gets By With Less. *Current Directions in Psychological Science* **21**, 329-334 (2012).

Keil, F.C. The feasibility of folk science. *Cognitive science* **34**, 826-862 (2010).

Kloor, Keith. GMO Opponents Are the Climate Skeptics of the Left. *Slate* (Sept. 26, 2012), available at http://www.slate.com/articles/health_and_science/science/2012/09/are_gmo_foods_safe_opponents_are_skewing_the_science_to_scare_people_.html.

Liang, X.X. Value predispositions as perceptual filters: Comparing of public attitudes toward nanotechnology in the United States and Singapore. *Public Understanding of Science* **24**, 582-600 (2015).

Lempert, R.J., Groves, D.G. & Fischbach, J.R. Is it Ethical to Use a Single Probability Density

Function? (Santa Monica, CA: RAND Corporation, 2013).

McFadden, B.R. & Lusk, J.L. What consumers don't know about genetically modified food, and how that affects beliefs. *The FASEB Journal* (2016).

Lynch, D. & Vogel, D. The regulation of GMOs in Europe and the United States: A case-study of contemporary European regulatory politics. *Council on Foreign Relations* (2001).

Margolis, H. *Patterns, thinking, and cognition : a theory of judgment* (University of Chicago Press, Chicago, 1987).

Margolis, H. *Paradigms and Barriers* (University of Chicago Press, Chicago, 1993).

Margolis, H. *Dealing with risk : why the public and the experts disagree on environmental issues* (University of Chicago Press, Chicago, IL, 1996).

Marx, S.M., Weber, E.U., Orlove, B.S., Leiserowitz, A., Krantz, D.H., Roncoli, C. & Phillips, J. Communication and mental processes: Experiential and analytic processing of uncertain climate information. *Global Environ Chang* 17, 47-58 (2007).

Mooney, C. *The Republican Brain: The Science of Why They Deny Science--And Reality* (John Wiley & Sons, Hoboken, NJ, 2012).

National Research Council (U.S.). Board on Atmospheric Sciences and Climate. & National Research Council (U.S.). Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations. *Climate stabilization targets : emissions, concentrations, and impacts over decades to millennia* (National Academies Press, Washington, D.C., 2011).

National Research Council (U.S.). Committee on Chemistry and Physics of Ozone Depletion. *Causes and effects of stratospheric ozone reduction, an update : a report* (National Academy Press, Washington, D.C., 1982).

National Research Council (U.S.). Committee on Ecological impacts of Climate Change. *Ecological impacts of climate change* (National Academies Press, Washington, D.C., 2008).

National Research Council (U.S.). Committee on Genetically Engineered Crops. *Genetically Engineered Crops: Experiences and Prospects* (National Academies Press, Washington, D.C., 2016).

National Research Council (U.S.). Panel on Atmospheric Chemistry. *Halocarbons, environmental effects of chlorofluoromethane release* (National Academy of Sciences, Washington, 1976).

National Science Foundation. *Science and Engineering Indicators 2016* (Wash. D.C., 2016).

Olson, R. *Don't be such a scientist : talking substance in an age of style* (Island Press, Washington, DC, 2009).

Peters, E.M., Burraston, B. & Mertz, C.K. An Emotion-Based Model of Risk Perception and Stigma Susceptibility: Cognitive Appraisals of Emotion, Affective Reactivity, Worldviews, and Risk Perceptions in the Generation of Technological Stigma. *Risk Analysis* 24, 1349-1367 (2004).

Popper, K.R. *Conjectures and refutations; the growth of scientific knowledge* (Basic Books, New York,, 1962*a*).

Popper, K.R. On the Sources of Knowledge and of Ignorance. in *Conjectures and Refutations* 3-40 (Oxford University Press London, 1962*b*).

Popper, K.R. *The open society and its enemies* (G. Routledge & sons, London,, 1945).

Sato, K. *Meanings of genetically modified food and policy change and persistence: The cases of France, Japan and the United States* (Princeton University, 2007).

Science, Media, and the Public Research Group (SCIMEP).. Exploring Public Opinion and Risk Perceptions of Food in Wisconsin. University of Wisconsin-Madison. Madison, WI: Department of Life Sciences Communication (2016). Available from http://scimep.wisc.edu/projects/reports/

Shapin, S. *A social history of truth : civility and science in seventeenth-century England* (University of Chicago Press, Chicago, 1994).

Sunstein, C.R. *Laws of fear : beyond the precautionary principle* (Cambridge University Press, Cambridge, UK ; New York) (2005).

Sunstein, C.R. On the Divergent American Reactions to Terrorism and Climate Change. *Columbia Law Rev* 107, 503-557 (2007).

Tims, D.. Measure 92, GMO-labeling initiative, fails narrowly. *Oregonian* (Nov. 5, 2014), at http://tinyurl.com/o33zs2c.

Vance, M.E., Kuiken, T., Vejerano, E.P., McGinnis, S.P., Hochella, M.F., Jr., Rejeski, D. & Hull, M.S. Nanotechnology in the real world: Redeveloping the nanomaterial consumer products inventory. Beilstein Journal of Nanotechnology 6, 1769-1780 (2015)

Watts, D.J. *Everything is Obvious: Once You Know the Answer: How Common Sense Fails* (Atlantic Books, 2011).

Journal of Science Communication, Vol. 14, No. 3, 2015

What is the "science of science communication"?

*Dan M. Kahan**

This essay seeks to explain what the "science of science communication" is by *doing* it. Surveying studies of cultural cognition and related dynamics, it demonstrates how the form of disciplined observation, measurement, and inference distinctive of scientific inquiry can be used to test rival hypotheses on the nature of persistent public conflict over societal risks; indeed, it argues that satisfactory insight into this phenomenon can be achieved *only* by these means, as opposed to the ad hoc story-telling dominant in popular and even some forms of scholarly discourse. Synthesizing the evidence, the essay proposes that conflict over what is known by science arises from the very conditions of individual freedom and cultural pluralism that make liberal democratic societies distinctively congenial to science. This tension, however, is not an "inherent contradiction"; it is a problem to be solved — *by the science of science communication* understood as a "new political science" for perfecting enlightened self-government.

Introduction

Public opinion on societal risks presents a disorienting spectacle. Is the earth warming up as a result of human activity? Can nuclear wastes be safely stored in deep underground rock formations? Can natural gas be safely *extracted* by hydraulic fracturing of bedrock? Will inoculating adolescent girls against the human papilloma virus — an extremely common sexually transmitted disease responsible for cervical cancer — lull them into engaging in unprotected sex, thereby increasing their risk of pregnancy or of other STDs? Does allowing citizens to carry concealed handguns in public increase crime — or *reduce* it by deterring violent predation?

Never have human societies *known so much* about mitigating the dangers they face but *agreed so little* about what they collectively know. Because this disjunction features the persistence of divisive conflict in the face of compelling scientific evidence, we can refer to it as the "science communication paradox" (Figure 1).

Resolving this paradox is the central aim of a new *science of science communication*. Its central findings suggest that intensifying popular conflict over collective knowledge is in fact a predictable byproduct of the very conditions that make free, democratic societies so hospitable to the advancement of science. But just as science has equipped society to repel myriad other threats, so the science of science communication can be used to fashion tools specifically suited to dispelling the science communication paradox.

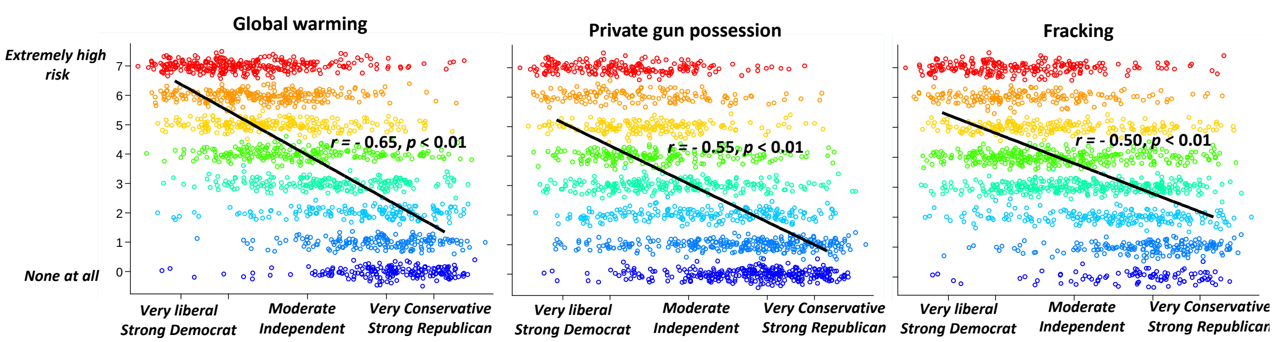

Figure 1. Polarization over risk. Scatterplots relate risk perceptions to political outlooks for members of nationally representative sample (N = 1800), April–May 2014 [Kahan, 2015].

* Elizabeth K. Dollard Professor of Law and Professor of Psychology, Yale Law School. dan.kahan@yale.edu.

The "public irrationality thesis"

What is the "science of science communication"? One could easily define it with reference to some set of signature methods and aims [Fischhoff and Scheufele, 2013]. But more compelling is simply to do the science of science communication — to show what it means to approach the science communication paradox scientifically.

The most popular explanation for the science communication paradox can be called the "public irrationality thesis" or "PIT." Members of the public, PIT stresses, are not very science literate. In addition, they do not think like scientists. Scientists assess risk in a conscious, deliberate fashion, employing the analytical reasoning necessary to make sense of empirical evidence. Members of the public, in contrast, appraise hazards intuitively, on the basis of fast-acting unconscious emotions. As a result, members of the public overestimate dramatic or sensational risks like terrorism and discount more remote but more consequential ones — like climate change [Weber, 2006; Marx et al., 2007; Sunstein, 2007; Sunstein, 2005].

PIT features genuine cognitive mechanisms known to be important in various settings [Kahneman, 2003; Frederick, 2005]. It therefore supplies a very plausible explanation of the science communication paradox.

But there will inevitably be a greater number of plausible accounts of any complex social phenomenon than can actually be true [Watts, 2011]. Cognitive psychology supplies a rich inventory of dynamics — "dissonance avoidance", "availability cascades", "tipping points", "emotional numbing", "fast vs. slow cognition", and the like. Treating these as a grab bag of argument templates, any imaginative op-ed writer can construct a seemingly "scientific" account of public conflict over risk.

So does PIT withstand empirical testing? If the reason members of the public fail to take climate change as seriously as scientists think they should is that the public lacks the knowledge and capacity necessary to understand empirical information, then we would expect the gap between public and expert perceptions to narrow as members of the public become more science literate and more proficient in critical reasoning.

But that does not happen (Figure 2). Members of the public who score highest in one or another measure of science comprehension, studies show, are no more concerned about global warming than those who score the lowest [Kahan, 2015; Kahan et al., 2012]. The same pattern, moreover, characterizes multiple other contested risks, such as the ones posed by nuclear power, fracking, and private possession of firearms [Kahan, 2015].

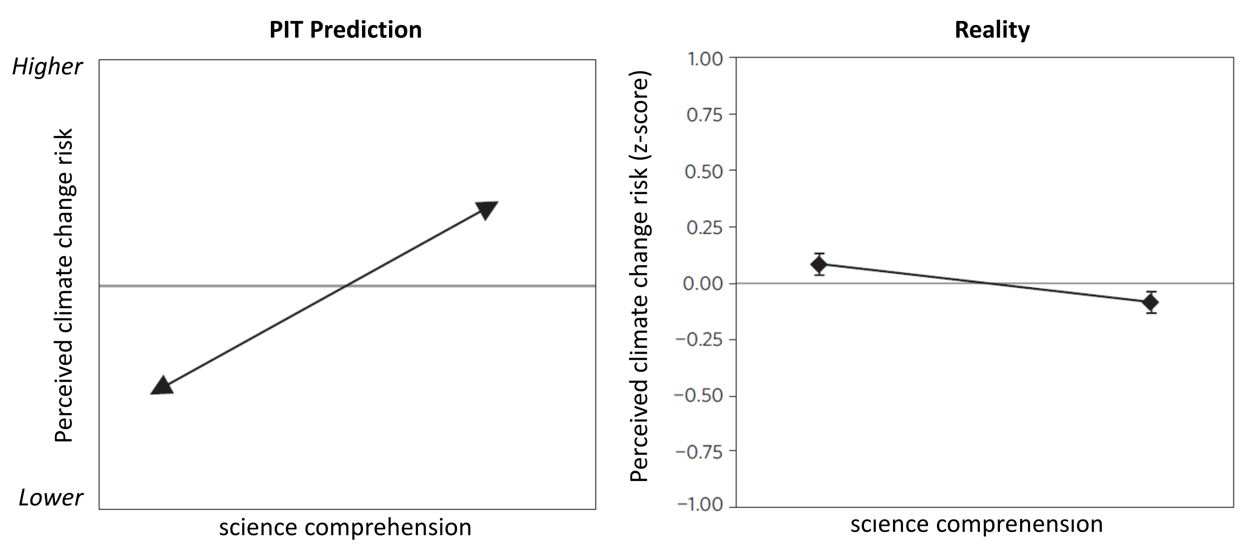

Figure 2. Impact of science comprehension on climate change polarization. Error bars are 0.95 confidence intervals (N = 1540) [Kahan et al., 2012].

The "cultural cognition thesis"

Another plausible conjecture — another *hypothesis* about the science communication paradox — is the "cultural cognition thesis" (CCT). CCT posits that certain types of group affinities are integral to the mental processes ordinary members of the public use to assess risk [Kahan et al., 2010].

"Motivated reasoning" refers to the tendency of people to conform their assessments of all sorts of evidence to some goal unrelated to accuracy [Sood, 2013; Kunda, 1990]. Students from rival colleges, for example, can be expected to form opposing perceptions when viewing a film of a disputed officiating call in a football game between their schools, consistent with their stake in experiencing emotional solidarity with their peers [Hastorf and Cantril, 1954].

CCT says this same thing occurs when members of the public access information about contested societal risks. When positions on *facts* become associated with opposing social groups — not universities but rather everyday networks of people linked by common moral values, political outlooks, and social norms — individuals selectively assess evidence in patterns that reflect their group identities [Kahan, 2011].

Numerous studies support CCT. In one, my colleagues and I examined the impact of cultural cognition on perceptions of scientific consensus [Kahan, Jenkins-Smith and Braman, 2013]. We asked our subjects — a large, nationally representative sample of U.S. adults — to indicate whether they regarded particular scientists as "experts" whose views an ordinary citizen ought to take into account on climate change, nuclear waste disposal, and gun control. We picked these issues precisely because they feature disputes over empirical, factual issues among opposing cultural groups

The scientists were depicted as possessing eminent qualifications, including degrees from, and faculty appointments at, prestigious universities. However, half the study subjects saw a book excerpt in which the featured scientist took the "high risk" position (global warming *is* occurring; underground disposal of nuclear waste is *unsafe*; permitting carrying of concealed handguns *increases* crime) and half an excerpt in which the same scientist took the "low risk" position (there's *no* clear evidence human-caused global warming; underground disposal of nuclear wastes is *safe*; permitting concealed carry *reduces* crime).

The subjects' assessments of the scientists' expertise, we found, depended on the fit between the position attributed to the expert and the position held by most of the subjects' cultural peers. If the featured scientist was depicted as endorsing the dominant position in a subject's cultural group, the subject was highly likely to classify that scientist as an "expert" on that issue; if not, then not (Figure 3).

Like sports fans motivated to *see* the officiating replay as supporting their team, the subjects selectively credited or discredited the evidence we showed them — the position of a highly qualified scientist — in a manner supportive of their group's position.

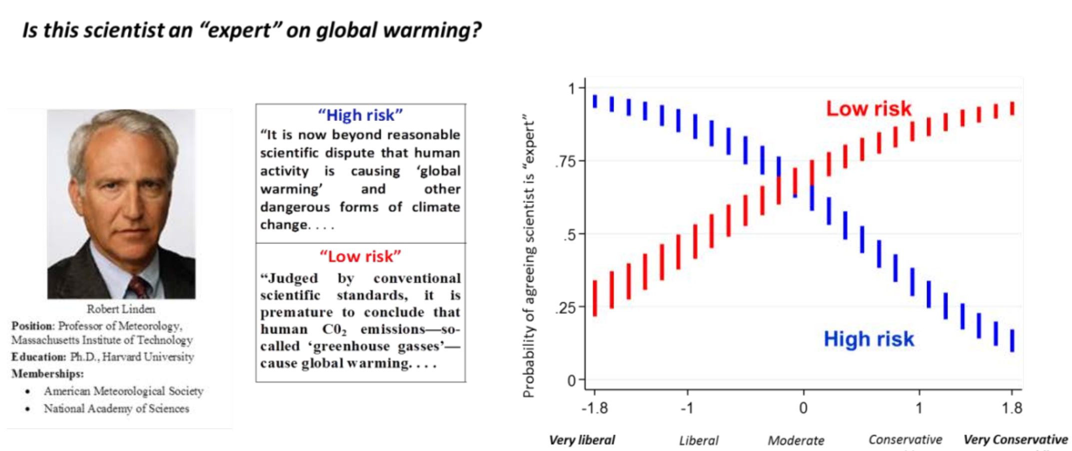

Figure 3. Biased perceptions of scientific expertise. Colored bars reflect 0.95 confidence intervals (N = 1336) [Kahan, Jenkins-Smith and Braman, 2013].

If this is how members of the public assess evidence of "expert consensus" outside the lab, we should expect members of diverse cultural groups to be polarized not just on particular risks but also on the weight of scientific opinion on those risks. In a survey component of the study, we found exactly that: subjects of diverse affiliations all strongly believed that the position that predominated in their group was consistent with "scientific consensus." In relation to National Academy of Sciences "expert consensus reports", all the groups were as likely to be right as wrong across the run of issues.

Science comprehension and polarization

PIT and CCT have also squared off face-to-face. Under PIT, one should expect individuals who are high in science comprehension to use their knowledge and reasoning proficiency to form risk perceptions supported by the best available scientific evidence. Individuals who lack such knowledge and reasoning proficiencies must "go with their gut", relying on intuitive heuristics like "what do people like me believe?" [Weber and Stern, 2011; Sunstein, 2006]. Accordingly, under PIT one would predict that as members of opposing cultural groups become more science literate and more adept at analytical reasoning — and thus less dependent on heuristic substitutes for science comprehension — they should converge in beliefs on climate change.

But the evidence refutes this prediction. In fact, the most science-comprehending members of opposing cultural groups, my colleagues and other researchers [Kahan et al., 2012; Hamilton, Cutler and Schaefer, 2012] have found, are the *most polarized* (Figure 4). This is the outcome CCT predicts. *If* people can be expected to fit their assessments of evidence to the dominant position within their cultural groups, then those individuals most adept in reasoning bout scientific data should be even "better" at forming culturally congenial beliefs than their less adept peers. This hypothesis is borne out by experiments showing that individuals who score highest on tests of one or another reasoning disposition opportunistically use that disposition to search out evidence supportive of their cultural predispositions and explain away the rest.

Pathological vs. normal cases

Scientific investigation of the science communication paradox, then, suggests that CCT furnishes a more satisfactory explanation than PIT. But it also reveals something else: such conflict — including the magnification of it by science comprehension — is *not* the norm. From the dangers of consuming artificially sweetened beverages to the safety of medical x-rays to the carcinogenic effect of exposure to power-line magnetic fields, the number of issues that do *not* culturally polarize the public is orders of magnitude larger than the number that do (Figure 5 and Figure 6).

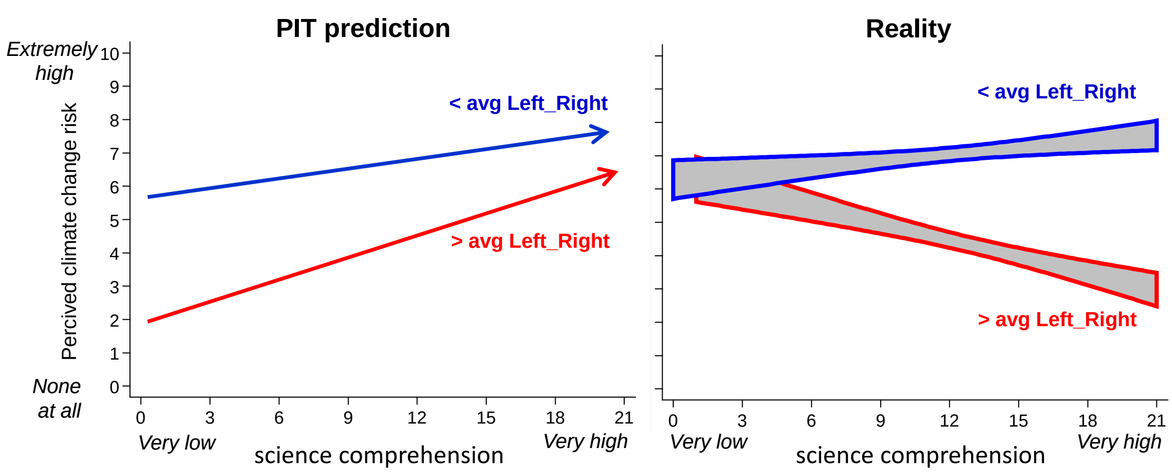

Figure 4. Polarizing impact of science comprehension on climate-change risk perceptions. Nationally representative sample (N = 1540). Shaded areas represent 0.95 confidence intervals [Kahan et al., 2012].

Members of the public definitely do not have a better grasp of the science on the myriad issues that don't polarize them than they have of the few that do. In order simply to live — much less live well — individuals need to accept as known by science much more than they could comprehend or verify on their own. They do this by becoming experts at figuring out who knows what about what. It does not matter, for example, that half the U.S. population (science literacy tests show) believe "antibiotics kill viruses as well as bacteria" [National Science Foundation, 2014]: they know they should go to the *doctor* and take the medicine she prescribes when they are sick.

The place in which people are best at exercising this knowledge-recognition skill, moreover, is inside of identity-defining affinity groups. Individuals spend most of their time with people who share their basic outlooks, and thus get most of their information from them. They can also read people "like them" better — figuring out who genuinely knows what's known by science and who is merely pretending to [Watson, Kumar and Michaelsen, 1993].

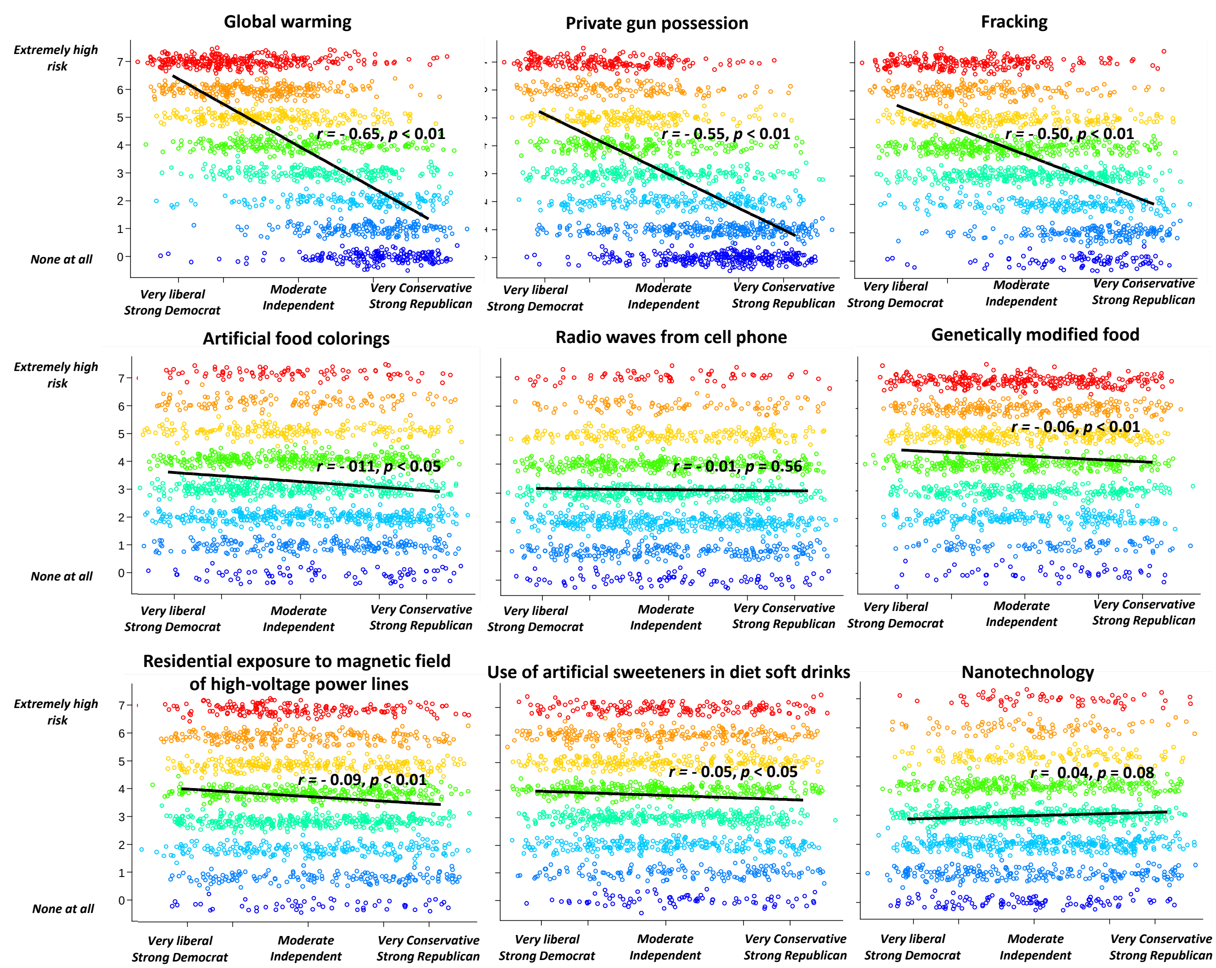

Figure 5. "Polarized" vs. "unpolarized" risk perceptions. Scatterplots relate risk perceptions to political outlooks for members of nationally representative sample (N = 1800), [Kahan, 2015].

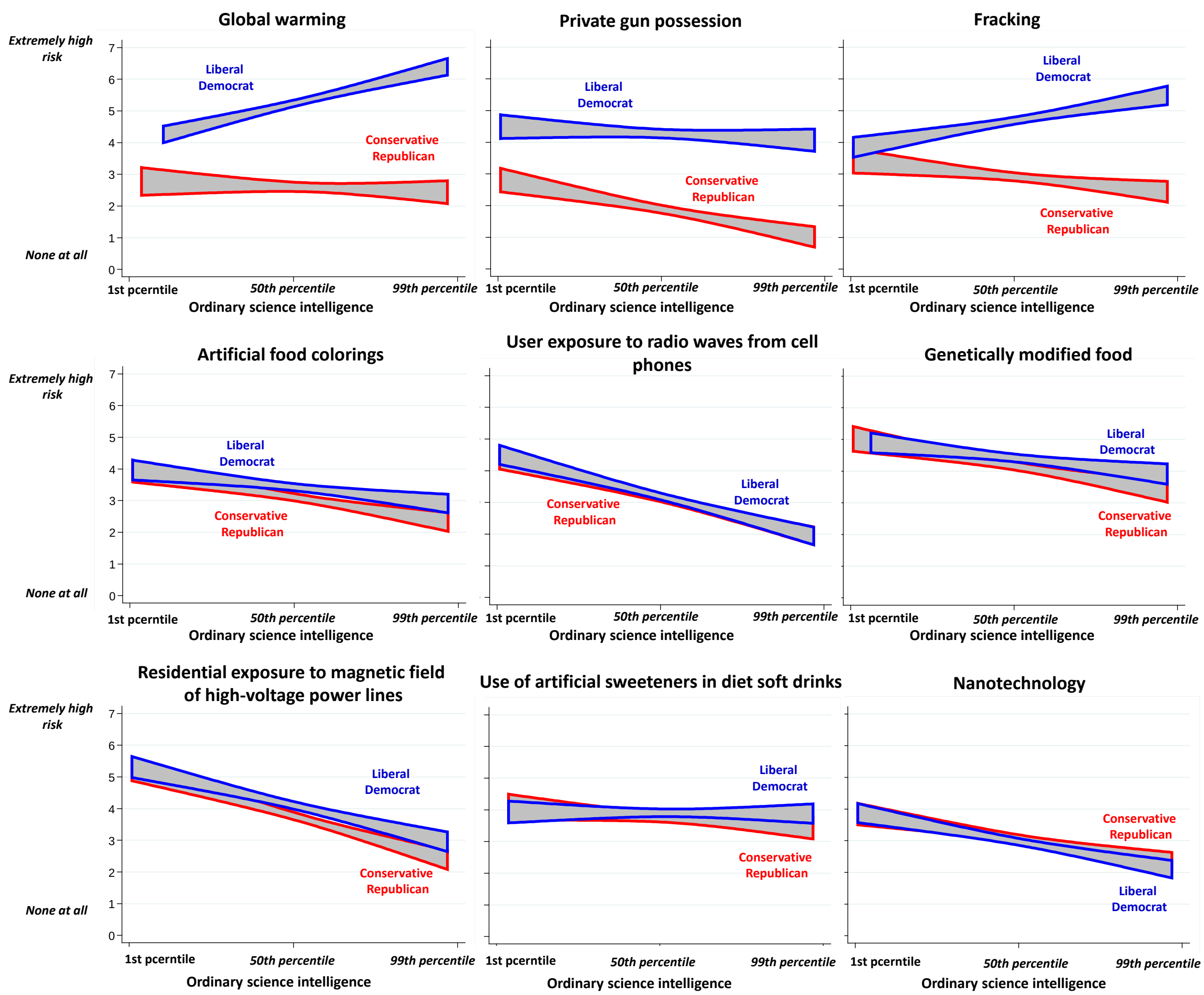

Figure 6. Science comprehension and polarization. Nationally representative sample (N = 1800), April-May 2014. Shaded areas represent 0.95 confidence intervals [Kahan, 2015].

This strategy is admittedly insular. But that is not usually a problem either: all the major cultural groups with which people identify are amply stocked with highly science-comprehending members and all enjoy operational mechanisms for transmitting scientific knowledge to their members. Any group that consistently misled its members on matters known to science and of consequence to their well-being would soon die out. Thus, ordinary members of diverse groups ordinarily converge on what is known by science.

Persistent nonconvergence — polarization — is in fact pathological. It occurs when factual issues become entangled in antagonistic cultural meanings that transform positions on them into badges of loyalty to opposing groups. In that circumstance, the same process that usually guides ordinary members of the public to what's known by science will systematically deceive them.

Popper's revenge . . .

It's no accident that the best philosophical exposition of science's distinctive way of knowing — *The Logic of Scientific Discovery* [Popper, 1959] — and one of if not *the* best philosophical expositions of liberal democracy — *The Open Society and its Enemies* [Popper, 1966] — were both written by Karl Popper. Only in a society that denies any institution the authority to stipulate what must be accepted as true, Popper recognized, can individuals be expected to develop the inquisitive and disputatious habits of mind that fuel the scientific engine of conjecture and refutation.

But as Popper understood, removing this barrier to knowledge does not dispense with the need for reliable mechanisms for certifying what science knows. What's distinctive of the Popperian "liberal republic of science" is not the absence of a social process for certifying valid knowledge but the multiplication of potential certifiers in the form of the pluralistic communities entered into by freely reasoning citizens.

Again, these communities typically will converge on what's known to science. But as the volume of knowledge and number of cultural certifiers both continue to grow, the occasions for disagreement among cultural groups necessarily increases. An expanding number of conflicts is thus guaranteed by sheer fortuity alone, although the occurrence of them can no doubt be instigated for strategic gain as well. Thus, the science communication paradox — the simultaneous increase in knowledge and conflict over what's known — is built into the constitution of the liberal republic of science. The science communication paradox is Popper's revenge.

The disentanglement principle

But as Popper also taught, there are no immutable forces at work in human history. The same tools used to fashion a scientific account of the source of the science communication paradox can be used to dispel it. The fundamental source of the paradox, empirical study suggests, is the entanglement of opposing factual beliefs with people's identities as members of one or another cultural group. It's logical to surmise, then, that the solution is to *disentangle* knowledge and identity when communicating scientific information [Kahan, 2015].

Lab experiments have been used to model this dynamic. In one, my research group tested U.S. and U.K. subjects' assessments of valid evidence on global warming [Kahan et al., 2015]. As expected, those we had first exposed to information on carbon-emission reductions were even more polarized on the validity of the global-warming evidence than were members of a control group. The images and language used to advocate carbon-emission limits triggered cultural cognition by accentuating the symbolic association between belief in climate change and conflict between groups defined by their opposing moral attitudes toward commerce, industry, and free markets.

Polarization dissipated, however, among subjects who had first been exposed to information on plans to study geoengineering. This technology resonates with the values of cultural groups whose members prize the use of human ingenuity to overcome environmental limits. By affirming rather than denigrating their cultural identities, the information on geoengineering dissolved the conflict those individuals experienced between crediting human-caused global warming and forming stances that express their defining commitments.

This lab-study insight comports with studies of "disentanglement" strategies in real-world settings. For example, research shows that standardized test questions that assess "belief" in evolution don't genuinely measure knowledge of either evolutionary science or science generally. Instead, they measure commitment to a form of cultural identity that features religiosity (Figure 7) [Kahan, 2015; Roos, 2012; Bishop and Anderson, 1990].

Consistent with this finding, education researchers have devised instructional protocols that avoid conflating students' knowledge of evolutionary science with their professions of "*belief in*" it. By disentangling acquisition of knowledge from the obligation to make an affirmation that denigrates religious students' identities, these instructional methods enable students who say they "don't disbelieve in" evolution to learn the elements of the modern synthesis — natural selection, random mutation, and genetic variance — just as readily as nonreligious students who say they "do believe in" it [Lawson and Worsnop, 1992; Lawson, 1999].

Real-world communicators have also successfully used disentanglement to promote public engagement with climate science. Members of the Southeast Florida Regional Climate Compact — a coalition of local governments in Broward, Miami-Dade, Monroe, and Palm Beach Counties — have adopted a "Regional Climate Action Plan" containing over 100 distinct mitigation and adaption measures.

As it happens, the residents of Southeast Florida are as polarized on whether human activity is causing global warming as are those in the rest of the U.S. But the deliberative process that generated the Regional Climate Action Plan didn't put *that* question; instead, officials, guided by evidence-based methods, focused, relentlessly, on how communities could *use* scientific knowledge to address the region's practical, everyday needs. The highly participatory process that led to adoption of the Regional Climate Action Plan enveloped residents with vivid, genuine examples of diverse local stakeholders — including businesses and local homeowner associations — evincing confidence in climate science through their words and actions. That *process* disentangled "what should we do with what we know", a question that unifies Southeast Floridians, from "whose side are you on", the divisive question that shapes the national climate science debate [Kahan, 2015].These examples teach a common lesson — the science communication *disentanglement principle*. To negotiate the dynamics that form Popper's Revenge, science communication professionals must protect citizens from having to choose between *knowing what's known by science* and *being who they are* as members of diverse cultural communities.

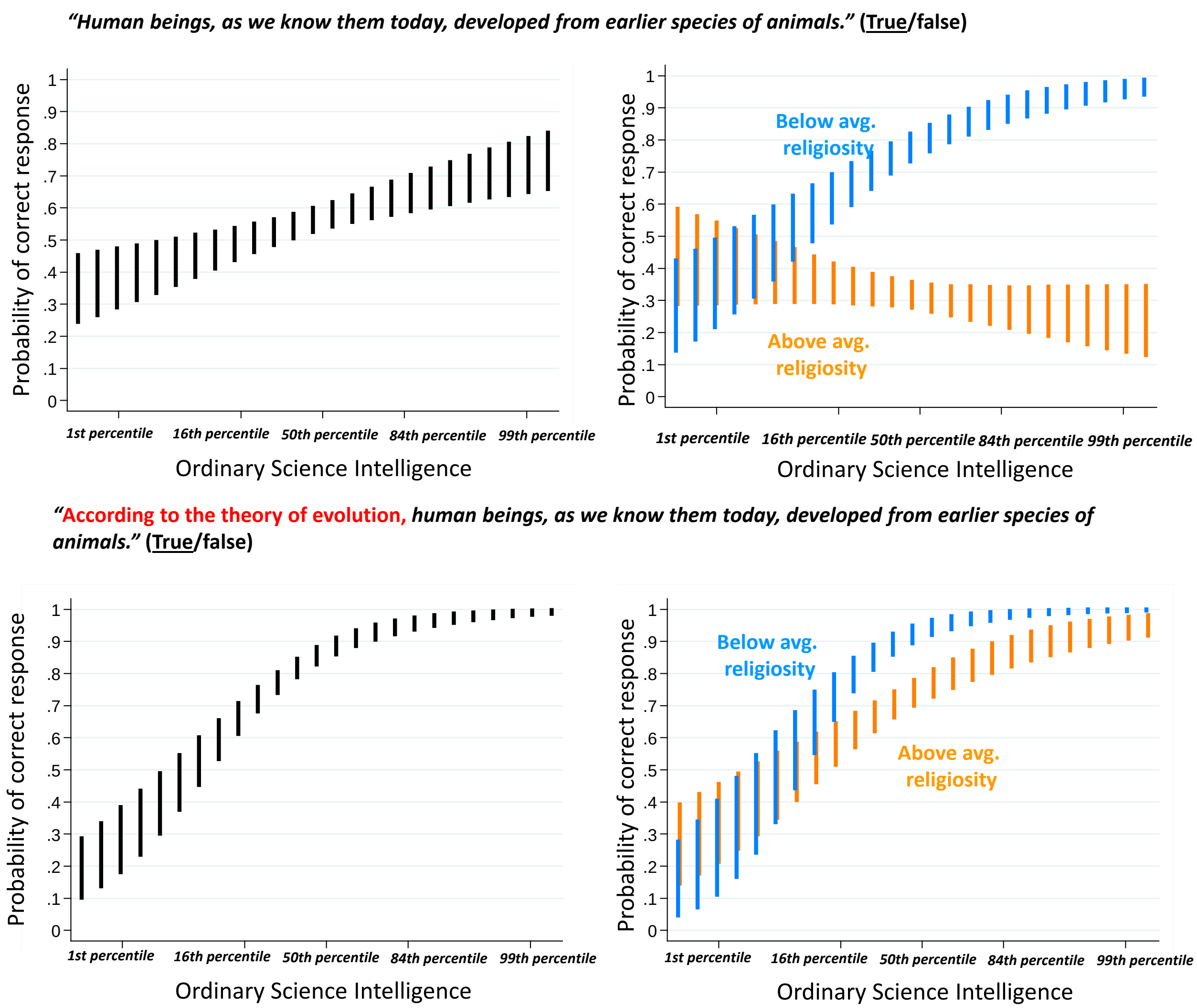

Figure 7. Disentangling identity from knowledge. Colored bars are 0.95 levels of confidence. Standardized test items on evolution generate biased results when administered to highly religious persons, but the effect can be erased by "disentangling" identity and knowledge in the item wording [Kahan, 2015].

A "new political science . . ."

But like other forms of scientific insight geared to protecting human societies from danger, the disentanglement principle cannot be expected to implement itself.

Government regulatory procedures will need to be revised, programs of education reorganized, and professional norms updated to refine and exploit the knowledge generated by the science of science communication.

Identifying the precise nature of these reforms and the means for implementing them, moreover, will likewise require *empirical* study and not mere imaginative story-telling. These were the central themes of a pair of historic colloquia on the science of science communication recently sponsored by the National Academy of Sciences in 2012 and 2013.

As aristocratic forms of government yielded to modern democratic ones in the early 19th century, Tocqueville famously called for a "new political science for a world itself quite new" [Tocqueville, Reeve and Spencer, 1838]. Today, mature liberal democracies require a "new political science", too, one suited to the distinctive challenge of enabling citizens to reliably recognize the enormous stock of knowledge that their freedom and diversity make possible.

The science of science communication *is* that new political science.

References

Bishop, B. A. and Anderson, C. W. (1990). 'Student conceptions of natural selection and its role in evolution'. *Journal of Research in Science Teaching* 27 (5), pp. 415–427.

Fischhoff, B. and Scheufele, D. A. (2013). 'The science of science communication'. *Proceedings of the National Academy of Sciences* 110 (Supplement 3), pp. 14031–14032.

Frederick, S. (2005). 'Cognitive Reflection and Decision Making'. *Journal of Economic Perspectives* 19 (4), pp. 25–42.

Hamilton, L. C., Cutler, M. J. and Schaefer, A. (2012). 'Public knowledge and concern about polar-region warming'. *Polar Geography* 35 (2), pp. 155–168.

Hastorf, A. H. and Cantril, H. (1954). 'They saw a game: A case study'. *The Journal of Abnormal and Social Psychology* 49 (1), pp. 129–134.

Kahan, D. M., Jenkins-Smith, H. and Braman, D. (2013). 'Cultural Cognition of Scientific Consensus'. *J. Risk. Res.* 14, pp. 147–174.

Kahan, D. M. (2011). 'Fixing the Communications Failure'. *Nature* 463, pp. 296–297.

— (2015). 'Climate-Science Communication and the Measurement Problem'.

Advances in Political Psychology 36, pp. 1–43.

Kahan, D. M., Braman, D., Cohen, G. L., Slovic, P. and Gastil, J. (2010). 'Who Fears the HPV Vaccine, Who Doesn't, and Why? An Experimental Study of the Mechanisms of Cultural Cognition'. *Law Human Behav.* 34 (6), pp. 501–516. DOI: 10.1007/s10979-009-9201-0.

Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D. and Mandel, G. (2012). 'The polarizing impact of science literacy and numeracy on perceived climate change risks'. *Nature Climate Change* 2, pp. 732–735. DOI: 10.1038/nclimate1547.

Kahan, D. M., Jenkins-Smith, H., Tarantola, T., Silva, C. L. and Braman, D. (2015). 'Geoengineering and Climate Change Polarization: Testing a Two-Channel Model of Science Communication'. *Annals of the American Academy of Political and Social Science* 658, pp. 192–222. DOI: 10.1177/0002716214559002.

Kahneman, D. (2003). 'Maps of Bounded Rationality: Psychology for Behavioral Economics'. *Am. Econ. Rev.* 93 (5), pp. 1449–1475.

Kunda, Z. (1990). 'The Case for Motivated Reasoning'. *Psychological Bulletin* 108, pp. 480–498.

Lawson, A. E. (1999). 'A scientific approach to teaching about evolution & special creation'. *The American Biology Teacher* 61 (4), pp. 266–274. DOI: 10.2307/4450669.

Lawson, A. E. and Worsnop, W. A. (1992). 'Learning about evolution and rejecting a belief in special creation: Effects of reflective reasoning skill, prior knowledge, prior belief and religious commitment'. *Journal of Research in Science Teaching* 29 (2), pp. 143–166.

Marx, S. M., Weber, E. U., Orlove, B. S., Leiserowitz, A., Krantz, D. H., Roncoli, C. and Phillips, J. (2007). 'Communication and mental processes: Experiential and analytic processing of uncertain climate information'. *Global Environ. Chang.* 17 (1), pp. 47–58. DOI: 10.1016/j.gloenvcha.2006.10.004.

National Science Foundation (2014). Science and Engineering Indicators. Arlington, VA, U.S.A.: National Science Foundation.

Popper, K. R. (1959). The logic of scientific discovery. New York, U.S.A.: Basic Books.

— (1966). The open society and its enemies. 5th ed. London, U.K.: Routledge and K. Paul.

Roos, J. M. (2012). 'Measuring science or religion? A measurement analysis of the National Science Foundation sponsored science literacy scale 2006–2010'. *Public Understanding of Science* 23 (7), pp. 797–813. DOI: 10.1177/0963662512464318.

Sood, A. M. (2013). 'Motivated Cognition in Legal Judgments-An Analytic Review'.

Annual Review of Law and Social Science 9, pp. 307–325.

Sunstein, C. R. (2005). Laws of Fear: Beyond the Precautionary Principle. Cambridge, U.K.; New York, U.S.A.: Cambridge University Press.

—(2006). 'Misfearing: A reply'. *Harvard Law Review* 119 (4), pp. 1110–1125.

— (2007). 'On the Divergent American Reactions to Terrorism and Climate Change'. *Columbia Law Rev.* 107 (2), pp. 503–557.

Tocqueville, A. de, Reeve, H. and Spencer, J. C. (1838). Democracy in America. New York, U.S.A.: G. Dearborn & Co.

Watson, W. E., Kumar, K. and Michaelsen, L. K. (1993). 'Cultural Diversity's Impact on Interaction Process and Performance: Comparing Homogeneous and Diverse Task Groups'. *The Academy of Management Journal* 36 (3), pp. 590–602.

Watts, D. J. (2011). Everything Is Obvious: *Once You Know the Answer. How Common Sense Fails. London, U.K.: Atlantic Books.

Weber, E. (2006). 'Experience-Based and Description-Based Perceptions of

Long-Term Risk: Why Global Warming does not Scare us (Yet)'. *Climatic Change*

77 (1), pp. 103–120.

Weber, E. U. and Stern, P. C. (2011). 'Public Understanding of Climate Change in the United States'. *Am. Psychologist* 66, pp. 315–328.