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Now what do people know about global climate change? Survey studies of educated laypeople

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Abstract

In 1992 a mental models-based survey in Pittsburgh, Pennsylvania, revealed that educated laypeople often conflated global climate change and stratospheric ozone depletion, and appeared relatively unaware of the role of anthropogenic carbon dioxide emissions in global warming. This study compares those survey results with 2009 data from a sample of similarly well-educated laypeople responding to the same survey instrument. Not surprisingly, following a decade of explosive attention to climate change in politics and in the mainstream media, survey respondents in 2009 showed higher awareness and comprehension of some climate change causes. Most notably, unlike those in 1992, 2009 respondents rarely mentioned ozone depletion as a cause of global warming. They were also far more likely to correctly volunteer energy-use as a major cause of climate change; many in 2009 also cited natural processes and historical climatic cycles as key causes. When asked how to address the problem of climate change, while respondents in 1992 were unable to differentiate between general "good environmental practices" and actions specific to addressing climate change, respondents in 2009 have begun to appreciate the differences. Despite this, many individuals in 2009 still had incorrect beliefs about climate change, and still did not appear to fully appreciate key facts such as that global warming is primarily due to increased concentrations of carbon dioxide in the atmosphere, and the single most important source of this carbon dioxide is the combustion of fossil fuels.

[1]For an example see http://www.easyjet.com/en/Environment/index.html Accessed April 15, 2010.

Keywords

Climate Change; Global Warming; Mental Models; Risk Communication; United States; Laypeople

1. INTRODUCTION

In 1992 we conducted a survey of beliefs and attitudes in the United States concerning global climate change.[1] Since that time both the public discourse, and media coverage of the issue, have changed almost beyond recognition. By 2008 climate change was at the forefront of popular media. Al Gore had starred in an Academy Award winning movie on climate change; rock stars like David Gilmour and U2 offered "carbon neutral" CDs; and marketers, auto manufacturers, and even airlines were beginning to promote their products based on their reduced effects on climate change.[1] Whereas in 1992 there was little official acknowledgement of global warming, in 2008 both U.S. presidential candidates proposed explicit policies designed to reduce or slow climate change.

The increasing political and media profile of climate change has raised awareness among many segments of the U.S. population,[2,3,4] with recent surveys confirming that most people in the U.S. today are at least minimally aware of climate change.[5,6,7,8,9] Despite widespread scientific agreement and increasing public acceptance that climate change is occurring, however, much uncertainty and confusion remains. This stems in part from the complexity of the climate system itself[10] with results from climatological modeling studies often being largely inaccessible to laypeople.[11,12,13] In this context, politicians and the mass media have become extremely important sources of information for the lay public, and for the most part, they have filled this role admirably well.[14,15,16,17] Nonetheless, both sources are not without their shortcomings. For example, to inform accurately public figures must maintain the difficult distinction between "climate" and "weather", and not fall prey to the trap of interpreting hot days as evidence for climate change, and cold days as evidence against.[18] In reality, this distinction has not been maintained,[19,20] with dramatic weather events such as the 2003 heat wave in France widely used, both by politicians and the media, as occasions to heighten the profile of climate change. Although hot weather might sometimes be attributable to global warming,[20] a general tendency to interpret weather events as evidence of climate change may hamper the development of consistent support for climate change-related policies, since it also invites people to treat the absence of extreme weather as evidence that there is no problem.[18] Media and politicians also exaggerate the level of scientific disagreement about climate change, further muddling public understanding of the problem.[21,22,23,24] As a result today, even when consensus is reached on an issue by a vast majority of scientists, scientifically-based warnings or recommendations may be misunderstood or outright rejected as politically biased by the lay populace.[25]

It is nearly a tautology to state that what people believe about climate change will influence the support they give to public policies aiming to address the problem, as well as their own climate-related behavior.[5,26,27] A growing literature on public perceptions of global warming provides some insights into what patterns of beliefs have historically prevailed.

[28,29] In the early 1990s research into mental models or "cultural" models[4,30] showed the prevalence of a "pollution model" [31], wherein a general concern about contaminated air and water in terms of both health and ecosystem impacts was driving people to respond negatively to perceived environmental "bads." Studies found that people who held a pollution mental model of global warming differentiated little between causes of climate change and many other environmental pollutants (e.g., agrochemicals).[32, 33,34] Other studies demonstrated that people commonly confused the greenhouse effect and stratospheric ozone depletion[4,30,31] and did not fully appreciate the close link between burning of fossil fuels and carbon dioxide emissions. Some study respondents believed that smoke and soot were likely causes of global warming, when in fact such particulate emissions actually have a net cooling effect.[1,4,35]

In more recent efforts to better target risk communications, researchers have begun to link different perceptions and understandings of climate change to an array of demographic and psychographic factors. Research in the United States and other high-income countries has shown that people frequently view climate change as a distant threat,[36,37] falling behind more immediate concerns such as health, family, safety, personal comforts, and finances.[5,38,39] These preoccupations may in part explain findings that people in richer countries tend to be less concerned about climate change than those in poorer countries.[40,41] Meanwhile at least one additional study has found those with more risk expertise to appear more concerned about global climate change than those with less.[42] Finally other variables such as faith, political affiliation, value/belief systems[5,42,43] and preexisting opinions on the topic[44,45] have all been linked with increased or decreased levels of understanding and concern over global warming.

Since publication of our original paper[1] other authors have advocated expanded roles for psychology in risk communication and environmental promotion[45]; however, few studies have looked in depth at mental models, to more fully characterize laypeople's attitudes and actions in the climate change arena.[46-47] In this study, we investigated if people's beliefs and attitudes in the U.S. today resemble those held in the early 1990s. We did this by asking people in 2009 exactly the same questions we asked in 1992. We found that although perceptions have changed in the decade-and-a-half since 1992, the changes are smaller than one might expect.

2. METHOD

2.1. Questionnaire

The survey instrument was the one first used by Read *et al.*[1] to validate findings from a mental models interview study.[34] Mental models are internal representations of external realities – they are the engines of inference. When individuals receive new information on a given topic, they process that new information in light of their preexisting beliefs of "how the world works." In an effort to better understand mental models of climate change in the United States, the Read *et al.* survey covered several categories of questions: (I) basic facts and definitions surrounding weather and climate processes (19 items); (II) causes of climate change (15 items); (III) effects of both the greenhouse effect and global warming (15 items); and (IV) the effectiveness of different policy responses (21 items). Initial open-ended

questions asked respondents to list the causes, effects, and policy responses they saw to be of greatest importance. Subsequent basic facts, causes, and effects questions were answered on a 5-point scale comprised of "true," "probably true," "don't know," "probably false," and "false" (abbreviated *T, ~T, ?, ~F,* and *F* in the Results section below). Policy effectiveness questions were judged on a 6-point scale consisting of "slow or stop global warming," "slightly slow global warming," "no effect," "slightly speed global warming," "speed global warming," or "don't know." Demographic questions at the end of the survey collected information on educational attainment, income, age, and residence. The 2009 survey also included four new questions on political affiliation, internet and other media use, and willingness to pay a tax to help address possible effects of climate change.[2] These questions were added at the end of the survey so they would not influence what came before.[(48)]

2.2. Respondents

The 2009 sample included 248 respondents excluding one unusable questionnaire. An initial 48 surveys were collected at a public street fair in Seattle, Washington in May, 2008; the remaining 200 surveys were collected at a public park in the city of Pittsburgh, Pennsylvania in July, 2009. To ensure comparability with the 1992 study, recruitment procedures were designed to be nearly identical across all study locations and time periods. All survey venues included a small financial incentive (a gift card for a major retail chain) for completing the questionnaire, and the researchers refrained from mentioning environmental issues or climate change during recruitment. Finally, in both the 1992 and 2009 studies the majority of respondents were recruited at Point Park in Pittsburgh on the 4th of July. Though we initially analyzed the 2008 Seattle data and the 2009 Pittsburgh data separately, the results for the two subsamples were very similar and thus, as with the two subsamples in the 1992 study, we aggregated them.[3] The combined data are referred to as "the 2009 sample" for simplicity.

The 2009 sample bears a strong demographic resemblance to the sample in the 1992 study.[(1)] Ages ranged from 18 to 92 (mean, 40; SD, 15.9). Fifty-six percent were female. Overall, respondents were well-educated: 93% had finished high school, 40% had completed college, and 25% had at least some graduate training. This level of education is much higher than the national average, where only 84% have finished high school and 27% have finished college.[4] Notably, there were relatively fewer college-educated respondents in 2009 as compared to 1992, possibly reflecting a changing demographic in Pittsburgh's Point Park visitors over the past two decades. In most respects, however, the two samples appear highly comparable.[5] Age and educational characteristics of both samples are presented in Table 1.

[2]The full questionnaire is available upon request from the authors. Findings based on the questions added to the end of the questionnaire in 2009 will be reported in a future manuscript.

[3]Education is higher in Seattle ($p=0.02$), and there are more Blacks and fewer Asians in Pittsburgh ($p<0.01$). With regard to other results, using ANOVA, the only significant differences between Pittsburgh and Seattle responses are for fossil fuel, deforestation, and tropical clearing (as causes), ecological disasters (as consequence), and stopping fossil fuel use (as response). In all cases the trend is Pittsburgh respondents are less likely to give a correct response.

[4]http://factfinder.census.gov/servlet/ACSSAFFFacts?_submenuId=factsheet_1&_sse=on Accessed January 13, 2010.

[5]We considered statistically generating a sample that would increase the average 2009 education level (i.e. over-sampling the educated respondents within the 2009 sample to create a simulated sample more comparable in terms of education level with the 1992 sample). However preliminary bivariate tests showed very few systematic differences between knowledge of causes, personal actions, knowledge of consequences, and policy support responses of college-educated versus less educated respondents, so the original 2009 sample was retained.

2.3. Data Analysis

The 2009 data were coded and analyzed in the same way as those in the 1992 study.[1] Responses to true-false questions (causes of climate change, and effects) were transformed into a degree of agreement (DA) score, ranging from 2 (complete agreement with the statement) to -2 (complete disagreement). For answers to questions about policy response strategies, a belief in effectiveness (BE) score was used, ranging from 2 (strong belief that a strategy would effectively abate climate change) to -2 (strong belief that strategy will *aggravate* climate change).[6] Because judgments of "don't know" and "no effect" could imply either that respondents do not expect an effect, that they expect an effect but do not know its direction, or that they do not have enough information to predict an effect confidently, all of these responses were assigned a value of 0. Statistically significant differences between 1992 and 2009 results were assessed in the form of a z-test for proportions for general knowledge questions (correct versus incorrect), and a two-sided t-test for changes in mean DA (causes, effects) and BE (response strategies) scores. In some cases a χ^2 test statistic was used to explore changes in the distribution of categorical responses (e.g., changes from "strongly agree" to "agree"), and ANOVA was used to distinguish between responses to groups of questions within or across time periods.

Responses to open-ended questions were classified by a trained coder based on the coding scheme used in the 1992 Read *et al.* study.[1] The 1992 coding scheme itself was based on categories from an expert model (taking the form of an influence diagram) showing scientifically established linkages among climate change causes, processes, and consequences. This model and coding scheme are described in detail in Bostrom *et al.*[34] A second coder also classified all 2009 responses to obtain a measure of inter-coder reliability. Reliability was assessed in the form of percentage agreement between raters, as reported in each results section (generally 80% or higher). The classifications discussed in the text are those made by the first coder, and generally only codes applicable to more than 5% of respondents are reported and discussed. Unless otherwise stated, claims regarding what scientists believe are derived from the 2007 report of the Intergovernmental Panel on Climate Change (IPCC).[49]

3. RESULTS

The following sections compare and contrast the results of the 1992 and 2009 surveys. For ease of presentation, 2009 results are presented in the main text or in parentheses, e.g. (98%), while 1992 results are presented in italicized brackets, e.g. *[98%]*. For a more thorough discussion of 1992 results we direct readers to the Read *et al.* paper.[1]

3.1. Has Warming Occurred, and How Much?

When we directly asked respondents "How likely do you think it is that human actions have changed global climate?" the great majority in both 1992 *[98%]* and 2009 (89%) believed it was at least somewhat likely.[7] Perhaps surprisingly – and in spite of nearly two decades of

[6]The belief in effectiveness index (BE) used here is identical to the belief in abatement index (BA) used in our 1994 paper.[1] This change in terms was made following reader comments that the similar acronyms BA (belief in abatement) and DA (degree of agreement) were confusing.

risk communications efforts, convictions that anthropogenic climate change is occurring appear to be no stronger in 2009 than in 1992, with only 33% of 2009 respondents indicating that anthropogenic climate change is "certain"*[37%]* and an additional 56% saying that it is "somewhat likely" or "very likely" *[61%]*. Furthermore, while only *[1%, or 2 people]* in the 1992 sample stated that human-induced climate change was "not likely", this increased to 9% (22 people) in the 2009 sample, with 7 respondents describing such change as "impossible" ($\chi^2(4) = 65.9$, $p < 0.001$).

Although fewer people in 2009, compared to 1992, were sure that anthropogenic global warming was likely, both groups nonetheless thought temperatures had already increased – and to a much greater degree than they actually had. Respondents were asked by how many degrees Fahrenheit global temperature had changed to date due to human actions, and also how much it would change in 10 years, and by 2050. The response format was symmetric – respondents were first asked to check a box indicating that temperature was unchanged, increased or decreased. Then, if they thought it had changed, they indicated by how much. Figure 1 presents cumulative frequency distributions of our subjects' estimates of the amount of change for all three time ranges. We converted responses to Celsius for analysis. Current IPCC estimates of global warming since the mid-1800s are in the range of 0.56 to 0.92°C.[49] Our 2009 subjects' median estimate of warming to date was 1.7°C, with a mean of 2.6°C *[median: 2.0°C, mean: 2.7°C in 1992]*. The tendency to overestimate temperature change also extended to the "10 year" and "2050" questions, as shown in Figure 1. While the IPCC estimates global temperatures will increase approximately 0.19 degrees Celsius over the next 10 years, our respondents' median estimate was nearly 8 times this value (1.5°C), and the mean estimate was over 20 times higher (3.9°C) over this same time period. Respondents' median and mean estimates of global temperature change by 2050, meanwhile, were 2 and 4 times higher than estimates produced by the IPCC. Moreover, none of these average respondent estimates have changed appreciably since 1992 ($t = 0.23$, 1.18, and 0.17 respectively). Such persistent gaps between estimates raise the important question of whether political will to address climate change will wane even if people receive accurate information – an individual expecting a 10°C increase in global temperatures, for example, may receive as "good news" (requiring no policy action) a report of new scientific findings predicting temperatures will "only" increase by 1-3°C.

3.2. Basic Processes

3.2.1. Climate Versus Weather—In their mental models interviews, Bostrom *et al.*[34] reported that many U.S. respondents had difficulty distinguishing between weather and climate. This finding was confirmed in the Read *et al.* questionnaire in 1992[1] which explored this issue with six questions. Our current findings show that, despite the greatly expanded publicity given to climate change over the past decade, many members of the public still do not understand exactly what climate is.

Respondents were first presented with two statements: a correct definition, "Climate means average weather" and an incorrect one, "Weather means average climate." Fifty-nine percent

[7]Responses were on a 5-point Likert scale including: "certain", "very likely", "somewhat likely", "not likely", and "impossible."

of the 2009 respondents agreed with the correct definition that climate means average weather *[68%]*, although 41% disagreed with it – more than in 1992 *[32%]* ($z = 1.79$, $p = 0.078$). Moreover a surprising 40% agreed with the *incorrect* definition, far more than in 1992 *[23%]* ($z = 3.57$, $p < 0.001$), and 35% of 2009 respondents agreed that "Climate means pretty much the same thing as weather," also an increase from 1992 *[22%]* ($z = 2.79$, $p = 0.005$).

A second pair of statements read "Weather often changes from year to year" and "Climate often changes from year to year." The first statement is obviously correct, and most people agreed with it (91% in 2009, *[89%]*). The second statement is incorrect, yet in 2009 over 69% of respondents agreed with it, an increase over 1992 *[42%]* ($z = 5.45$, $p < 0.001$). With regard to historic patterns of climate change, fewer 2009 respondents (67%) correctly rejected the statement that "the earth's climate has been pretty much the same for millions of years" *[78%]* ($z = 2.37$, $p = 0.028$).

This confusion between climate and weather may have important implications for public policy and risk communication. To exemplify this, we contrasted the beliefs of respondents who responded that climate means pretty much the same thing as weather (referred to as "believers") with all other respondents ("nonbelievers"). Just like those in 1992, the 2009 believers were more likely than others to (incorrectly) agree that weather is average climate (67% versus 25%; $\chi^2(1) = 42.79$, $p < 0.001$), and that climate changes from year to year (88% versus 57%; $\chi^2(1) = 24.69$, $p < 0.001$). Contrary to 1992, there was also a significant difference between believers and nonbelievers in response to the correct statement "climate means average weather" (82% versus 47%; $\chi^2(1) = 27.65$, $p < 0.001$). Thus, while in 1992 we concluded that believers had an internally consistent, although meteorologically incorrect, system of beliefs about these terms, in 2009 the belief system was no longer consistent: it appears that in 2009 respondents were even more confused than those in 1992 about the difference between weather and climate.

The distinction between believers and nonbelievers may also correspond to important market segments for risk communication. In our sample, believers were more likely to have other knowledge gaps: for example, they provided significantly fewer correct responses to the false statement "The hole in the Antarctic ozone layer is a major cause of climate change" (74% of believers as opposed to 53% of nonbelievers agreed; $\chi^2(1) = 10.51$, $p = 0.002$). They were also more likely to incorrectly assert that the space program ($p < 0.001$) and the use of nuclear power ($p = 0.003$) are major causes of climate change. Finally, believers also failed to endorse some true causes of climate change, with significantly more believers than nonbelievers responding incorrectly (or saying "Don't Know") to the true statements "Clearing tropical rainforests is a major cause of global warming" ($p = 0.017$) and "Cows, rice paddies, termites and swamps all contribute to global warming" ($p = 0.028$).

Misunderstanding of these causal relationships will have important implications for believers' support of public policies aiming to address climate change. More generally, believers' failure to recognize that climate is a statistical concept having a low correlation with individual local weather excursions such as "hot spells" may translate directly into

greater weather-related fluctuations in public concern about the climate change problem. (20,21)

3.2.2. Climate Processes—We further asked about important processes relevant to the understanding of climate change. Most people in both 1992 and 2009 correctly agreed (responded *T* or ~*T*) that the Earth's temperature is influenced by the gases in the atmosphere (86% *[93%]*) and by the sun (83% *[96%]*).[8] Both samples were also generally aware that the "greenhouse effect" occurs when the atmosphere traps heat from the sun (77% *[81%]*), and slightly more 2009 respondents agreed that the temperature of the earth is influenced by the ocean (73% *[63%]*; $z = 2.09$, $p = 0.037$). That said, relatively large percentages of respondents in both studies also believed incorrectly that climate can be affected by the phases of the moon (42% *[37%]*).

Finally, as we found in 1992, the 2009 respondents remained split over whether the greenhouse effect "keeps the earth from being as cold as outer space" (48% *[48%] T* or ~*T*; 23% *[39%] F* or ~*F*), suggesting that many people still do not recognize that the greenhouse effect is a normal process vital to human survival. Our 2009 respondents also showed limited improvement relative to 1992 in responses to questions about the global level movement of heat. Slightly more 2009 respondents agreed with the correct statement that the atmosphere carries heat from the equator to the poles (55% *[41%]*; $z = 2.75$, $p = 0.006$), but 2009 respondents were also more likely to agree with the false statement that heat moves from the poles to the equator (29% *[18%]*; $z = 2.49$, $p = 0.013$). Only 21% of 2009 respondents *[25%]* answered both questions correctly.

We also asked several questions about the climatologically important concept of albedo.[9] Cloud cover, dust suspended in the atmosphere (aerosols), and large volcanic eruptions (whose effect is to increase aerosols) all increase albedo, and these in turn *decrease* mean global temperatures. The answers to these questions indicated respondents had a weak to moderate understanding of the mechanisms of albedo (a term we did not use), and this had not changed much since 1992.

More 2009 than 1992 respondents agreed that clouds influence temperature (66% *[48%]*; $z = 3.61$, $p < 0.001$), while fewer 2009 respondents recognized that dust suspended in the atmosphere can influence temperature (65% *[83%]*; $z = -3.99$, $p < 0.001$). Even so, the 2009 sample was much more likely to agree that climate can be affected by meteor impacts (65% *[36%]*; $z = 5.80$, $p < 0.001$), which influence climate by lofting additional dust into the

[8]This sizeable increase in the share of respondents who believed that the temperature of the earth is not influenced by the sun (13%, ($z = 3.98$, $p < 0.001$)) attracted our attention. In fact, in 2009 there were 19 respondents (8% of the sample) who gave the seemingly absurd response that the temperature of the earth is *not* influenced by the sun (an additional 9% said they did not know). We considered the possibility that these respondents were not taking the survey seriously – upon closer inspection, however, it appears that these respondents may constitute a distinct group of "climate change zealots." Individuals who stated that the temperature of the earth is not influenced by the sun also consistently rejected other natural causes of climate change (meteors, clouds, the ocean), and consistently affirmed anthropogenic causes (fossil fuels, deforestation) more than the remainder of the sample. This group was also demographically distinct: members were relatively highly educated (18 out of 19 had at least some college education) and three quarters were female. One possibility is that these respondents were mistakenly associating the scientific statement "The temperature of the earth is influenced by the sun" with the political statement "Global warming is a natural process [not human-caused]." We intend to explore this in future research.

[9]Albedo is the proportion of light (or shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the Earth's surface.

atmosphere. Finally, only 54% of 2009 respondents agreed with the (correct) general statement that "the temperature of the earth is affected by whether the earth's surface is light or dark colored" – showing essentially no change from the 1992 survey *[57%]*. When taken all together, these responses suggest there has been little or no increase in public understanding of albedo.

3.3. What causes global warming?

Respondents were asked to "please list all of the things that you think of that could cause global warming." In 2009, the 248 respondents gave 577 answers to this question, which a trained coder classified into 33 categories (including small "other" and "nonsensical" categories). A total of 17 of these categories were listed by more than 5% of 2009 respondents. While 15 of these frequently-mentioned categories were analogous to categories devised by Read *et al.*[1] in 1992, an additional 2 new categories (both related to methane emissions) were evident in 2009. When the full coding scheme was used for the 2009 data, the two independent raters agreed on 78% of the classifications. Figure 2 shows the causes of climate change cited by 5% or more participants in 2009 contrasted with those from 1992.

Some important differences between the 2009 and 1992 responses stand out. First, far fewer respondents in 2009 mentioned deforestation or other loss of biomass as compared with our 1992 respondents. This is surprising given recent publicity surrounding "tree planting" as a way to achieve carbon neutrality.[49] Automobiles and industry were mentioned by more than a third of respondents, suggesting a general appreciation for these major causes of climate change (though these findings show no improvement over 1992 responses). An additional 26% of 2009 respondents mentioned fossil fuel use specifically (slightly up from 1992), and methane was much more prominent in 2009 respondents' mental models, with fully 10% listing either landfills or agriculture as major causes of global warming *[0%]*. At the same time, however, non-anthropogenic causes of climate change were even more frequently cited – nearly 18% of 2009 respondents implicated natural causes (solar flares, changes in the Earth's axis) as primary drivers of global warming *[14%]*.

Finally, CFCs were mentioned by only 5.5% of the 2009 respondents, compared to 20% in 1992. This appears to reflect a reduced degree of confusion between climate change and stratospheric ozone depletion – CFCs are a cause of both, but it is likely that many in the 1992 sample listed CFCs because they knew its role in ozone depletion.[1] In line with this view, other ozone-related issues were mentioned by very few respondents in 2009. Ozone layer depletion itself was mentioned by 3% of respondents (down far from 1992 *[27%]*), although several respondents still mentioned aerosol cans as a cause of climate change (10% *[26%]*).

Following the open-ended question, we asked 12 closed-form questions about causes of global warming. These confirmed that our 2009 respondents had a better grasp of some, but not all, major causes of climate change. The mean Degree of Agreement (DA) for the true statement "Cows, rice paddies, termites, and swamps are causes of climate change" was higher in 2009 (0.16 *[-0.04]*; $t = 2.16$, $p = 0.012$), while the DA for the false statement "Aerosol spray cans are causes of climate change" was lower (0.67 *[1.16]*; $t = 3.67$, $p <$

0.001). Nevertheless even in 2009 many respondents still agreed (incorrectly) that tropospheric ozone pollution in cities (mean DA = 0.99, with 72 % *T* or ~*T*) and the hole in the Antarctic stratospheric ozone layer (mean DA = 0.62, 60% *T* or ~*T*) were major contributors to global climate change, suggesting that while ozone-based explanations for climate change may no longer be at the front of people's minds, such misperceptions still persist. Figure 3 summarizes the results of the 12 closed-form questions, rank ordered by mean DA scores (according to 1992 rankings).

3.3.1. Responsible Countries—We asked whether three countries were among the top five nations contributing to global warming: China, currently the largest contributor of greenhouse gases; the United States, now ranked a close second; and Bangladesh, a relatively insignificant source of greenhouse emissions. Our respondents' beliefs were roughly in line with these true rankings, but not entirely. In 1992 the mean DAs for these three countries all differed significantly, with the U.S. squarely at the top (true at the time), Bangladesh clearly at the bottom (also true), and China in between (though 1992 respondents perhaps underestimated China's contribution to global greenhouse emissions). In 2009, the mean DA for the United States was 1.25, a slight but non-significant decrease from 1992 *[1.40]*, and that for China was 1.11 – dramatically up from 1992 *[0.55]* ($t = 5.04$, $p < 0.001$). There was no significant difference between the 2009 mean DAs for these two countries ($p = 0.401$), and given that China only recently surpassed the U.S. as the world's largest emitter of greenhouse gases (in 1992 the U.S. was number 1 by far), this set of findings makes some sense. More surprisingly, however, most 2009 respondents were uncertain about the degree to which Bangladesh was a major contributor to global warming – the mean DA was 0.03 (corresponding to an average response of "Don't Know"), up from in 1992 *[-0.45]* ($t = 3.87$, $p < 0.001$). The 2009 DA for Bangladesh was still significantly lower than the DAs for China or the U.S. ($F(2, 741)=83.38$, $p < 0.001$). However the fact that 2009 respondents were unable to distinguish between major greenhouse gas emitters (China, the U.S., Russia, India, and Japan are the true "top 5") and a smaller developing country like Bangladesh may indicate an increased desire to "share the blame" for global warming. U.S. citizens appear to have internalized the widely publicized message that large developing countries such as China and India are major contributors to the greenhouse effect, but they may be erroneously generalizing this understanding to the Southeast Asian region as a whole, or to developing nations in general.

3.3.2. Personal Responsibility—Respondents were asked whether there was anything that they "personally do that might contribute to global warming," and, if so, to indicate "What things that you do were you thinking about?" Of the 70% *[75%]* who answered "yes" to the first question, many apparently misunderstood it, because 29% offered suggestions typically considered to *reduce* climate change (e.g., "drive less", etc.).[10] The remaining 120 respondents who we judged to have understood the question produced a total of 278 responses (mean = 2.32 responses per respondent), which were classified into 12 response

[10]This was also a problem in 1992, with *[34%]* reporting such suggestions for combating global warming – this may simply reflect confusion over the question, or it may reflect a preference among respondents in both periods to answer the "easier" question of what they do to combat climate change, as opposed to the more personally difficult (and potentially guilt-laden) question of how they contribute to the problem.

categories, with 5 new categories in 2009 and an inter-rater agreement of 88%. Figure 4 presents the categories mentioned by at least 5% of respondents.

Consistent with their responses to the general causation questions, respondents in 2009 frequently mentioned driving and waste generation, with 9% explicitly characterizing their own consumption or waste generation as "excessive." Again largely absent from the 2009 open-ended responses was the use of aerosol cans (only 5 respondents mentioned aerosol cans at all), which figured far more prominently in the 1992 responses *[38%]*. Several of the 2009 respondents also stated that their own "existence" contributed to global warming – for example, one respondent stated simply "I live," while two others wrote "I eat" and "body heat." Finally, although many respondents saw deforestation as a primary cause of global warming, none mentioned their own use of wood or paper products as contributing to global warming, while some had in 1992 *[7%]*.

3.4. Consequences

Figure 5 reports responses to closed-form questions about possible consequences of global warming. The DA scores differed significantly among one another ($F(13,3446) = 15.04$, $p < 0.001$, HSD = 0.073), suggesting our respondents were distinguishing different sorts of climate change consequences. But we note that many respondents affirmed both realistic statements predicting disastrous consequences of global warming, including "agricultural problems and starvation in many places" (mean DA = 1.03) and ''ecological disasters" (mean DA = 0.95) as well as unrealistic "consequences" of climate change, such as "increased incidence of skin cancer" (mean DA = 0.66, with fully 57% *T* or ~*T*). Ultimately, as we asserted in Read *et al.*[1], we suspect that people are predisposed to view *any* future ecological or political disaster as a plausible consequence of climate change.

One ecological disaster that has been the topic of widespread debate is rising sea levels. Respondents generally agreed that sea-level rise is one result of global warming. Many scientists expect thermal expansion of the oceans to be a large contributor to this sea level rise, though many respondents in Bostrom *et al.*'s 1992 qualitative study[34] cited only melting glaciers and ice caps. In the closed-form questionnaires, respondents in both our 1992 and 2009 surveys agreed that "the primary cause of sea-level rise" would be ice melting at the poles (mean DA = 1.13*[1.14]*). However, more respondents in 2009 acknowledged the role of heating of the ocean's waters as compared to in 1992 (mean DA = 0.42*[-.22]*; $t = 2.33$, $p = 0.020$), suggesting increased understanding of this issue. Finally, it is interesting to note that while 1992 respondents generally rejected the possibility that climate change would cause New York City to be flooded, 42% of 2009 respondents stated that it was true or probably true that global warming will cause the ocean to flood all of the city of New York. This rise in concern may be the result of widely publicized apocalyptic scenarios, both in the media and even in academic journals.[50]

3.5. Response Strategies

3.5.1. What Can You Do?—In response to the open-ended question, "If you personally decided to help prevent global warming, what are the most effective actions that *you* could take?" 213 respondents offered a total of 403 potential actions (mean = 1.9 responses per

respondent). Responses were classified into 13 categories (including 4 new categories in 2009), with an inter-rater agreement of 80%. Figure 6 summarizes the responses given by respondents in 2009, contrasted with 1992.

Consistent with their other responses about causes (Figures 2-3) and personal contributions to climate change (Figure 4), our 2009 respondents most frequently proposed cutting back on their driving to combat global warming. This was followed by recycling (mentioned by 29% of respondents); both strategies that were also prominently cited in 1992. However, in contrast to 1992 when only a small fraction *[11%]* of respondents suggested that they could reduce their energy consumption (the most effective personal response to limit climate change), in 2009 saving energy placed third in terms of personal global warming mitigation strategies and was mentioned by 25% of respondents. Perhaps not surprisingly, 11% of 2009 respondents specifically mentioned "purchasing a hybrid car" as something they could do to address climate change (not mentioned in 1992). Another difference was relatively fewer respondents suggested that they could pursue political actions. This is in contrast to 1992, when many respondents proposed political activities such as voting, writing to legislators, and becoming active in legislation as strategies they could undertake to address the problem. Finally, while the 1992 study saw frequent references to the need to increase *personal* awareness (perhaps suggesting respondents were not comfortable with their own knowledge of climate change), in 2009 only 3% of respondents stipulated a need to raise awareness of climate change issues.

3.5.2. What Can the Government Do?—In response to the open-ended question, "If the United States government decided to try to prevent global warming, what are the most effective actions that it could take?" 223 of our 2009 respondents produced 500 responses (mean = 2.24 per respondent). In total, 14 scoring categories were devised (including 2 new categories in 2009), with an overall inter-rater agreement of 88%. Figure 7 shows those most frequently mentioned by 1992 and 2009 respondents.

The most frequently mentioned actions were responses to the frequently mentioned causes of global warming from the previous section. Automobile use, pollution, fossil fuels, and industry were at the top of the list of causes of global climate change (Figure 2), and the top solutions were to reduce automobile use, promote alternative energy, reduce pollution/ increase recycling, and reduce industry emissions in order to combat climate change (Figure 7). This is in contrast to 1992, when "protect biomass" *[34%]* followed by "stop or limit pollution" *[31%]* were the most cited recommendations for government. Indeed, the proportion of respondents mentioning biomass protection is substantially lower in 2009 (7% *[34%]*). Thus it appears that concern over biomass may have waned as other concerns have moved higher up on the public agenda. For example, Figure 7 shows roughly twice as many 2009 respondents mentioned alternative energy as compared to 1992. At the same time, while in the 1992 study no one mentioned specific policies such as carbon taxes or CAFE standards (for increasing automobile fuel efficiency), in the 2009 study both of these policies were cited by 5% or more of respondents. Finally, more than 12% of 2009 respondents advocated for environmental legislation on climate change, and 7% called for government reform or strong industrial regulation as key steps towards addressing global warming.

3.5.3. Closed-Form Questions about Response Strategies—For the closed-form questions about response strategies, respondents evaluated 21 possible strategies for addressing global warming, which were chosen to vary widely in feasibility.[11] Figure 8 rank orders these abatement strategies by mean belief in effectiveness (BE). These mean BE scores differed significantly among themselves ($F(20,5161) = 25.92$, $p < 0.001$, HSD = 0.06).

There was a great deal of similarity in the ratings of these strategies by the 2009 and 1992 samples. The ranks were correlated 0.89, and the mean BE scores themselves were correlated 0.94. Just as in 1992, a majority of the 2009 respondents judged all but 4 of the 21 strategies to be effective (that is, more than half stated that the strategy would "slow" or "probably slow" global warming). In both time periods the main exceptions (those where the BE for more than half of the sample was 0 or less) involved geoengineering. Fertilizing the ocean (mean BE = 0.38 *[0.33]*) and making more clouds high in the atmosphere (mean BE = 0.24 *[0.35]*), though scientifically plausible abatement strategies, were roundly rejected in both 1992 and 2009. Similarly, well over half of respondents thought the strategy of putting dust in the stratosphere would negligibly impact climate change or, possibly, worsen it (mean BE = -0.07 *[-0.39]*), though the negative reaction to this controversial strategy was less extreme than in 1992 ($t = 2.94$, $p = 0.015$). Finally, most respondents correctly rejected the notion than stopping the space program would slow climate change. These results again, however, do not suggest learning in the broader public, as similar results were obtained in 1992.

At the opposite extreme, planting trees was judged to be among the most effective strategies by both the 1992 and 2009 samples, although it received significantly less support in 2009 (mean BE = 1.09 *[1.29]*; $t = 2.61$, $p < 0.001$). This was followed closely in 2009 by the relatively general strategy of reducing fossil fuel use (mean BE = 1.03), which was also rated highly in 1992 *[1.15]*. More specific strategies to achieve reduced fossil fuel use, however, (such as switching to natural gas or nuclear power) received only modest endorsement in both time periods. And interestingly, the general strategy of adopting all known energy conservation measures – the highest rated strategy in 1992 – received much less support in 2009 (mean BE = 0.96 *[1.41]*; $t = 5.25$, $p < 0.001$). This decrease might reflect a popular misconception that the low-cost gains from industrial and household energy conservation have already been realized. But then again, one of the most significant *increases* in mean BE scores was for switching to energy-efficient lighting: in 2009 a large majority judged the use of efficient lighting to be an effective climate change mitigation strategy (mean BE = 0.86 *[0.67]*; $t = 2.67$, $p < 0.001$), presumably reflecting the influence of the greatly expanded publicity and availability of compact fluorescent and other low-energy bulbs on consumers, even while broader energy conservation strategies have lost some popular appeal.

[11]Note that the feasibility of some strategies has changed since the early 1990s – the widespread use of hybrid automobile technology may have rendered "Switching to electric cars" more feasible, for example. Another item on the closed-form questionnaire, "Banning CFCs" has already been done in the U.S.

Finally, although banning CFCs (mean BE = 0.72 *[1.02]*; t = -3.59, p < 0.001) and stopping the use of aerosol spray cans (mean BE = 0.82 *[1.09]*; t = -3.46, p = 0.001) were judged less effective strategies by 2009 respondents than 1992, many in the 2009 group still believed that climate change could be reduced by such ozone-related abatement strategies. Stopping the use of aerosol cans in the United States and preventing the release of coolant fluids were each supported by roughly 2/3 of the sample (65% and 67% respectively), and even switching from Styrofoam cups and plates to paper was generally thought to have a positive effect by 58% of respondents. All of these erroneous beliefs from 1992 persist in 2009.

4. Discussion

Laypeople in 1992 displayed a variety of misunderstandings and confusions about the causes and mechanisms of climate change.[1] When we re-administered the same survey in 2009 we found evidence of better understanding of some issues – including key climate change causes – and reduced confusion about the relationship between ozone depletion and climate change. But overall we found that laypeople's mental models now have changed surprisingly little since 1992. This finding of few major differences in beliefs between the two groups, 17 years apart, is all the more noteworthy.

In both time periods we observed widespread acknowledgement of both anthropogenic and natural sources of greenhouse gases, and of many agricultural, ecological, and weather-related impacts of global warming; yet we also found persistent support for erroneous assertions such as climate change being caused by lunar cycles and for qualitatively incorrect predictions that global warming will lead to increased skin cancer levels. Indeed, even those responses that have substantially changed since 1992 do not necessarily reflect increased understanding of climate change issues: for example, since 1992 one of the main shifts in ozone-related beliefs was that relatively fewer 2009 respondents thought that "banning the use of CFCs" would reduce global warming – but this may merely reflect respondents' knowledge that CFCs have already been eliminated from most consumer products. Similarly, the main shift in beliefs surrounding energy-related strategies to combat climate change was an increased support for the use of energy-efficient lighting – but it should be pointed out that energy-efficient lighting was a less viable consumer option in 1992.

Undoubtedly, some of the survey questions were difficult for laypeople. However, they all addressed issues that are important for even a rudimentary scientific understanding of climate change. Ultimately, it appears that despite 17 years of debate around the subject of climate change, public understanding has not advanced appreciably.

4.1. Good Environmental Practice

In a final set of analyses, following our technique in Read *et al.*[1] we divided both the causes and the abatement options into two dichotomous categories according to (a) whether they reflected good environmental practice and (b) whether they were plausibly related to global warming. Figure 9 presents these partitions according to "good environmental practice" and "plausible" categorizations in 1992. (We note that some of these categorizations have changed in 2009; this point is discussed further below). The top half of

Figure 9 shows that respondents were likely to agree with causes that both constitute poor environmental practice and are scientifically plausible. However, they also implicated implausible causes that we classified as poor environmental practices. Similarly, in the lower half of Figure 9, the strongest endorsements for strategies to address climate change were for strategies that were good practices, regardless of scientific plausibility.

We regressed the mean DAs (mean Degree of Agreement for causes) and mean BEs (mean Belief in Effectiveness for abatement) onto these two categories ("plausible" and "good practice"). For both analyses, the two predictors were coded as dummy variables as indicated in Figure 9 (e.g., "clearing tropical rainforests" was assigned a code of 1 for plausibility and 0 for good environmental practice). The resulting regression equations are as follows:

$$\text{mean DA(causes)} = 0.60 - 1.0(\text{good practice}) + 0.49(\text{plausible}) \quad \text{(Equation 1)}$$

$$\text{mean BE(effectiveness)} = 0.32 + 0.55(\text{good practice}) + 0.02(\text{plausible}) \quad \text{(Equation 2)}$$

The proportion of the variance accounted for by the mean DA equation (Equation 1, for causes) was very high and statistically significant ($R^2 = 0.97$; $F = 158.2$, $p < 0.001$). Both plausibility ($t = 9.4$) and good practice ($t = 15.1$) contributed significantly to the prediction. The mean BE equation (Equation 2, for effectiveness of abatement strategies) was also statistically significant but with a lower R^2 ($R^2 = 0.67$; $F > 18.0$, $p < 0.001$). Good practice accounted for a significant amount of the mean BE variance ($t = 5.8$), but plausibility was not a significant predictor of mean belief in effectiveness ($t = 0.29$).

To compare, the regression results from Read *et al.*[1] are reproduced below:

$$[\textit{mean DA}(\textit{causes}) = -0.64 - 1.35(\textit{good practice}) + 0.55(\textit{plausible})] \quad \text{(Equation 3)}$$

$$[\textit{mean BE}(\textit{effectiveness}) = 0.23 + 0.78(\textit{good practice}) + 0.06(\textit{plausible})] \quad \text{(Equation 4)}$$

In 1992, for causes (Equation 3) both plausibility *[t = 5.88]* and good practice *[t = 3.00]* contributed significantly to the prediction (as in 2009). Meanwhile, for effectiveness of abatement strategies (Equation 4), good practice accounted for a significant amount of the mean BE variance *[t = 5.45]*, but plausibility did not *[t = 0.42]*, also consistent with our 2009 findings. As we concluded in Read *et al.*[1] these results suggest some of our respondents' correct beliefs may have been "right for the wrong reasons" – while lay respondents in both 1992 and 2009 gave responses that were consistent with an in-depth understanding of climate change processes and potential mitigation strategies, it was also possible that poorly informed respondents were making fortuitously correct inferences from what they saw as good environmental practices.

We noted however that some abatement strategies have become more or less plausible since 1992: banning CFCs has already been done and is thus an implausible abatement strategy in 2009; electric cars on the other hand are now clearly a plausible way to reduce greenhouse gas emissions from transportation. We therefore recoded banning CFCs as "implausible abatement" and electric cars as "plausible abatement" and re-ran the regressions. As shown below, even with these modifications the results are largely consistent with the previous discussion.

$$\text{mean BE} = 0.22 + 0.78(\text{good practice}) + 0.07(\text{plausible2009}) \quad \text{(Equation 5)}$$

$$\text{mean BE} = 0.32 + 0.55(\text{good practice}) + 0.02(\text{plausible1992}) \quad \text{(Equation 2)}$$

$$[\textit{mean BE} = 0.23 + 0.78(\textit{good practice}) + 0.06(\textit{plausible}1992)] \quad \text{(Equation 4)}$$

The revised 2009 regression (Equation 5) is statistically significant ($R^2 = 0.63$; $F = 15.28$, $p < 0.001$), and the variable "plausible2009" has a slightly larger coefficient than "plausible 1992" (in Equation 2). But even after accounting for the new plausibility of some mitigation strategies in 2009, the effect of plausibility on mean belief in effectiveness remains statistically insignificant ($t = 0.55$). Indeed, the coefficients for both plausibility and good practice ($t = 5.47$) in the revised 2009 regression show virtually no change from 1992 (Equation 4). These additional analyses demonstrate again that environmental "good practice" explains far more of the variability in beliefs about climate change mitigation strategies than does plausibility, in 2009 just as it did in the past.[12]

5. Conclusion

We argued in Read *et al.*[1] that two facts are essential to understanding the climate change issue:

1. If significant global warming occurs it will be primarily the result of an increase in the concentration of carbon dioxide in the earth's atmosphere.

[12]In subsequent regression analyses not reported here we used *individual*-level BE scores as a dependent variable (as opposed to the *mean* BE scores used here and in Read *et al.*), thus allowing us to control for individual-level covariates including income, education, and location. These individual-level regressions, not surprisingly, displayed comparatively low adjusted R^2 values (ranging from $R^2 = 0.07$ to 0.11), suggesting that additional factors – such as specific mental models, belief systems[5,42,43] and preexisting opinions on the topic[44-46] – substantially shape what people think about strategies to address climate change. As for covariate effects, earning more than $50,000 per year had no discernible impact on individual BE scores, nor did having a college education ($p > 0.206$). However survey location did have a significant effect: specifically, Seattle respondents were likely to give somewhat higher BE scores than Pittsburgh respondents as a function of both good practice ($t=2.89$, $p < 0.001$) and plausibility ($t=2.57$, $p<0.001$). These interactions ultimately suggest that Seattle respondents were in general more predisposed to favor any proposed climate change mitigation strategy, whether effective or not. That said, the adjusted R^2 values are nearly identical between the equations that allow coefficients to vary by location and the corresponding equations that don't – thus adding location provides little additional predictive power, supporting our decision to combine the data for most analyses. Moreover, even after controlling for location, "good practice" still consistently explains far more of the variability in individual BE responses than does plausibility. Nevertheless, future research might more explicitly examine when and where location-specific risk communication strategies might be appropriate.

2. The single most important source of carbon dioxide in the earth's atmosphere is the combustion of fossil fuels, most notably coal and oil.

The relatively well-educated laypeople we surveyed in 1992 did not have a clear understanding of these facts. Instead, their mental models of the climate issue were encumbered with many secondary, irrelevant, and incorrect beliefs. In that paper we argued that risk communications designed to help laypeople participate in ongoing national debates on this topic were unlikely to be effective without stressing these two simple facts and their implications. Our findings from administering an identical survey in 2009 suggest some changes have occurred. Compared to people in 1992, our 2009 respondents were more familiar with a broader range of causes and potential effects of climate change, and were less likely to conflate climate change and stratospheric ozone depletion. It is therefore tempting to infer that U.S. laypeople's mental models in 2009 are “better” – in the sense that people today know more about climate change causes and processes (including 1 and 2 above), and may therefore be relatively more able to incorporate new information into coherent and scientifically accurate internal representations of how climate change works. Nevertheless even in 2009 some potentially problematic misconceptions remain.

Both the United States and the rest of the world are currently considering policy responses to the issue of climate change that would entail costs and expenditures amounting to trillions of dollars. Democratic debate on climate-related policy choices is likely to increase and improve as lay mental models become better informed. Rather than targeting laypeople with deluges of new and potentially overwhelming information, therefore, simple steps, such as better differentiating between weather and climate in news reports and political commentary, may help clarify what climate is – and thereby better inform lay beliefs surrounding what human activities influence climate change (and what policies might plausibly mitigate it). The clarifications needed to produce better public understanding appear to be well within the capabilities of modern risk communication,[51,52,53,54] but they will require concerted efforts on the part of researchers, politicians, and the media to listen to lay perspectives and respond in such a way that their communications support effective decision making.

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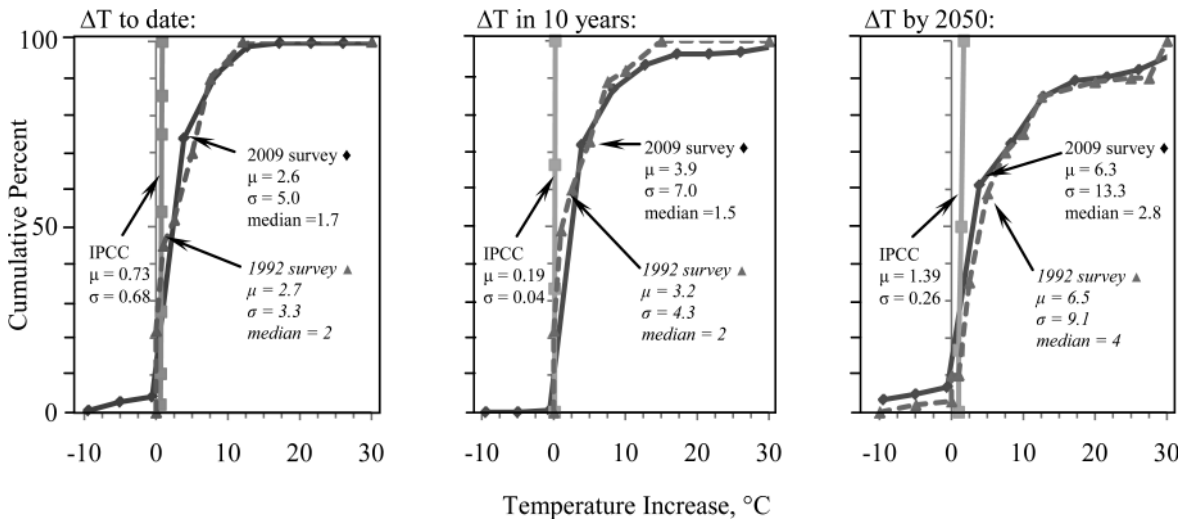

Fig. 1.

Cumulative distributions of respondents' point estimates of the amount of warming in degrees centigrade that has occurred to date (left), will occur in 10 years (center), or will occur by the year 2050 (right), compared with a distribution we derived making plausible assumptions about IPCC consensus estimates.[49]

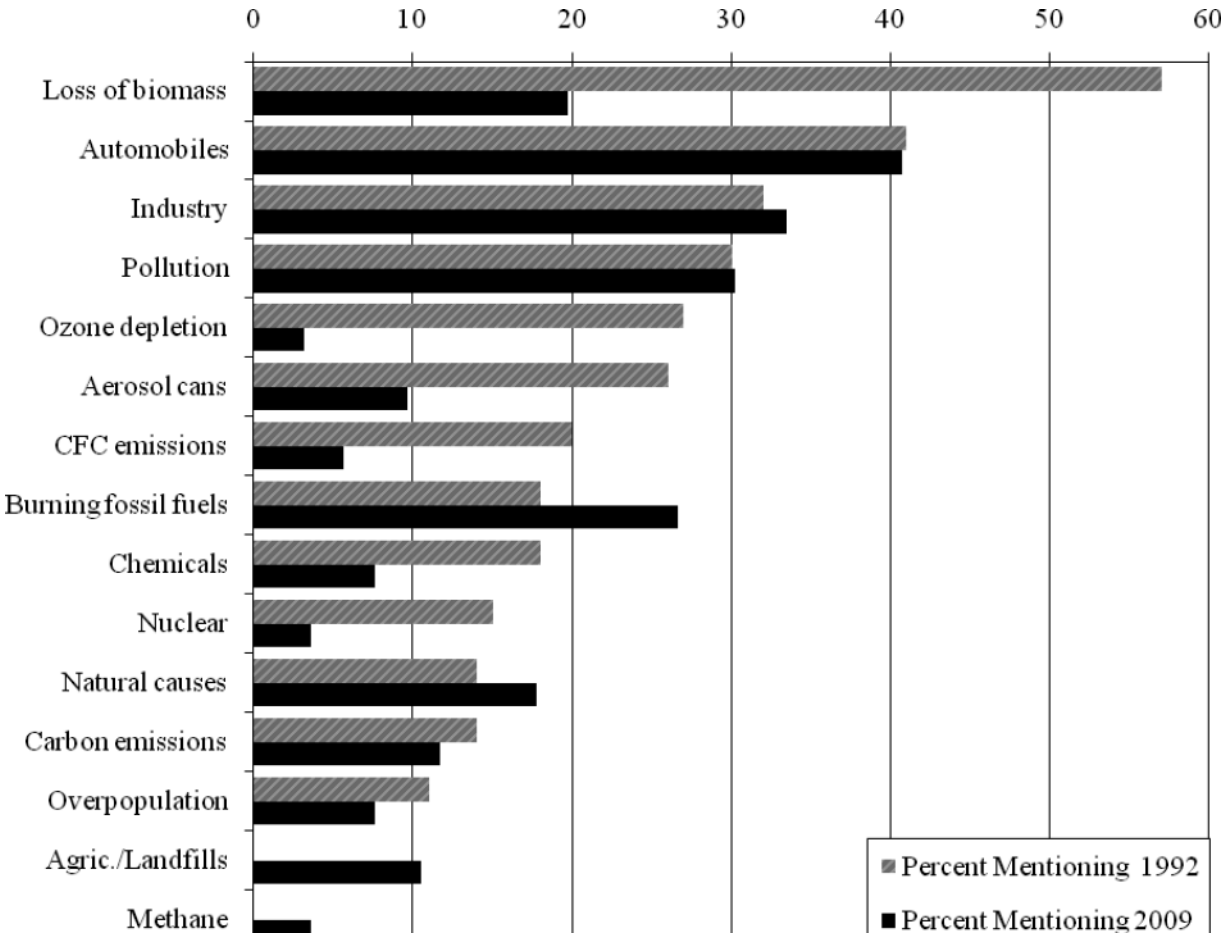

Fig. 2.

Most Frequently Mentioned "Things" that "Could Cause Global Warming": Responses Provided to an Open-Ended Question that Asked for a List

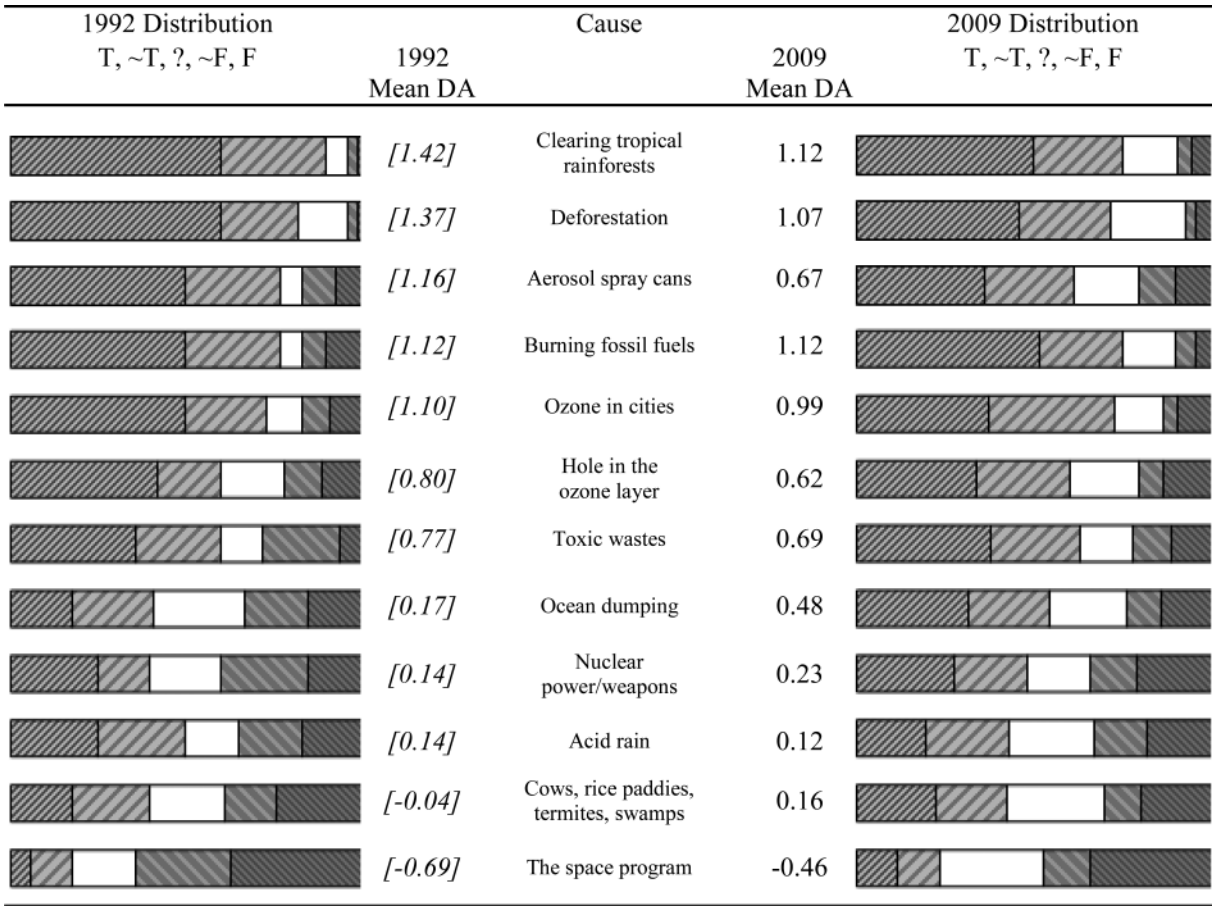

Fig. 3.

Responses to closed-form questions about causes of global warming, rank-ordered by mean Degree of Agreement (DA) index for 1992. The full distribution of responses for 1992 is on the left; the distribution for 2009 is on the right. The mean DA indices are strongly positively correlated between the two time periods (r=0.95). T means true; ~T means probably true; ? means don't know; ~F means probably false; F means false.

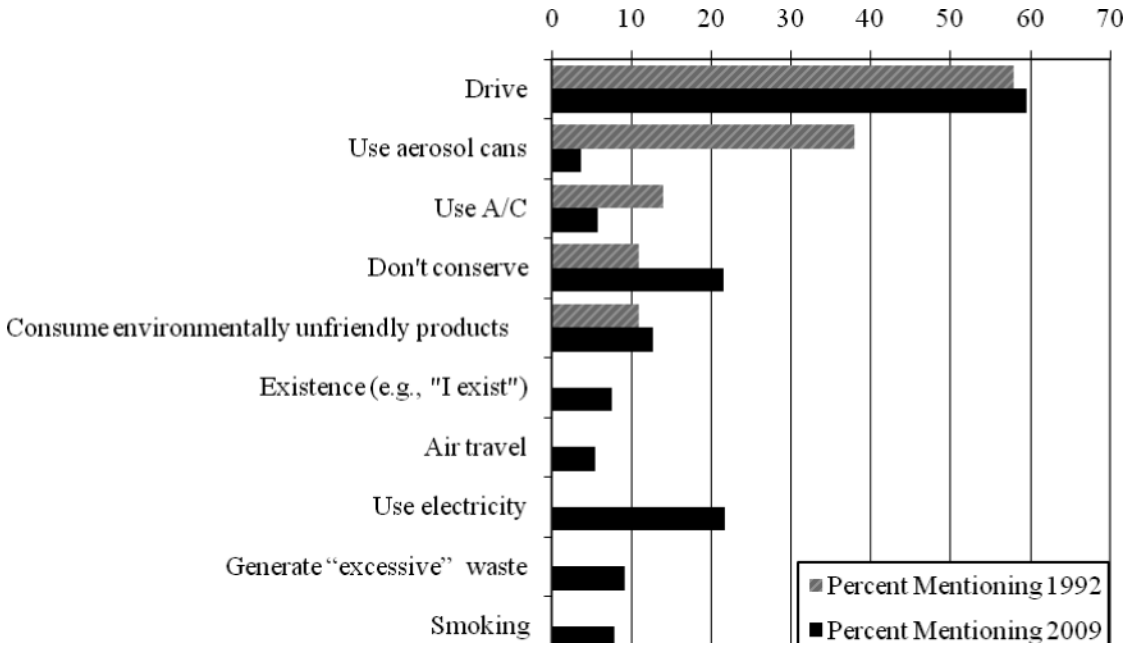

Fig. 4.

Behaviors Most Frequently Cited as "Things" Respondents Do that "Could Contribute to Global Warming": Responses Provided to an Open-Ended Question that Asked for a List

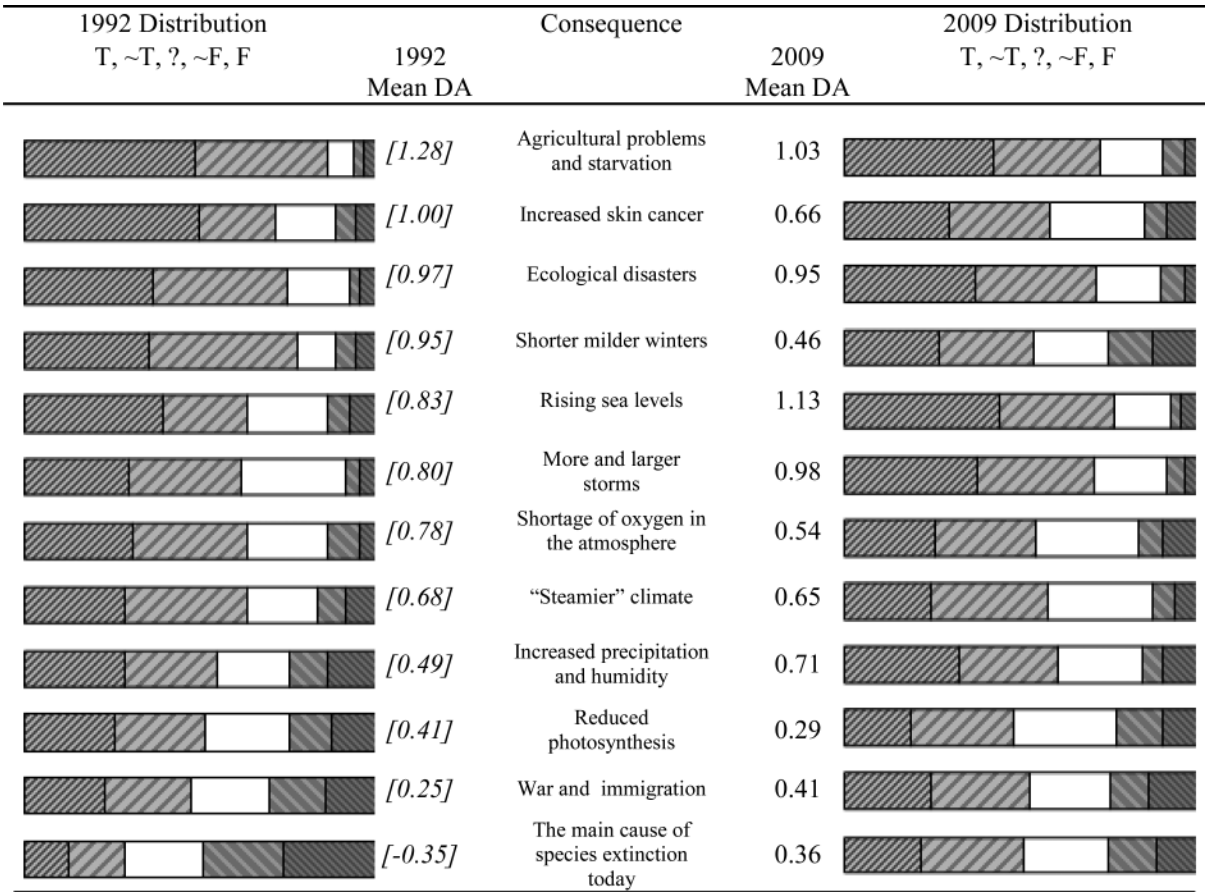

Fig. 5.

Responses to closed-form questions about consequences of global warming, rank-ordered by mean DA index for 1992. The full distribution of responses is displayed in the shaded bars. T means true; ~T means probably true; ? means don't know; ~F means probably false; F means false.

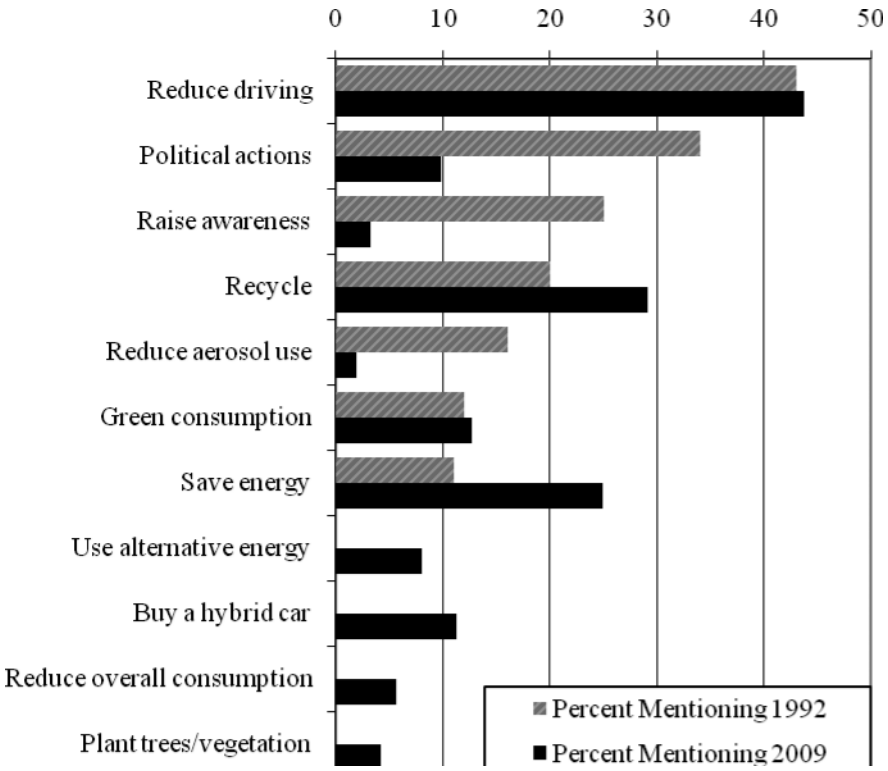

Fig. 6.

Actions Most Frequently Cited as "the Most Effective Actions" the Individual Respondent Could Take to Help Prevent Global Warming: Responses Provided to an Open-Ended Question that Asked for a List

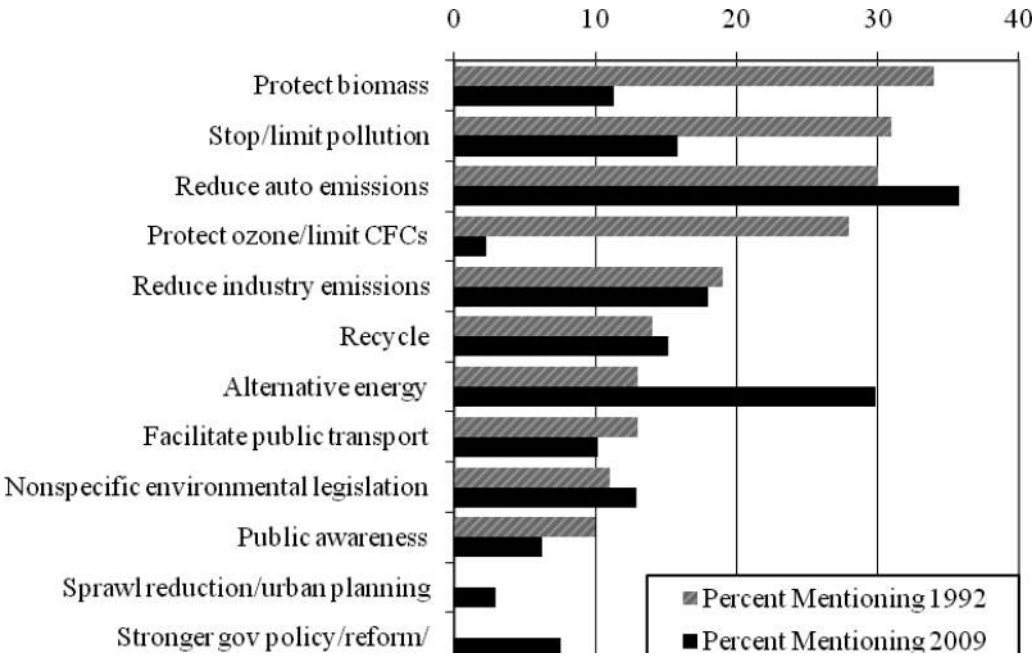

Fig. 7.

Actions Most Frequently Cited as "the Most Important Actions" the U.S. Government Could Take to Prevent Global Warming: Responses Provided to an Open-Ended Question that Asked for a List

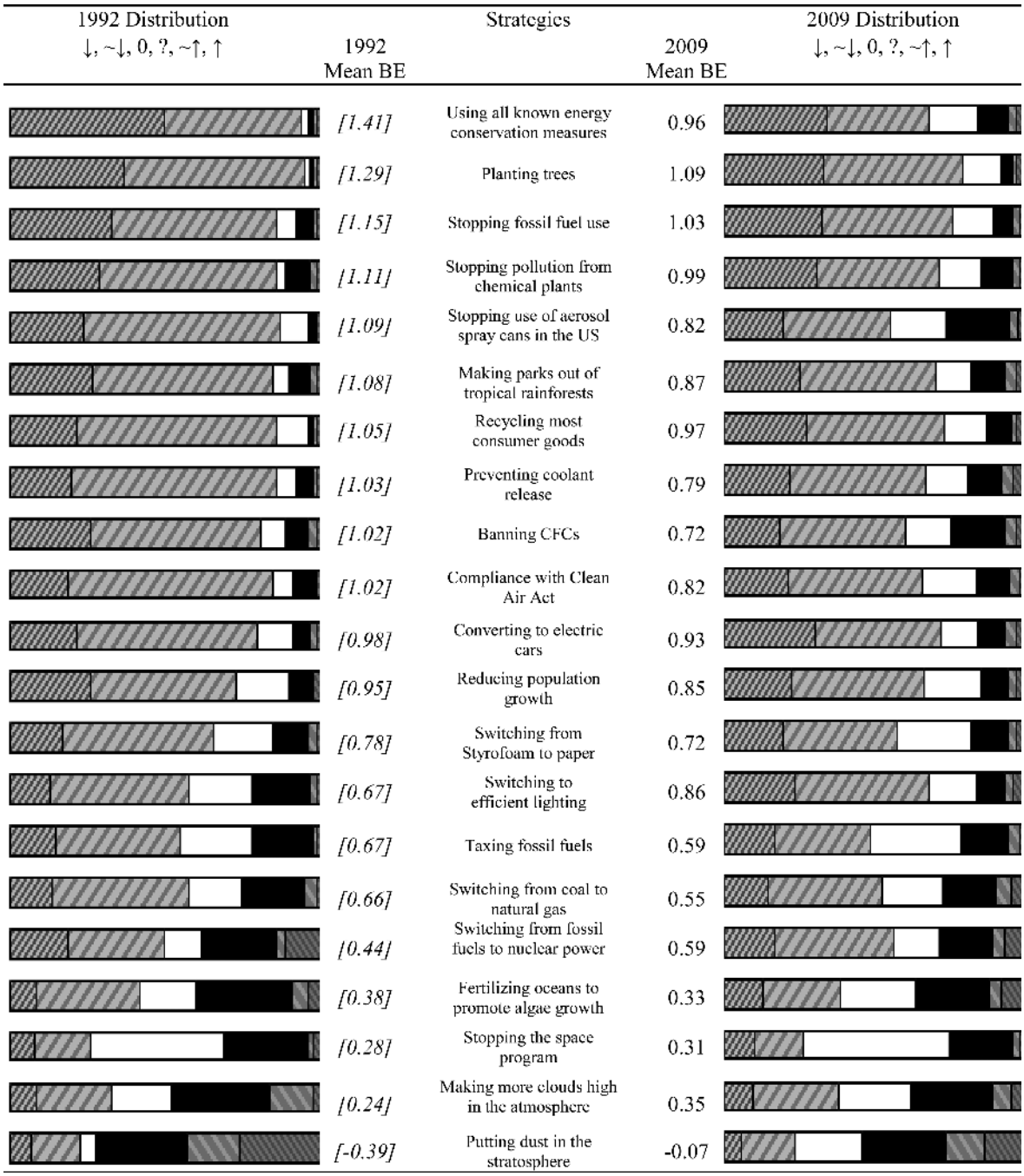

Fig. 8.

Responses to closed-form questions about the likely impacts on global warming of various strategies, rank-ordered by mean BE for 1992. The full distribution of responses is displayed in the columns. ↓ means will slow global warming; ~↓means will probably slow global warming; 0 (in white) means no effect; ? (in black) means unclear effect; ~↑ means will probably speed global warming;↑ means will speed global warming.

Causes (retabulated from Figure 3)

	Plausible Cause (Code = 1)			**Implausible Cause** (Code = 0)		
		DA	Rank		DA	Rank
Neutral or Good Environmental Practice (Code = 1)	Cows, rice paddies, termites and swamps	0.16	10	The space program	-0.46	12
	Mean	0.16	10.0	Mean	-0.46	12.0
Poor Environmental Practice (Code = 0)	Clearing rainforest	1.12	1	Aerosol spray cans	0.67	6
	Deforestation	1.07	3	Hole in the ozone layer	0.62	7
	Burning fossil fuels	1.12	2	Toxic wastes	0.69	5
	Ozone in cities	0.99	4	Ocean dumping	0.48	8
	Mean	1.08	2.5	Mean	0.62	6.5

Response Strategies (retabulated from Figure 8)

	Plausible Abatement (Code = 1)			**Implausible Abatement** (Code = 0)		
		BE	Rank		BE	Rank
Good Environmental Practice (Code = 1)	Using all energy conservation measures	0.96	5	Stopping pollution from chemical plants	0.99	3
	Planting trees	1.09	1	Stopping use of aerosol cans in the U.S.	0.82	10
	Stopping fossil fuel use	1.03	2	Recycling most consumer goods	0.97	4
	Preventing coolant release	0.79	12	Compliance with Clean Air Act	0.82	11
	Reducing population growth	0.85	9	Changing from Styrofoam to paper	0.72	14
	Switching to efficient lighting	0.86	8			
	Banning CFCs (1992)*	0.69	13	Converting to electric cars (1992)†	0.93	6
	Converting to electric cars (2009)†	0.93	6	Banning CFCs (2009)*	0.69	13
	Mean	0.90	7.1	Mean	0.88	8.0
Poor or Neutral Environmental Practice (Code = 0)	Switching from coal to natural gas	0.55	17	Stopping the space program	0.31	20
	Switching from fossil fuels to nuclear power	0.59	16			
	Fertilizing the ocean	0.33	19			
	Putting dust in the stratosphere	-0.07	21			
	Mean	0.35	18.3	Mean	0.31	20.0

Fig. 9.

Partition of causes of climate change (above) and responses to climate change (below) along the dimensions of "environmental practice" and "scientific plausibility." For the former dimension, climate change causes are classified as reflecting either "poor" or "good or neutral" environmental practice, while responses are classified as reflecting either "good" or "poor or neutral" environmental practice.

† "Banning CFCs" was a plausible abatement strategy in 1992, but in 2009 is implausible (since it has already been done). "Converting to electric cars" was implausible in 1992 but in

2009 is clearly plausible. The original (1992) coding is used in Equations 2 and 4; the revised (2009) coding is used in Equation 5.

Table I

Summary Sample Statistics –1992 and 2009

	Pittsburgh 1992	Pittsburgh/Seattle 2009
Recruitment location	4th of July Fair / Leadership Seminar	4th of July Fair / University Street Fair
Age – mean	36 (12.8)	41 (16.1)
Female Education	58%	55%
High School Grad	91%	93%
College Grad	62%	38%
Graduate School	34%	24%
N	177	248

* The 1992 study and the 2009 study each contained 2 sub-samples; however few significant differences were found between the two subgroups in each time period. Statistics reported are thus for the full 1992 sample (n=177) and the full 2009 sample (n = 248).