Indiscriminate, irrelevant, and sometimes wrong: Causal misconceptions about climate change

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Abstract

Prior research demonstrates widespread persistence of beliefs about climate change causes and risks that are arguably misconceptions. They include believing pollution causes climate change, believing ozone depletion causes climate change, the combination of these two "green beliefs," referred to as *environmental problems*, and believing natural climate variation significantly contributes to current climate trends. Each of these causal beliefs has the potential to weaken or divert support away from effective climate change risk mitigation policies. To assess this potential, we explore the nature and prevalence of these beliefs in the U.S. with a national sample of interviews (N=77) and two national surveys (N=1013, N=1820), and apply regression and mediation analyses to explore whether they explain any of the variation in individuals' concern or support for policy to mitigate climate change. Adherence to these beliefs—which reflect a variety of misconceptions illustrated in the interviews—differs by political ideology but is common, with over a third of interviewees mentioning one or more. Controlling for general knowledge, political ideology and other factors, misconceptions about environmental problems are still associated directly with support for climate change policies. On average adherence to the belief that environmental problems cause climate change is associated with a 25% higher probability of policy support. In contrast, believing natural climate variability is a major recent cause of climate change is associated with a 7% lower probability of supporting climate policy, even after controlling for political ideology and other knowledge about climate change.

Key words: climate change, mental models, risk perceptions

1. Introduction

The notion that adding carbon dioxide to the atmosphere would lead to global warming has been around for well over a century (Rodhe & Charlson, 1998). Yet people still often lack a clear understanding of how climate change works (Bostrom, 2018). Despite the evident risk (USGCRP, 2017), people are not yet doing enough to mitigate the worst effects of climate change. One explanation for this might be that important misconceptions about climate change causes contribute to people misunderstanding climate change risks and risk mitigation. If so, these misconceptions may explain concern and support for policies to mitigate climate change. This paper investigates how specific misconceptions influence these two important factors.

Research into the ways people tackle complex information about risk shows that individuals use mental models—i.e., their causal beliefs—to interpret and assess events and risks (Appendix 1), and may rely on analogy to make sense of new information (Bostrom, 2008). Several types of mental models of climate change have persisted over time: a carbon emissions model, in which climate change is caused by the emissions primarily from fossil fuels; a stratospheric ozone depletion model, which conflates stratospheric ozone depletion and climate change; an air pollution model, where individuals treat climate change as a pollution problem, either conflating greenhouse gases with common smog or air pollutants like particulate matter, or lumping air pollution problems like greenhouse gas emissions and smog together; and a weather model that does not distinguish between weather and climate (Bostrom, 2018). The latter three may be useful approximations in one or more regards, but also appear to be based on fundamental misconceptions about the causes of climate change.

Research has not shown a definitive relationship between how much knowledge an individual possesses about climate change and their concern. Studies using proxy measures of knowledge, such as general scientific literacy, report that those with high scientific literacy are not more concerned (Kahan et al., 2012). However, many studies have shown that specific knowledge of climate change is correlated with concern (Bostrom, Hayes, & Crosman, 2019; Guy, Kashima, Walker, & O'Neill, 2014; O'Connor, Bord, & Fisher, 1999).

One of the most prominent misconceptions identified in research on climate change perceptions is the tendency to conflate one or more broader environmental problems with climate change. This phenomenon has been termed the "green effect" or green beliefs. This refers to a lack of differentiation between environmental problems and a tendency to consider all environmental problems as one big issue (Dryden et al., 2018; Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994; Reynolds, Bostrom, Read, & Morgan, 2010). Throughout this paper, these green beliefs will be referred to as *environmental problems*. Consistent with identified mental models of climate change, the two environmental problems that are mentioned most often as a cause of global warming—regardless of culture or location—are air pollution and stratospheric ozone depletion (Bostrom, Morgan, Fischhoff, & Read, 1994; Kempton, 1991; Löfstedt, 1991). These findings from the early 1990s have persisted (Crosman, Bostrom, & Hayes, 2019; Huxster, Uribe-Zarain, & Kempton, 2015; Leiserowitz, Smith, & Marlon, 2010; Reynolds et al., 2010).

Another prominent misconception held by individuals is the belief that climate change is primarily due to natural variability of the climate system. In the last decade, lay people's survey and interview responses have referenced natural climate variability more often than previously

(Bostrom, 2016; Reynolds et al., 2010). This emphasis may be due in part to intentional campaigns of misinformation that emphasized natural climate variability and the appearance of scientific conflict (Freudenburg, Gramling, & Davidson, 2008). As of November 2019, a small majority (59%) of Americans believed climate change is human caused, and nearly a third (30%) reported believing that natural variability is the primary cause (Leiserowitz, Maibach, Rosenthal, Kotcher, Bergquist, Ballew, Goldberg & Gustafson, 2019). Skepticism about human causation of climate change encourages thinking of natural cycles as the primary cause of climate change; individuals have shown confusion about how much of a role natural cycles play compared to human-caused greenhouse gas emissions (Huxster et al., 2015). Individuals often also conflate weather variation and climate, frequently discussing them synonymously (Bostrom et al., 1994; Bostrom & Lashof, 2007; Reynolds et al., 2010; Leiserowitz et al., 2010). This could lead individuals to believe that normal weather variation means the same thing as natural climate variation, which—at least to the extent people distrust weather forecasts—may lead to less concern and support for policy. Nearly half of Americans reported in one study that scientists cannot predict future climate (Leiserowitz et al., 2010).

These two classes of misconceptions may form divergent bases for concern. Arguably, the majority of the American population has become more aware of climate change over time (Leiserowitz, 2005; Leiserowitz et al., 2019), and a majority of Americans have indicated they are worried about climate change (Leiserowitz et al., 2015; 2019), although concern levels have varied (Bowman, O'Neill, & Sims, 2016). In addition, those who see environmental problems (e.g. air pollution, ozone depletion) as a cause of climate change are more likely to perceive a dreaded nature of climate change risk (Bostrom et al., 2012). The hole in the ozone layer

engendered deep public concern due to the relative ease of understanding the risk it posed (Ungar, 2000). This feeling of concern may transfer to climate change if individuals see climate change and the ozone hole as the same thing. This is important if, as some research suggests, affect is the most important predictor of perceived risk (Finucane, Alhakami, Slovic, & Johnson, 2000; van der Linden, 2015). Supporting this view, people who hold strong beliefs about environmental problems are more likely to accept the reality of climate change (Hornsey, Harris, Bain, & Fielding, 2016) and support immediate action to address climate change (Dryden et al., 2018). This plausibly leads to the inference that individuals who believe the misconception that general *environmental problems* (e.g. air pollution and ozone depletion) lead to climate change will exhibit greater overall concern about climate change.

However, misconceptions about climate change drivers have increased the amount of doubt around human contributions to climate change and led to unfamiliarity with the risks it poses (Leiserowitz et al., 2010). Those who are skeptical about the causes of climate change—even if they possess greater knowledge about the issue—show less concern (Malka, Krosnick, & Langer, 2009). Further, simply providing more knowledge to individuals does not necessarily increase their concern (NASEM, 2017). This suggests that misconceptions that are consistent with thinking climate change occurs due to natural variability (e.g. natural cycles, natural "cyclical" or weather variability) lead to less overall concern about climate change.

Misconceptions about climate change may be politically driven. One of the largest and most consistent predictors of concern is political ideology (McCright & Dunlap, 2011), accounting for nearly twice as much concern than other demographic measures (Hornsey et al., 2016). Carbon-

focused policies could be less accepted because the terms used to describe them, such as global warming, are subject to political ideological thinking that supports misconceptions about natural climate variation (Mossler et al., 2017; Schuldt, Konrath, & Schwarz, 2011). Depending on how misconceptions are related to overall knowledge, cultural, and demographic factors, they may contribute significantly to individuals' risk perceptions, concern, and support for policy (van der Linden, 2015). It follows that depending on how individuals identify politically, they may be more or less likely to hold certain classes of misconceptions, and misconceptions could predict concern. Individuals who identify as Democrat or liberal consistently express more concern than those who identify as Republican or conservative (Konisky, Hughes, & Kaylor, 2016; Malka et al., 2009; Guy et al., 2014). Further, party identification has been shown to moderate the interaction between concern about climate change and an individual's self-assessed understanding of the issue (Hamilton, 2011). This implies that political ideology will moderate the effect of specific misconceptions on concern. Individuals who are more concerned about climate change are more supportive of policy measures to mitigate its effects (Bostrom et al., 2018; Shi, Visschers, & Siegrist, 2015). So the misconceptions individuals hold are likely to be associated with concern, and with support for policies to mitigate climate change, to the extent that concern drives behavior.

How the public views the risks of climate change and their corresponding support for policy can significantly influence how those risks are addressed (Leiserowitz, 2005). The type of policies individuals support depends on their preexisting beliefs, knowledge, and values (Bostrom et al., 2012; Hornsey et al., 2016; O'Connor, Bord, & Fisher, 1999). Individuals who think air pollution causes global warming are more likely to support policies to regulate air pollution and industry

(Bostrom et al., 2012; Reynolds et al., 2010). Research has also shown that individuals who lack specific knowledge of climate change, and who adhere to pollution models or ozone depletion models, will tend to support policies seen as good environmental practice (Huxster, Uribe-Zarain, & Kempton, 2015). This suggests that individuals who believe the misconception that *environmental problems* (e.g. air pollution and ozone depletion) cause global warming will support all climate policy actions. This could, however, possibly lead individuals to believe that climate change can be fixed easily with sufficient attention and commitment. Allowing for ideological differences and the influence of perceived risk or personal threat, people will tend to support only those policies they think will be effective, and some believe carbon-focused policy will be ineffective (Fig. 1, Bostrom et al., 2012; 2019). Believing climate change occurs due to natural variability (e.g. due to natural or "cyclical" cycles, natural weather variability, or natural climate variability) could depress support for policy actions.

In sum, this paper investigates three interrelated questions. Specifically, what is the nature of the most common misconceptions about climate change? Are they associated with political ideology? And how do they correlate with concern and support for policies? To address these questions, we conduct content analysis of mental models interviews and use survey responses to estimate the relationships between these variables, in a model based on Witte et al.'s (1994; Maloney et al., 2011) extended parallel process model (EPPM), adapted to include the role of specific causal misconceptions (Fig. 1). Note that Figure 1 includes two additional constructs from EPPM: perceived *harm* from climate change—which is one aspect of perceived risk—and perceived ease (*self-efficacy*) and effectiveness (*response efficacy*) of climate change policy.

--FIGURE 1 about here--

2. Methods

This paper presents three studies. For *Study 1*, a national sample recruited by GfK Knowledge Panel services was interviewed in depth. *Study 2* surveys a national sample of adults recruited through Amazon Mechanical Turk services. *Study 3* surveys a U.S. nationally representative sample of adults recruited through GfK Knowledge Panel services.

2.1. Sampling

Study 1: Telephone interviews were conducted from December 22, 2016 to January 13, 2017, with 77 respondents recruited from the nationally representative GfK Knowledge Panel (KnowledgePanel (United States), 2017). For this recruitment, GfK characterized the interview as being on a topic of current interest. GfK reported a study-specific average panel recruitment rate of 13%, a telephone study completion rate (PCOMR) of 21.8%, resulting in a cumulative response rate (recruitment and telephone with online task) of 1.1%. One interview was incomplete.

Study 2: Launched through Amazon's Mechanical Turk (MTurk) service on Tuesday, April 5, 2016, a human intelligence task (HIT) of 1000 participants linked to the survey, implemented in Qualtrics. The total number of participants was 1013,[1] excluding 101 people who started but did not complete the survey, and 29 who failed attention checks. The HIT was constrained to people in the U.S. who had completed 50 HITs previously and had HIT approval rates over 95. An IP address block through Qualtrics ensured that a person could only take the survey once.

Study 3: This survey was launched February 25, 2017 and administered to 3500 GfK Knowledge

[1] Methodological information originally compiled by Max Mossler for his thesis (for details and complete reference see Mossler et al., 2017).

Panelists. The survey completion rate was 52%, resulting in a final sample of 1820.

2.2 Data Collection

Study 1: The interview consisted of 22 questions gauging individuals' knowledge, support for policies, general feelings, and efficacy beliefs about climate change. Individuals were randomly assigned to one of three initial questions (i.e. frames, Table 1). In each frame, they were prompted at least twice more to follow up on their initial response (e.g., *Does anything else come to mind?* for the control; or, in the "how" frame, *You mentioned ___, ho*w?).

--TABLE 1 about here--

Interviewees were then reminded to think in the context of this prompt for the first 14 interview questions, which were broad, open-ended questions designed to elicit causal beliefs, including questions about exposure, effects, benefits and costs, risk management, and uncertainty about climate change (see Bostrom et al., 1994), such as *What factors, if any, might be changing our climate?* Questions 15-18 of the interview asked participants to define specific concepts (e.g., climate change, air pollution). Questions 19-22 of the interview asked respondents about their experience with the interview and whether or not they prepared beforehand. No respondents reported looking up information prior to the interview. The interview also included an online task where individuals were shown 12 images and asked to think aloud while deciding whether the images were or were not related to climate change. Interviews each lasted 30-45 minutes. Vanan Online Services transcribed the interviews verbatim. Quality control was assured by initially giving Vanan one very difficult audio recording to transcribe and having one researcher check the transcription against the audio. Coders content-analyzed transcribed interviews using ATLAS.ti.

Study 2: The MTurk survey included five randomly assigned initial carbon emissions framings: air pollution, carbon pollution, climate change, global warming, and ocean acidification (Mossler et al., 2017). A subset of the data and questions from this survey are included in the analysis presented here. For that subset, we limit the questions regarding policy support and concern to a single frame (climate change). The survey used a sparse matrix design in which some questions, such as knowledge questions, were assigned at random to participants (i.e., not every participant received every knowledge question). Responses missing at random due to this assignment were imputed using the Amelia package in R (Honaker et al., 2011). Participants indicated their political affiliation on a five-point scale (*Democrat*, *Republican*, *Independent*, *Unaffiliated*, and *Other*) and ideology on a seven-point scale (*Extremely liberal* to *Extremely conservative*).

Study 3: The GfK survey was nearly identical in design to the MTurk survey for the purposes of this study, with the exceptions noted here. In this survey all participants were initially randomly assigned to respond to one of the same three prompts used for the interview studies; all other questions followed, including political affiliation and ideology, with no subsequent reminders of the initial prompt. Political affiliation was measured on a seven-point scale in the GfK survey (from *Strong Democrat* to *Strong Republican*), and ideology was measured as above. This survey also asked a question about the role of natural climate variability that was not in *Study 2*.

2.3. Measurement

Study 1: All interviews were coded using a hierarchical coding scheme (Table S3 in Crosman et al., 2019). The coding scheme is based on a decision model of global climate change risk reduction (Appendix 1), derived from an integrated climate assessment model developed in the

early 1990s at Carnegie Mellon University (Bostrom et al., 1994; Morgan et al., 2002; Reynolds et al 2010). The guidance to coders was to identify and code any participant statement that could be interpreted as reflecting a concept related to climate change. When a participant mentions a concept in their interview, a code is attached to that phrase; if there is no code in the model that can be interpreted as corresponding to the concept, the coder is instructed to add a code. Coders added concepts sparingly in this study. The first author coded all interviews, blind to the study questions; the research questions and hypotheses for this study were generated subsequently, before beginning the analyses reported here. A second coder independently coded five interviews from a pilot study not reported here, in order to assess the reliability of coding, achieving an average intercoder reliability (Cohens kappa) of 0.77 (range .59 to .98, median 0.66). This corresponds to between 83% and 93% agreement, and is good reliability.

Study 2: To determine support for policies to mitigate climate change, participants were asked: *How much do you support or oppose reducing climate change by reducing carbon emissions?* (five-point response scale from *Strongly support* to *Strongly oppose)*. To determine concern about climate change, participants were asked: *How concerned, if at all, are you about climate change?* (five-point response scale from *Not at all* to *A great deal)*.[2]

Each participant was asked 23 true/false climate change knowledge questions (nine items were asked of every participant; the remaining 14 were randomly assigned from the list in App. 2). Participants answered on five-point response scale: *True*, *Probably True*, *Don't know*, *Probably False*, *False*. Answers to questions were re-coded on a distance-from-correct scale where 0

[2] Responses were imputed for this question when respondents were assigned (at random) to other frames (see Mossler et al., 2017), also using the Amelia package (Honaker et al., 2011).

indicates a correct response, with a maximum distance-from-correct of 4. The true/false questions relating to misconceptions that were used for this analysis were:

1. *Ozone in cities (e.g., smog in Los Angeles) is a major cause of global warming (Smog).*
2. *Air pollution is a major cause of global warming (Air Pollution).*
3. *Aerosol spray cans are a major cause of global warming (Aerosol).*
4. *Toxic wastes (e.g., hazardous chemicals in dumps) are a major cause of global warming (Toxic Waste).*
5. *The hole in the Antarctic ozone layer is a major cause of global warming (Ozone Hole).*

None of the MTurk survey questions directly asked whether an individual believes natural climate variability is a primary cause of climate change.

Study 3: The policy support and concern questions in the GfK survey were identical to those in *Study 2*. Each participant was asked 33 true/false questions about climate change (Appendix 2), with the same response scale as in *Study 2*. The misconception-related true/false questions used for this analysis included questions 1, 3-5 above, plus: *Natural climate variability is a major cause of any recent global warming.* The air pollution question was not included in the GfK survey.

Studies 2 & 3: The analyses treat "ozone depletion" as a single variable (question five above) measured with a single item, "air pollution" as a single variable measured with multiple items (questions one through four above; Cronbach's alpha=0.79 for study 3), and "natural processes" as a single variable measured with a single item. The "environmental problems" variable includes all misconceptions except the "natural processes" item (see online supplement;

Cronbach's alpha=0.83 for study 3). Other variables included in the model (Fig. 1) have in prior studies been associated with concern and support for policies to mitigate climate change risks (e.g., Bostrom et al., 2019). They are *harms, self-efficacy, response efficacy, knowledge, sex, age, party*, and *political affiliation.* The variable *harms* is an average of responses to three questions: *How much do you think climate change harms [you personally / others in the United States / people around the world]?* with a five-point response scale from *Not at all to A great deal*. The variable *self-efficacy* is an average of responses to two questions: *How easy or hard would it be for [you personally / everyone in the United States collectively] to reduce [your/our] household energy use by 20%?* with a seven-point response scale, from *Extremely easy* to *Extremely hard*.[3] The *response efficacy* variable is an average of responses to *What effect would the United States government taking this action have on global warming?* for four actions: *fully enforcing all the air pollution control standards currently specified in the U.S. Clean Air Act*; *increasing taxes on all fossil fuels (e.g. coal and oil)*; *funding research to make renewable energy technologies cheaper and more effective*; and *reducing annual greenhouse gas emissions by 20% (in five years or less) through Clean Air Act regulations*. Response efficacy was measured on a five-point scale (*Slow or stop climate change*, *Slow or stop climate change slightly (a trivial amount)*, *No effect*, *Speed climate change slightly (a trivial amount)*, and *Speed climate change)*. The *knowledge* variable is an average of answers coded as distance-from-correct, for knowledge questions asked of participants in each respective survey, excluding those used to measure the specific misconceptions we test (Appendix 2).

[3] These two items have a higher correlation than other pairs of self-efficacy items (Kendalls tau = 0.48, vs. an average pairwise correlation of 0.19 among all other pairs of self-efficacy items in the *Study 3* data, with a similar pattern in the *Study 2* data).

2.4. Analyses

To examine the effects[4] of misconceptions and political ideology on concern and policy support, we estimate ordinal probit models and report the marginal probability of being in the highest two concern (*A good deal*, or *A great deal* of concern) or policy (*Slightly Support* or *Strongly Support*) categories for the mediation and outcome model, respectively. *Party* is treated as binary (any type of Republican=1, all others=0), as is *Political ideology* for which responses of *Slightly Liberal* to *Extremely Liberal* are coded as 0, and responses from *Moderate, to Extremely Conservative* as 1.

In *Study 2*, we used multiple imputation to impute answers to questions participants did not receive (omitted at random; King et al., 2001; 10 total imputations). The first imputation was used to estimate all descriptive findings. The first imputation was also used to model the effect of misconceptions on concern and policy support as a robustness check for the findings from Study 3 (see online supplement).

A mediation analysis was conducted to estimate the total effect of misconceptions on policy support with concern as the mediating variable of interest (Appendix 3). Both regressions are estimated as ordinal probits, with concern as the dependent variable in the first regression and policy support as the dependent variable in the second regression. Other regression types were performed to determine an appropriate analysis (see online supplement). In addition to the

[4] While the text in this and following sections mentions 'effects', it should be noted that the survey did not contain an intervention that would allow us to identify a causal link between the independent and dependent variables. Instead, the term 'effects' is used to denote the relationships that are estimated by the models described here, which may not necessarily be causal.

measures of misconceptions, we control for demographic characteristics (age and gender) as well as political ideology and political party affiliation, and include *self-efficacy*, *response efficacy*, *knowledge*, and *harms* as independent variables in the regressions on concern and policy support (Fig.1). As the mediating variable, *concern* was also included as an independent variable in the policy support regression. The mediation analysis estimate uses a semi-parametric bootstrapping method based on the procedure describe in Imai, Keele, & Tingley (2010) to produce estimates of the average treatment effect of each misconception category on policy support for both *Studies 2 and 3*. The estimate represents the expected difference in probability of policy support when the misconception is set to the sample mean compared to a misconception value of zero for each respondent in the sample.

3. Results

3.1. Descriptive Findings

3.1.1. Sample characteristics

Respondents across all three studies tend to have more education than the U.S. adult population, although *Study 3* resembles the U.S. national population on most benchmark measures (18+ U.S. March 2016 Current Population Survey (CPS): gender (43% female *Study 1,* 51% *Study 2*, 50% *Study 3*, 52% CPS), race (% white non-Hispanic in *Study 1* is 74%, 79% *Study 2*, 73% in *Study 3* 64% CPS), income (household income of $150K or higher: 13% in *Study 1*, not asked in *Study 2*, 15% in *Study 3*, and 16% in the CPS), and education (Bachelor's degree or higher: *Study 1* 47%, NA in *Study 2*, 36% in *Study 3*, 31% CPS).

3.1.2 *Study 1 Interviews*

The interviews provide an in-depth picture of how individuals think about climate change, including their potential misconceptions, specifically those coded as referencing "air pollution," "ozone depletion," or "natural processes." In the open-ended interviews about climate change, the general concept of air pollution is more than twice as likely to be mentioned than the more specific concept of greenhouse gases (Fig. 2). Further, ozone depletion is slightly more likely to be mentioned than greenhouse gases, and natural variability more likely to be mentioned than carbon emissions (Fig. 2).

Ozone Depletion is mentioned by nearly a third of the participants in the interviews. Many of the people who mention ozone depletion believe it is an effect of climate change and that climate change is caused by air pollution. Many also see ozone depletion as the direct cause of climate change. Respondents frequently conflate ozone depletion and the greenhouse effect.

--FIGURE 2 about here--

When we include responses to items that ask respondents to define single terms, in addition to the earlier, open-ended prompts, 40% of ozone depletion mentions co-occur with mentions of the greenhouse effect, such as when this 27-year-old man is asked to define the greenhouse effect:

> Um, I mean air pollution is…uh…air pollution is reducing the um, the protection offered by the ozone layer, and as a result of that, uh the UV rays from the sun are having more of an effect on the earth which uh, in turn is leading to uh, to higher temperatures, the greenhouse effect, and um that is a contributor to global warming, aka climate change.

Out of all those who mention ozone depletion specifically, only one individual, a 29-year-old woman, acknowledges the misconception many people hold:

> Uh, oh, you're getting into the common misperception of people thinking that the ozone

> hole is related to climate change or its related to the greenhouse effect, it is not. […] actually, um, the ozone layer ... ozone is itself a greenhouse gas so, uh, the ozone layer getting thinner would actually decrease climate change.

Air Pollution is cited by many as a cause of ozone depletion, with nearly a quarter of ozone depletion mentions co-occurring with mentions of air pollution. An example is this 27-year-old man, responding to a request to define air pollution. Note the differences from the quote above:

> And people, and of course China is very polluted, and LA is very polluted, New York city to a much lesser extent and so these cities need to cut down on their emissions to improve climate change because as the air gets more polluted and we keep using, we continue to use harmful materials, our ozone and our atmosphere begin to deteriorate, and um, we start, we're seeing more rays from the sun.

The coding cannot be interpreted to directly imply that every time someone mentions an item they are adhering to a misconception. Sometimes, such as in the case of air pollution, there is an explicit decision to define a term very generally; some individuals consider carbon dioxide and other greenhouse gases as air pollution. In response to being prompted to define air pollution, one 41-year-old man responds:

> Oh, air pollution contains, like, carbon dioxide and everything else and these pollutants go up and they change the atmosphere, which the fine rays have to come through.

Sixteen out of the 75 individuals who mention air pollution in the course of defining it also mention carbon dioxide or greenhouse gases in the same passage. Additionally, some individuals do not distinguish or differentiate between carbon dioxide as a pollutant and pollutants like

smog, such as this 46-year-old woman:

> … when there's a lot of pollution in the air, it just kind of, it stays in there, it becomes stagnant, and it doesn't really move much through the atmosphere, so the earth in that particular location, where there's a lot of greenhouse gases, like, you know, carbon emissions and, uh, smoking, um, uh, you know, factory chimneys, things like that, the air becomes stagnant and the, uh, the environment becomes like a greenhouse. It's trapped, it becomes trapped in the atmosphere.

Many participants also mention carbon monoxide, by which some may mean carbon dioxide. A case in point is when this 32-year-old man is asked to define air pollution:

> Something we all contribute to. Um ... kind of like ... Carbon mono- or ... Ah ... What's a good way to do this? Air pollution comes from the combustions in my car ... Or, ah ... The burning of fossil fuels.

Natural Variation. Nearly equal numbers of people mention natural processes and carbon emissions, and just over a third of participants mention greenhouse gases specifically (Fig. 2). Mentions of natural processes are complex; some respondents merely acknowledge that climate does naturally vary over time, but many others cite natural climate variation as the primary cause of climate change, such as this 57-year-old man:

> I guess common belief that, that man has an effect on the climate. Um, I believe it's a natural occurring cycle that there has, there is climate change, but it is a naturally occurring cycle and humans have very little to do with uh, the actual climate change.

Just over 13% of such mentions directly co-occur with the code for *deny human causality*. Additionally, people who use the words "cycle" or "cyclical" use them repetitively, in a

distinctive fashion. Around 36% of individuals use these particular words when they mention natural processes, for example this 53-year-old woman:

> Personally I think climate change is cyclical and so there are you know I mean, so there are times where you know the weather is colder or warmer and those based cyclically, over decades, over you know hundreds of years. I don't think that we make, all, you know humans make all that much difference in climate change.

Individuals who believe natural variation is the primary cause of climate change relay little sense of efficacy with regard to humans slowing or stopping climate change. When asked what can be done about climate change, a 60-year-old man responded:

> Actually, nothing, because I believe it's more ... I don't believe that it's, uh, man that's making climate change. I believe that it's just a cycle that the earth is going through, coming up closer to the sun.

The interview data suggest that the ways individuals think about misconceptions related to climate change are complex. Misconceptions about the causes of climate change are cited as frequently as accurate conceptions, such as carbon emissions or greenhouse gases as causes of climate change. Many individuals conflate two ideas, for example ozone depletion and the greenhouse effect. Sometimes individuals entangle correct information and misconceptions, such as when individuals fail to distinguish carbon dioxide from other air pollutants. Misconceptions can also reflect errors, such as thinking that natural climate variability is the primary cause of recent climate change.

3.1.3. Studies 2 and 3 Surveys

Liberals are markedly more likely to be concerned about climate change than others; in both *Studies 2* and *3* the majority of liberals report *a good deal* (27% MTurk, 24% GfK) or *a great deal* (46% MTurk, 49% GfK) of concern. Those who do not self-report as liberal report less concern, ranging from 15% (percent *a great deal* in GfK) at the lowest, to 25% (percent *a great deal* in MTurk).

--FIGURE 3 about here--

Support for policies to mitigate climate change by reducing carbon emissions differs between liberals and conservatives (Fig. 3). Liberals are more likely to strongly support policies in both *Study 2* (64%) and *Study 3* (78%) (Fig. 3). Nevertheless, moderates and conservatives are more likely to support than oppose policies; over half select some form of support (Fig. 3).

All *environmental problems* misconceptions are highly and positively correlated. Responses to *Ozone in cities (e.g., smog in Los Angeles) is a major cause of global warming* (*smog*) are highly positively correlated ($p<0.05$) with responses to other pollution questions (e.g., $r=0.59$, with the *air pollution* question in Study 2), and are grouped with the other pollution questions even though it includes the word "ozone" (here referring to tropospheric ozone). Conservatives are less likely to agree with all misconception questions relating to environmental problems (Kendall's tau = -0.26, $p<0.001$). In contrast, conservatives are more likely to agree with the *natural variability* misconception (i.e., liberals are more likely to answer correctly, Kendall's tau=0.20, $p<0.001$). All misconception questions have average distance-from-correct scores greater than two. A score of two equates with answering *don't know* and a score of three equates to answering *probably true* when the correct answer is *false*. The lowest average distance-from-correct score for *Study 2*—where respondents' answers were closest to the true answer—is for aerosol spray cans, and the largest average distance-from-correct score is for *air pollution* (i.e.,

respondents were most likely to judge *Air pollution is a major cause of global warming* as a true statement). In Study 2, the lowest average distance-from-correct is for smog, and the largest average distance-from-correct score is for toxic waste.

The differences in means for average distance-from-correct across all misconception questions are significantly lower for conservatives than liberals. In *Study 2*, which excludes the *natural variability* question, liberals have an average *environmental problems* misconception score of 2.9 while conservatives have an average score of 2.6, or roughly equivalent to judging it *probably true* that these environmental problems cause climate change. For the *environmental problems* score in *Study 3*, liberals have an average misconception score of 2.5 while conservatives average 2.1. In contrast, for all knowledge questions excluding misconceptions the average distance-from-correct was 1.42 for liberals and 1.59 for conservatives (Fig. 4) in *Study 2*. Respondents were also asked to rate the following questions on the same *True* to *False* scale as other knowledge questions: *Burning fossil fuels (e.g., coal and oil) is a major cause of global warming*; and *The temperature of the earth is affected by the gases that make up the atmosphere.* The average distance-from-correct for knowledge about fossil fuels is 0.34 for liberals and 1.1 for conservatives (Fig. 4). The average distance-from-correct for knowledge about atmospheric gases is 0.60 for liberals and 0.82 for conservatives (Fig. 4). In other words, both liberals and conservatives provide mostly correct responses, but responses from liberals are more correct than those from conservatives, on average.

--FIGURE 4 about here--

There is also a significant difference between liberals and conservatives for each misconception. In *Study 2*, while conservatives have a larger distance-from-correct score for overall knowledge and for questions relating to fossil fuels and greenhouse gases, liberals have a larger score for all

questions relating to environmental problems (Fig. 5).

--FIGURE 5 about here--

Similarly, in *Study 3*, while conservatives have a larger distance-from-correct score for overall knowledge, and for natural climate variability as a major recent cause of global warming, liberals have a larger score for the environmental problems questions (Fig. 6).

--FIGURE 6 about here—

3.2. Modeling Results

To better understand the effects of misconceptions on concern and policy support, partial correlations were estimated between misconceptions and the other factors we expected to contribute to concern and policy support, including *harms*, *self-efficacy*, and *response efficacy*, while controlling for political and demographic characteristics. Misconceptions about general environmental problems are positively related to the expectation that climate change will cause personal and social harm across both datasets (Table 2). Similarly, the more likely respondents were to report general environmental misconceptions, the easier they reported it would be to take mitigative action individually or collectively (i.e., self-efficacy[5]) and the more effective they perceived government mitigative action to be (i.e., response efficacy). The relationship with response efficacy was stronger than for self-efficacy.

--TABLE 2 about here--

Dividing environmental misconceptions into *pollution* and *ozone*-related misconceptions reveals some differences in the relationships between misconceptions and *harms*, *response efficacy*, and

[5] As noted above, while individual and collective self-efficacy are distinct concepts, they are included here only as control variables, and because the items used are highly positively correlated are combined in a single measure.

self-efficacy. *Pollution*-related misconceptions demonstrate similar correlation patterns to *environmental problems* as a whole – positively correlated with anticipated *harms* as well as perceived *self-* and *response efficacy*, with a weaker relationship with *self-efficacy* than with *response efficacy*. The correlations between *ozone*-related misconceptions and *harms*, *self-efficacy*, and *response efficacy* follow a similar pattern, but weaker, suggesting that *ozone*-related misconceptions are held somewhat more randomly throughout the population than *pollution*-related misconceptions (Table 2).

--FIGURE 7 about here—

Three ordinal probit regression models are estimated using concern as the dependent variable, for Study 3. in the first model uses the combination variable *environmental problems* as an independent variable, the second includes ozone depletion and pollution as separate independent variables, and the third includes natural variation as an independent variable (Figure 7). The regressions indicate that greater concern is associated with stronger beliefs that general environmental problems are a major cause of climate change, and less concern is associated with stronger beliefs that natural variation is a major cause of climate change (Figure 7, see Appendix 4 for exact marginal effects and confidence intervals). Stronger individual beliefs that ozone depletion represents a major cause of climate change are associated with more concern. Similarly, stronger individual beliefs that *pollution* represents a major causes of climate change are associated with more concern (Figure 7).

Both stronger belief that climate change causes harm, and more knowledge are associated with greater concern (Figure 7). Being conservative or Republican are both associated with less concern (Figure 7). Age and sex do not have robust consistent associations with concern across

models. The mean marginal effect for all *environmental problems* suggests an individual is on average 10% more likely to be concerned if they are one unit farther away from correct responses on *environmental problems* questions, controlling for other factors in the model (Figure 7). The mean marginal effect for pollution questions suggests an individual is 6% more likely to be concerned if they are one unit farther away from correct (Figure 7). Similarly, the mean marginal effect for *ozone depletion* suggests that respondents are 4% more likely to be concerned if they are one unit farther away from correct (Figure 7). The mean marginal effect for the *natural variation* misconception suggests an individual is 4.5% less likely to be concerned if they are one unit farther away from correct (Figure 7). The mean marginal effect of ideology suggests an individual is about 5% less likely to be concerned if they are conservative, as opposed to liberal, and about 11% less likely to be concerned if they self-identify as Republican, controlling for all else. Knowledge has consistently high marginal effects; individuals are roughly 31% less likely to be concerned if they are one unit farther away from correct responses to all knowledge questions on average, controlling for all else. Perceived harms and response efficacy also have high marginal effects (Figure 7), controlling for the other factors in the model.

--FIGURE 8 about here--

Testing the possibility that ideology moderates the relationship between misconceptions and concern revealed some evidence this may be the case, but such models are problematic due to multicollinearity (Appendix 5). The results nevertheless suggest that political ideology does moderate the relationship between climate change related misconceptions and concern about climate change.

Three ordinal probit models are estimated with policy support as the dependent variable for Study 3. As in the regression models for concern, the first model uses the combination variable *environmental problems* as an independent variable, and the second includes ozone depletion and pollution as separate independent variables. and the third model includes natural variation as an independent variable (Figure 8). The mean marginal effect for all *environmental problems* on policy support suggests an individual is 8% more likely to support policies to mitigate climate change if they are one unit farther away from answering these questions correctly, all else equal (Figure 8, see Appendix 4 for exact marginal effects and confidence intervals). The mean marginal effect for *pollution* suggests an individual is 6% more likely to support policies to mitigate climate change if they are one unit farther away from correct (Figure 8), all else equal. The mean marginal effect for *ozone depletion* suggests an individual is 2% more likely to support policies to mitigate climate change if they are one unit farther away from correct (Figure 8), all else equal, although this estimate is not statistically significant. The mean marginal effect for *natural variation* suggests an individual is 3% less likely to support policies to mitigate climate change if they are one unit farther away from correct (Figure 8).

Perceived personal and social harms, knowledge, liberal ideology, and response efficacy all associate positively with support for policies to mitigate climate change (Figure 8), although with concern included in the model the estimated marginal effect of harms does not differ significantly from zero. Self-efficacy as measured here is also not reliably correlated with policy support. The estimated marginal effects of age, sex, and party are very weak, across models (Figure 8).

The mean marginal effect of concern suggests an individual is a little more than 13% more likely to support policies to mitigate climate change at one unit of concern higher (Figure 8), all else equal. The mean marginal effect of ideology suggests that those who do not self-identify as liberal are 2% less likely to support policies to mitigate climate change than liberals, controlling for other factors (Figure 8). Knowledge has consistently strong marginal effects, where individuals are around 8% less likely to support policies if they are one unit farther away from correct. The mean marginal effect of response efficacy suggests an individual is about 20% marginally more likely to support policies for a one unit increase in perceived response efficacy (Figure 8).

Including interactions between misconceptions and political ideology for policy support regressions reveals a similar pattern as for the concern regressions. The policy support regressions that include interactions suggest a more complicated relationship between misconceptions and policy support, but suffer from high multicollinearity (Appendix 5).

--TABLE 3 about here--

Table 3 tests whether concern mediates the effects of misconceptions on individuals support for policies. The direct and total effects of each of these misconceptions on policy support are significant (Table 3). The total effect of misconceptions on policy support is relatively high for environmental problems and pollution, and still significant, though smaller, for ozone depletion (Table 3). The total effect of natural variation, similarly, is small but significant (Table 3). All misconceptions also have a much greater direct effect than indirect (Table 3). Indirect effects are small, and for ozone are unreliable. In other words, contrary to expectations, concern mediates the effects of misconceptions on policy support only to a minor extent.

4. Conclusions and Discussion

Congruent with prior studies, the studies presented here show that more people are concerned about climate change than not, with liberals more concerned than conservatives. Similarly, across both surveys, a majority of respondents express support for policies that reduce CO_2 emissions, as expressed in these studies. However, these studies also suggest that misconceptions about the causes of climate change are associated with concern about climate change risks and, more importantly, support for policies to tackle them.

The interviews show how people think about each of these misconceptions. The way in which individuals think about air pollution is complex. Some individuals understand air pollution as smog, i.e., conventional air pollutants, but many also consider carbon dioxide air pollution. These findings are similar to the expected mental models of how air pollution relates to climate change (especially since individuals who talked about carbon dioxide as air pollution also often mentioned other forms of pollution). With the listing of carbon dioxide as an air pollutant by the Environmental Protection Agency (EPA), this mental model may become more prevalent, and it may become even more difficult to distinguish when individuals are thinking of conventional air pollutants versus carbon dioxide. Ozone depletion is commonly conflated with the greenhouse effect and also often mentioned with air pollution. Some individuals appear to assume that air pollution causes ozone depletion, and as a result, that the deterioration of the ozone layer causes the greenhouse effect (which some people assume is the hole in the stratospheric ozone layer) and global warming. Individuals' understanding of natural variation is also complex, but many

individuals who bring up natural variation also deny human causality of climate change and express little belief that taking actions to reduce greenhouse gas emissions or mitigate climate change will effectively slow or stop climate change.

All of these misconceptions are volunteered in about the same frequency or even more often than mentions of carbon emissions and the greenhouse effect, indicating they are (still) as prevalent in mental models of climate change as core correct ideas. Individuals are more inclined to answer *environmental problems* and *natural climate variability* misconception questions incorrectly compared to other knowledge questions. All average distance-from-correct scores significantly differ by ideology, with more liberal ideology associated with a larger distance-from-correct score for the specific *environmental problems* questions, and conservative ideology associated with a larger distance-from-correct score for *natural climate variability*.

These misconceptions interact with other factors in their associations with concern and support for policies to mitigate climate change, through a number of pathways. The *environmental problems* and *ozone depletion* misconceptions are positively correlated with how risky or harmful people believe climate change is, as well as with perceptions of how easy or effective it is to do something about it, although these correlations are weaker with *ozone depletion*. Misconceptions about natural variation are negatively correlated with perceptions of both *harm* and *efficacy* beliefs.

Although our results do not demonstrate causality, consistent with prior research they suggest that ideology and causal knowledge strongly influence how individuals think about and perceive

climate change. Given that attitudes may direct attention and motivate information seeking, it is difficult to determine whether concern is motivating learning, knowledge is motivating concern, or both. More research is warranted to learn how these variables interact with misconceptions to influence concern and policy support.

Holding a *stratospheric ozone depletion* mental model appears to have a weaker association with concern and policy support than other misconceptions, in light of the regression results. This may relate to a general appreciation of progress on this problem over time, for example the shrinking Antarctic ozone hole (De Laat & Van Weele, 2011). Holding the belief that *pollution* causes climate change has a robust positive association with both concern and policy support. An argument can be made that carbon dioxide is a pollutant, for which reason this is not so much an erroneous belief but a generalized way of thinking about climate change, and may reflect recent policy changes (Mossler et al., 2017). In contrast, believing *natural climate variability* is a major recent cause of climate change is associated with lower levels of concern and less support for climate change policies. Further, mediation analysis suggests misconceptions have a direct association with policy support; very little of their association with policy support is mediated by concern.

There may be an alternative explanation for the patterns seen here, in which misconceptions are a result rather than the driving force. Individuals may hold values about the environment that affect their concern and support for policies, and that in turn cause them to adhere to certain misconceptions. For example, they might value the environment and therefore be concerned about it and support policies to protect it; this value might cause them to believe all

environmental problems are also causes of climate change, or to not care about distinctions. Political ideology can be seen as a representation of values. Environmental values could be reflected in expressed misconceptions that are therefore associated with a specific political ideology. Depending on the strength of the values, this could cause the patterns seen, in which values are associated with the actual, specific knowledge individuals hold. Given our findings and this potential alternative explanation, testing our full conceptual framework (Figure 1) more specifically warrants further research. Differentiation between individual and collective self-efficacy could also further illuminate how efficacy beliefs drive policy support (e.g., Bostrom et al., 2019).

These results have potentially troubling ramifications for mitigating the risks of climate change. Those who believe that environmental problems cause climate change are more likely to support generic policy to mitigate climate change. One implication of this is that attempting to foster more discerning causal beliefs about greenhouse gases may risk weakening support for policy, or even boomerang. This creates an interesting dilemma if policy makers are committed to increasing knowledge around climate change, and also committed to mitigating it. In contrast, unless they are seen as an attack on values, campaigns that target misconceptions about the role of natural climate variability in observed and projected global warming appear likely to increase policy support.

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Table 1. Frames used in interview question one.

Frame	**Initial Question**
Control	*What comes to mind when you think of climate change?*
How	*How do people try to slow or stop climate change?*
Why	*Why do people try to slow or stop climate change?*

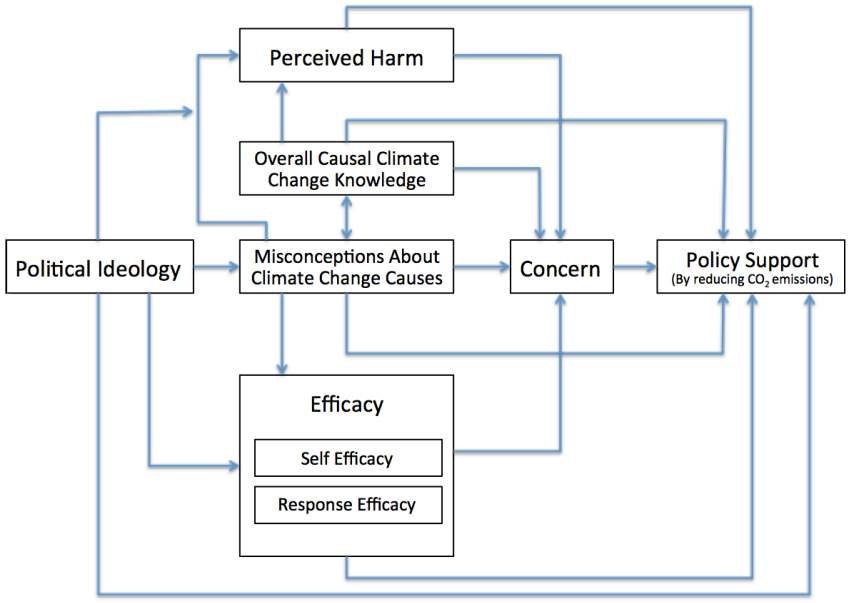
Table 2. Partial correlations between misconceptions and perceived harms, self-efficacy, and response efficacy, controlling for political ideology, party affiliation, gender, and age. All partial correlations significant at the 0.05 level.

	Harms		*Self-Efficacy*		*Response Efficacy*	
Misconception	Study 2	Study 3	Study 2	Study 3	Study 2	Study 3
Env Problems	0.40	0.44	0.22	0.21	0.36	0.31
Ozone	0.27	0.38	0.16	0.18	0.22	0.26
Pollution	0.29	0.42	0.17	0.20	0.23	0.30
Natl Variation		-0.14		-0.06		-0.20

Table 3. Mediation analyses estimating the expected change in probability of policy support that results from moving from no misconception to the average value for misconceptions related to environmental problem, ozone depletion, pollution, and natural variation. The total effect of the misconception on policy support is broken down into direct effects and indirect effects. The indirect effects represent the effect of concern as a mediating factor in the relationship between misconceptions and policy support, while direct effects represent the direct effect of the misconception on the probability of policy support. The estimated effects on the probability of Slight or Strong Policy Support (ordered probit) through the mediator variable of concern (ordered probit) were calculated using 5000 bootstraps (95% CI in brackets).

Study 3. GfK sample (N=1574)						
Independent Variable	Direct Effect		Indirect Effect		Total Effect	
Environmental Problems	0.20	[0.15.0.25]	0.06	[0.04,0.09]	0.25	[0.19,0.31]
Ozone Depletion	0.03	[-0.01,0.07]	0.02	[0.00,0.03]	0.05	[0.01,0.09]
Pollution	0.14	[0.09,0.20]	0.04	[0.02,0.06]	0.17	[0.12,0.24]
Natural Variation	-0.05	[-0.07,-0.03]	-0.02	[-0.02,-0.01]	-0.07	[-0.09,-0.04]

Figure 1. General model of how causal thinking-associated misconceptions, general causal knowledge, perceived harm from climate change, response and self- efficacy, and ideology interact and lead to concern and support for policies reducing CO_2 emissions.



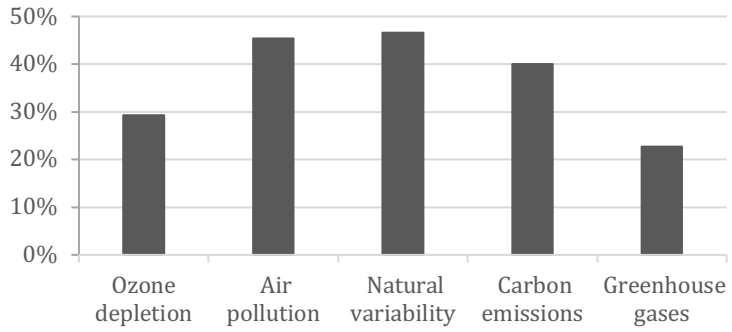


Figure 2. Percentage of interviewees who mentioned carbon emissions, greenhouse gases, or concepts of ozone depletion, air pollution, or natural variability, in response to open-ended prompts.

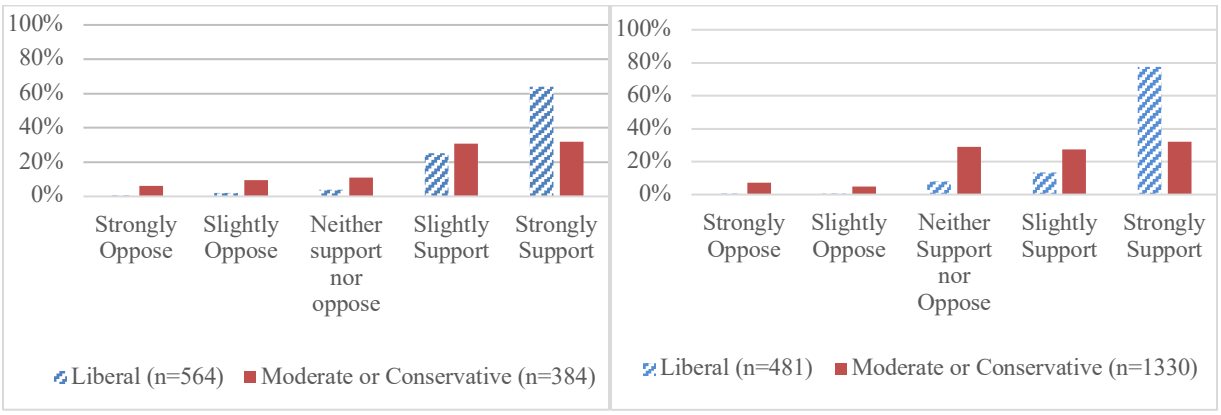


Figure 3. The proportion of answers to the question "How much do you support or oppose reducing climate change by reducing carbon emissions?" for liberals and moderates/conservatives from the *Study 2* (MTurk, left) and *Study 3* (GfK, right) studies. Imputed categorical answers (*Study 2* only) are rounded to the nearer integer.

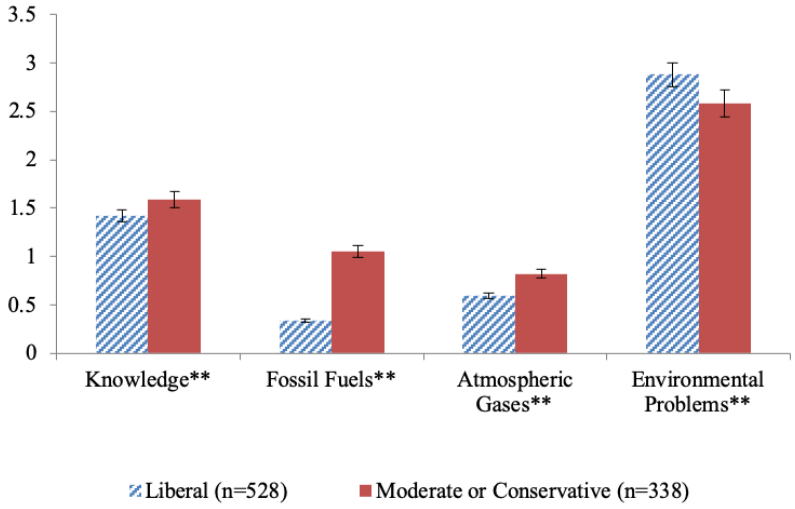


Figure 4. Average distance-from-correct for all knowledge questions, questions on causes of climate change, and all *environmental problems* questions for *Study 2*. Higher numbers equate with less knowledge, and with stronger agreement with for *environmental problems* misconceptions about climate change. See App. 2 for specific questions in each index. * difference significant at p=0.05, ** at p<0.01.

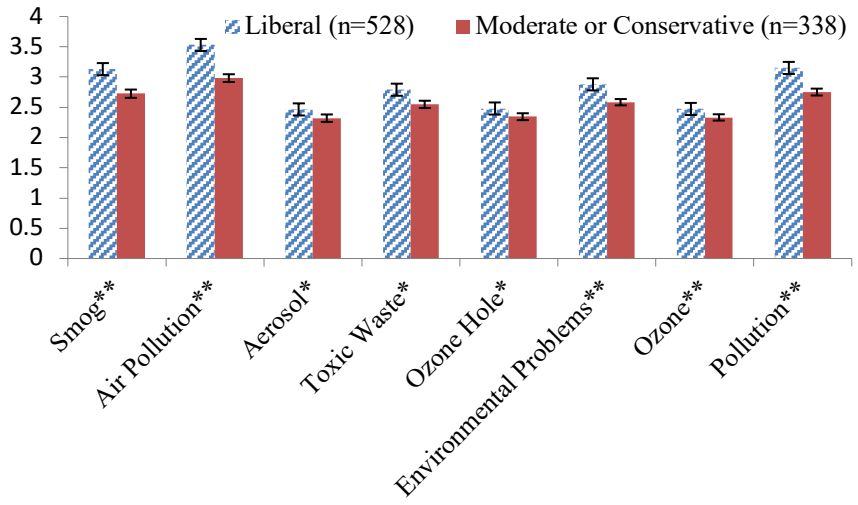


Figure 5. The average distance-from-correct for liberals and moderates/conservatives for all questions relating to environmental problems, ozone, and pollution with standard errors from the MTurk survey data. * difference significant at p=0.05, ** at p<0.01.

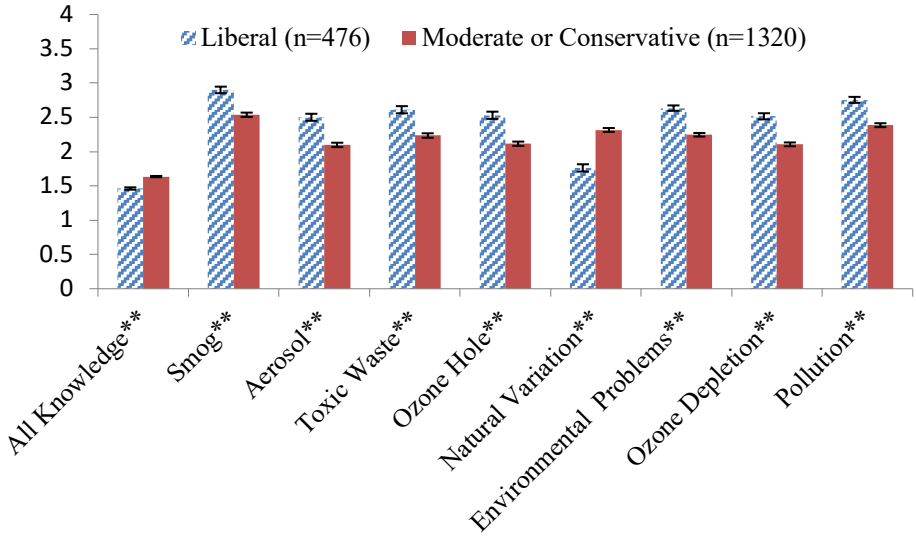


Figure 6. The average distance-from-correct for liberals and moderates/conservatives for all individual environmental problems questions, and the average of all questions relating to environmental problems, ozone, pollution, and natural climate variability with standard errors from the GfK survey data.* difference significant at p=0.05, ** at p<0.01.

Figure 7. Results of an ordered probit model of *concern* as a function of *ozone depletion, pollution, environmental problems*, and *natural variations* questions, where concern is determined by asking "How concerned are you about climate change?" Results reported as the marginal effect on the probability of a respondent expressing *A good deal* or *A great deal* of concern at the sample means. Only GfK data are used to estimate the model. All estimates with whiskers that do not cross zero are statistically significant. Details in Appendix 4.

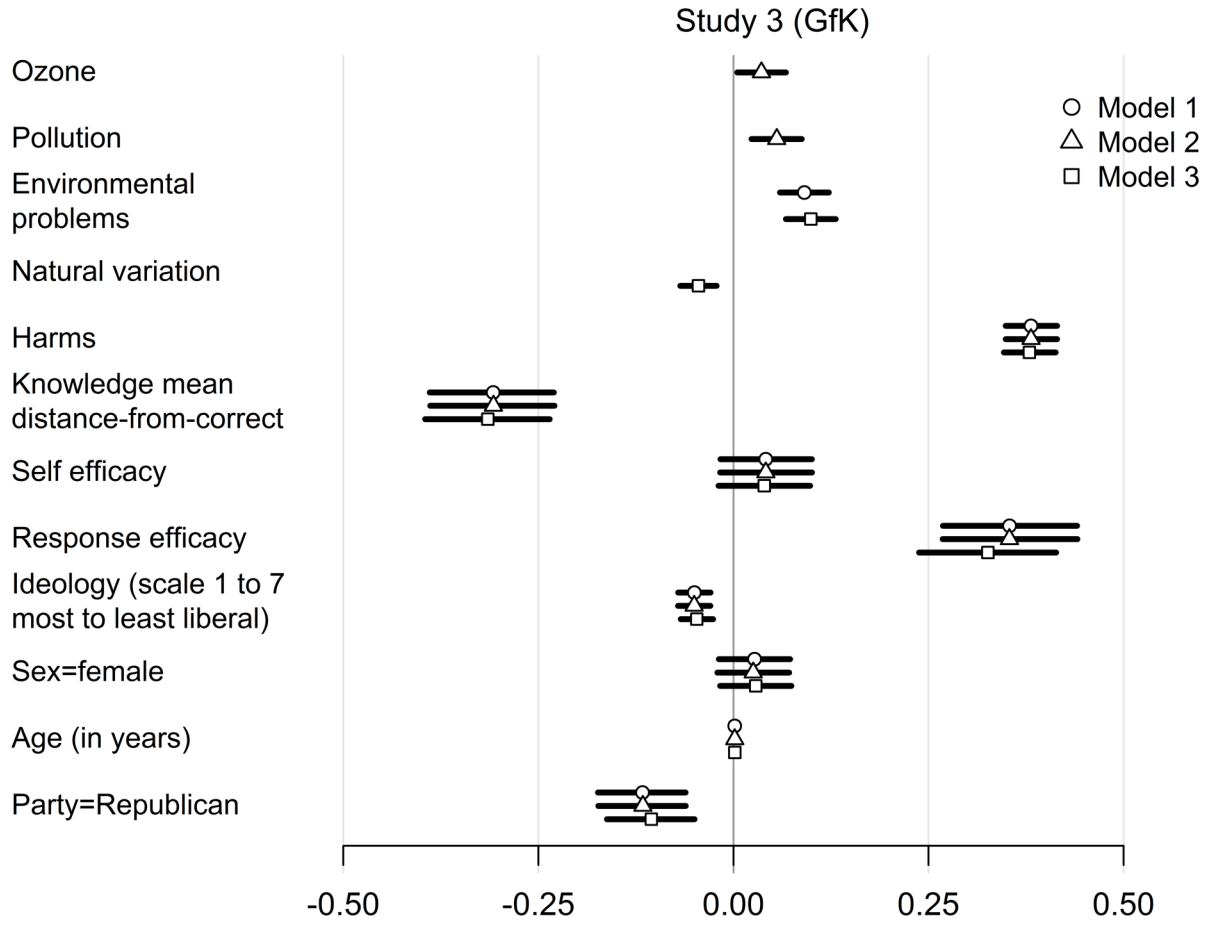
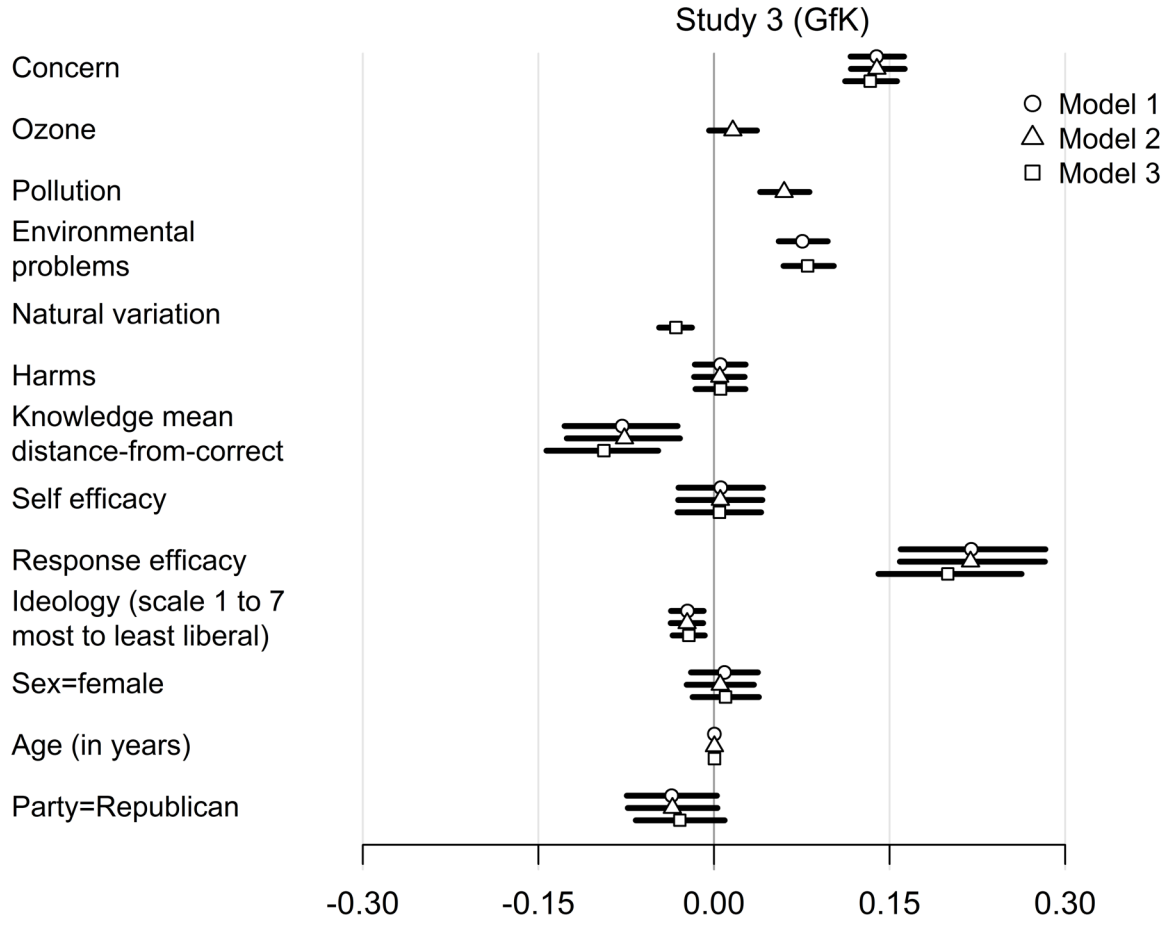


Figure 8. Results of an ordered probit model of policy support as a function of ozone depletion, pollution, environmental problems, and natural variations questions; results reported as the marginal effects on the probability of a respondent expressing slight or strong policy support at the sample means. Policy support is measured by the question "How much do you support or oppose reducing climate change by reducing carbon emissions?" (*Strongly Oppose, Slightly Oppose*, *Neither support nor oppos*e, *Slightly Support*, or *Strongly Support*). Only GfK data are used to estimate the model. All estimates with whiskers that do not cross zero are statistically significant. Details in Appendix 4.



Appendix 1. Climate Change Decision Model

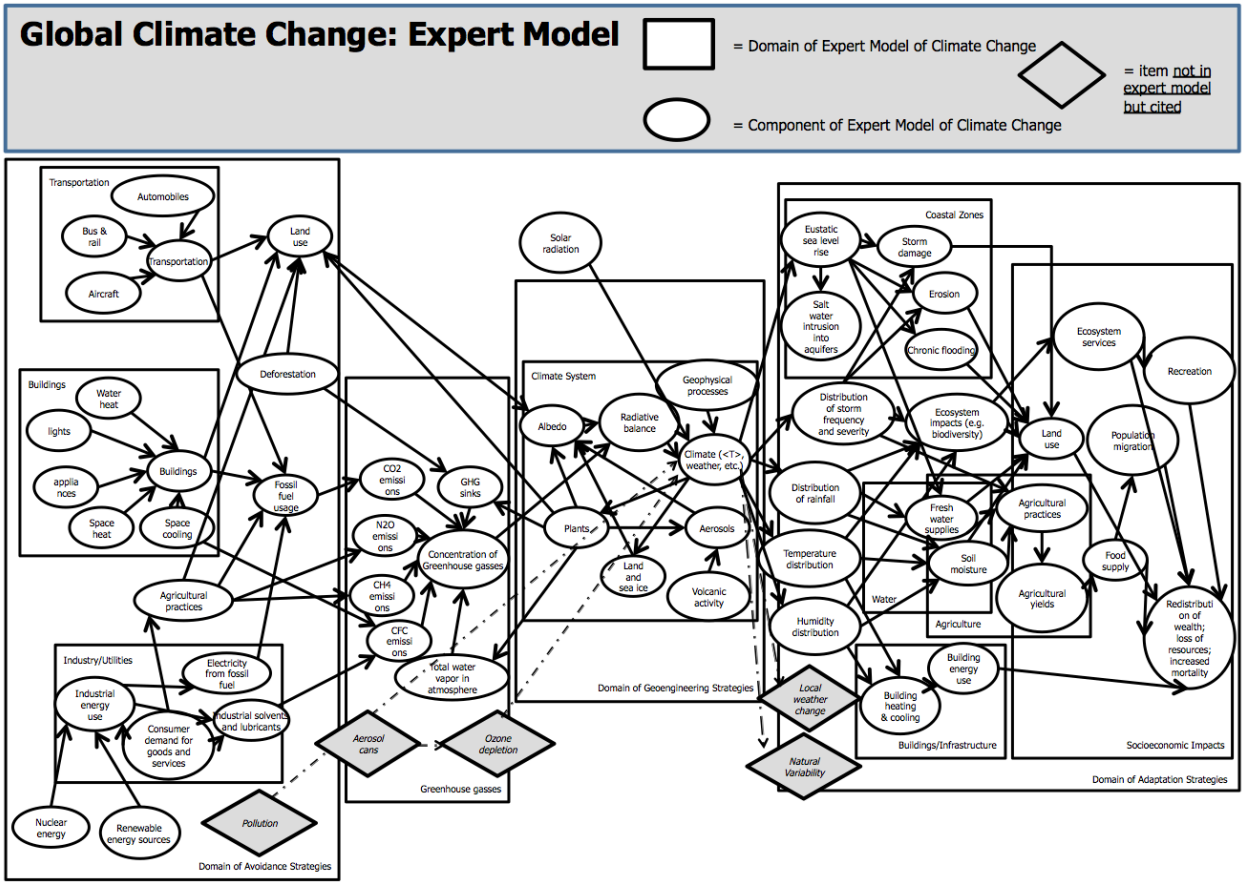


Figure A1.1. The influence diagram-type model developed at Carnegie Mellon University in the 1990's to support climate change risk reduction decisions, augmented subsequently to include commonly cited misconceptions.

Appendix 2. True or false knowledge questions posed to participants in the MTurk and GfK surveys.

MTurk Survey [the response coded as correct is indicated in brackets]

Global warming will lead to more and larger storms all over the world. [*True*]
**Ozone in cities (e.g., smog in Los Angeles) is a major cause of global warming. [*False*]
Cows, rice paddies, termites and swamps all contribute to global warming. *[True]*
Global warming is the main cause of species extinction today. [*False*]
Burning fossil fuels (e.g., coal and oil) is a major cause of global warming. [*True*]
**Air pollution is a major cause of global warming. [*False*]
The United States is among the top five nations contributing to global warming. [*True*]
The temperature of the earth is affected by the ocean. [*True*]
Your thoughtful responses on this survey will be helpful for our research. Although your response… [*True*]
The "greenhouse effect" will cause an increase in precipitation and humidity all over the earth. [*False*]
China is among the top five nations contributing to global warming. [*True*]
Global warming will lead to shorter, milder winters all over the world. [*False*]
Clearing tropical rainforests is a major cause of global warming. [*True*]
Global warming will contribute to war and large immigration problems in many places in the world. [*True*]
The concentration of carbon dioxide found in the Earth's atmosphere today has existed before, in... [*True*]

The space program is a major cause of global warming. [*False*]
The temperature of the earth is affected by the phase of the moon. [*False*]
Global warming will cause the ocean to flood all of New York City. [*False*]
The "greenhouse effect" is what keeps parts of the earth from being as cold as outer space. [*True*]
**Aerosol spray cans are a major cause of global warming. [*False*]
The temperature of the earth is affected by clouds. [*True*]
Global warming will increase the occurrence of skin cancer. [*False*]
Global warming will lead to a shortage of oxygen in the atmosphere. [*False*]
**Toxic wastes (e.g., hazardous chemicals in dumps) are a major cause of global warming. [*False*]
Global warming will contribute to agricultural problems and starvation in many places in the world. [*True*]
Use of nuclear power is a major cause of global warming. [*False*]
The temperature of the earth is affected by large volcanic eruptions. [*True*]
Bangladesh is among the top five nations contributing to global warming. [*False*]
The greenhouse effect occurs when the atmosphere traps solar heat as it reradiates from the ear... [*True*]
Global average sea level is the same or lower now than it was a century ago. [*False*]
*The hole in the Antarctic ozone layer is a major cause of global warming. [*False*]
The temperature of the earth is affected by the gases that make up the atmosphere. [*True*]
Deforestation is a major cause of global warming. [*True*]
The temperature of the earth is affected by whether the earth's surface is light or dark colored. [*True*]
The "greenhouse effect" will reduce photosynthesis in most plants. [*False*]
Overconsumption is a major cause of global warming. [*True*]
Global warming will lead to ecological disasters all over the world. [*True*]

GfK Survey
Climate means pretty much the same thing as weather. [*False*]
The earth’s climate has been pretty much the same for millions of years. [*False*]
The temperature of the earth is affected by the ocean. [*True*]
Cows, rice paddies, termites and swamps all contribute to global warming. [*True*]
**Ozone in cities (e.g., smog in Los Angeles) is a major cause of global warming. [*False*]
The "greenhouse effect" will cause an increase in precipitation and humidity all over the earth. [*False*]
China is among the top five nations contributing to global warming. [*True*]
Global warming will lead to shorter, milder winters all over the world. [*False*]
Clearing tropical rainforests is a major cause of global warming. [*True*]
Global warming will contribute to war and large immigration problems in many places in the world.
The space program is a major cause of global warming. [*False*]
The temperature of the earth is affected by the phase of the moon.
Global warming will cause the ocean to flood all of New York City. [*False*]
The "greenhouse effect" is what keeps parts of the earth from being as cold as outer space. [*True*]
**Aerosol spray cans are a major cause of global warming. [*False*]
The temperature of the earth is affected by clouds. [*True*]
Global warming will increase the occurrence of skin cancer. [*False*]
Global warming will lead to a shortage of oxygen in the atmosphere. [*False*]
**Toxic wastes (e.g., hazardous chemicals in dumps) are a major cause of global warming. [*False*]
Global warming will contribute to agricultural problems and starvation in many places in the world.
Use of nuclear power is a major cause of global warming. [*False*]
The temperature of the earth is affected by large volcanic eruptions. [*True*]
Bangladesh is among the top five nations contributing to global warming. [*False*]
The “greenhouse effect” occurs when the atmosphere traps solar heat as it reradiates from the earth. [*True*]
Global average sea level is the same or lower now than it was a century ago. [*False*]
*The hole in the Antarctic ozone layer is a major cause of global warming. [*False*]
The temperature of the earth is affected by the gases that make up the atmosphere. [*True*]
Deforestation is a major cause of global warming. [*True*]
The temperature of the earth is affected by whether the earth's surface is light or dark colored. [*True*]

The "greenhouse effect" will reduce photosynthesis in most plants. [*False*]
Overconsumption is a major cause of global warming.
Global warming will lead to ecological disasters all over the world. [*True*]
The United States is among the top five nations contributing to global warming. [*True*]

* Item used for ozone depletion
** Items are used as an index for pollution

Appendix 3. Procedure to model the mediating effect of concern on policy support.

Generate sample of betas:

(1) Bootstrap a dataset by drawing with replacement.
(2) Estimate both concern and policy support ordered probit models as specified.
(3) Repeat (1) and (2) until 10000 sets of estimates have been generated. When using imputed datasets, these bootstraps are drawn equally from each imputation.

Estimate effect of *Environmental Problems, Ozone, and Pollution* variables on policy support:

(1) Generate a bootstrapped dataset, and calculate the average value for the variable in question (environmental problems, ozone, or pollution), and denote this as the average `treatment' value T.
(2) Draw a set of coefficients from the generated sample of betas.
(3) For each observation in the bootstrapped dataset, calculate the predicted value of concern using two values for the treatment variable (one where treatment value equals T and another where the treatment value equals 0).
(4) For each predicted value of concern, calculate two predicted values of policy support using two values for the treatment variable (one where treatment value equals T and another where the treatment value equals 0) leaving the remainder of the values in the row the same as the original dataset (for the 2nd model, when there are two key independent variables, one variable at a time was isolated as the treatment for calculations in step (5) while the other variable took on its observed value).
(5) Calculate estimated total effect =
Policy_Support(concern(t=T),t=T) – Policy_Support(concern(t=0),t=0)
Calculate estimated direct effect =
Policy_Support(concern(t=0),t=T) – Policy_Support(concern(t=0),t=0)
Calculate estimated indirect effect =
Policy_Support(concern(t=T),t=0) – Policy_Support(concern(t=0),t=0)
(6) Repeat for 10,000 bootstraps (drawn equally from each imputation in the case of the MTurk study reported in the online supplement). Take the mean of all estimated effects as the expected effect and the values at 2.5 and 97.5 percentiles as the 95% confidence interval.

Appendix 4. Ordinal probit models for Concern (A4.1) and Policy support (A4.2) estimated for Study 3.

A 4.1. Marginal effects represent the marginal probability of being in the highest two concern categories (*A good deal*, or *A great deal* of concern).

	Dependent variable: Concern								
	Estimated marginal effect	Lower Bound .025	Upper bound .975	Estimated marginal effect	Lower Bound .025	Upper bound .975	Estimated marginal effect	Lower Bound .025	Upper bound .975
Environmental Problems	0.091	0.060	0.122				0.099	0.067	0.131
Ozone				0.036	0.005	0.067			
Pollution				0.055	0.023	0.087			
Natural variation							-0.045	-0.068	-0.022
Harms	0.381	0.349	0.415	0.381	0.349	0.415	0.379	0.346	0.413
Response efficacy	0.354	0.268	0.440	0.353	0.268	0.441	0.326	0.238	0.413
Self-efficacy	0.041	-0.017	0.100	0.041	-0.017	0.101	0.039	-0.019	0.098
Political ideology (=non-liberal)	-0.050	-0.071	-0.029	-0.050	-0.071	-0.030	-0.047	-0.068	-0.026
Sex=Female	0.027	-0.019	0.072	0.025	-0.021	0.071	0.028	-0.017	0.074
Age	0.002	0.000	0.003	0.002	0.000	0.003	0.002	0.000	0.003
Party=Republican	-0.117	-0.174	-0.062	-0.116	-0.173	-0.061	-0.105	-0.162	-0.050
Knowledge (=distance from correct)	-0.308	-0.389	-0.230	-0.308	-0.389	-0.229	-0.315	-0.395	-0.236
Adj. R^2	0.407			0.408			0.411		

A 4.2. Marginal effects represent the marginal probability of being in the highest two probability categories (*Slightly support* or *Strongly support*).

	Dependent variable: Policy support								
	Estimated marginal effect	Lower Bound .025	Upper bound .975	Estimated marginal effect	Lower Bound .025	Upper bound .975	Estimated marginal effect	Lower Bound .025	Upper bound .975
Environmental Problems	0.076	0.055	0.097				0.080	0.059	0.102
Ozone				0.016	-0.004	0.037			
Pollution				0.060	0.039	0.081			
Natural variation							-0.033	-0.047	-0.019
Concern	0.139	0.117	0.162	0.139	0.117	0.163	0.134	0.112	0.156
Harms	0.006	-0.016	0.027	0.005	-0.017	0.026	0.006	-0.016	0.027
Response efficacy	0.220	0.160	0.283	0.219	0.159	0.283	0.200	0.141	0.263
Self-efficacy	0.006	-0.030	0.042	0.005	-0.031	0.041	0.005	-0.031	0.040
Political ideology (=non-liberal)	-0.023	-0.037	-0.009	-0.023	-0.037	-0.009	-0.021	-0.035	-0.008
Sex=Female	0.009	-0.020	0.037	0.005	-0.023	0.034	0.010	-0.018	0.038
Age	0.000	-0.001	0.001	0.000	-0.001	0.001	0.000	0.000	0.001
Party=Republican	-0.036	-0.075	0.002	-0.036	-0.074	0.003	-0.029	-0.067	0.009
Knowledge (=distance from correct)	-0.078	-0.128	-0.031	-0.077	-0.126	-0.029	-0.094	-0.143	-0.048
Adj. R^2	0.380			0.382			0.386		

Appendix 5.

The variance inflation factors and the estimated coefficients and standard errors for the interaction terms of environmental harm with ideology and knowledge with ideology (linear regressions, MTurk data, data imputed for any knowledge questions missing at random.

A 5.1 Linear Regression and VIF

	Dependent Variable: Policy Support[1]				
	Coef.	Std. Err.	*t*-value	*p*-value	VIF
Concern	0.01	0.02	0.37	.714	1.57
Response Efficacy	0.26	0.04	6.16	<.001	1.55
Self-Efficacy	0.02	0.02	1.02	.310	1.11
Environmental Problems	0.03	0.01	3.25	.001	1.91
E. Problems x Ideology	0.08	.02	3.63	<.001	13.50
Knowledge	-0.25	0.04	-6.30	<.001	1.43
Ideology	-0.30	0.07	-4.22	<.001	14.42
Perceived Harm	0.08	0.01	4.40	<.001	3.06
Sex	0.04	0.02	2.13	.034	1.11
Age	0.00	0.01	0.80	.425	1.08
Party	0.06	0.03	2.22	.027	1.03

[1] $R^2 = 0.381$; adjusted $R^2 = 0.373$

A 5.2 Linear Regression

	Dependent Variable: Policy Support[1]				
	Coef.	Std. Err.	*t*-value	*p*-value	VIF
Concern	0.00	0.02	0.02	.981	1.56
Response Efficacy	0.26	0.04	6.23	<.001	1.55
Self-Efficacy	0.02	0.02	0.71	.478	1.11
Environmental Problems	0.05	0.01	4.04	<.001	1.83
Knowledge x Ideology	-0.02	.07	-0.24	.809	49.21
Knowledge	-0.27	0.05	-5.62	<.001	2.04
Ideology	-0.02	0.13	-0.17	.861	46.08
Perceived Harm	0.13	0.01	9.18	<.001	1.68
Sex	-0.04	0.02	2.14	.981	1.11
Age	-0.00	0.01	1.20	.229	1.08
Party	0.64	0.09	6.86	<.001	1.03

[1] $R^2 = 0.654$; adjusted $R^2 = 0.650$