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Key Points:
- Many Americans tend to see global warming as a distant threat, and opinions about the subject are highly polarized along political lines
- Informing people about the health effects of global warming can increase public engagement and reduce political polarization on the issue
- Some global warming health impacts are seen as more worrisome and novel than others, such as illnesses from contaminated food and water

Supporting Information:
- Supporting Information S1

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How Americans Respond to Information About Global Warming's Health Impacts: Evidence From a National Survey Experiment

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Abstract Americans tend to see global warming as a distant threat, but a small body of previous research suggests that information about the health implications of global warming may enhance public engagement with the issue. We sought to extend those findings with a longitudinal study that examined how Americans react to information about eight *specific categories* of health impacts from global warming. In winter 2017, we conducted a two-wave survey experiment using a quota sample of American adults (n = 2,254). Participants were randomly assigned to a treatment group who read eight brief essays about different categories of health impacts from global warming or to a control group who received no information. Participants answered questions before reading the essays, immediately after reading each essay and at the conclusion of all essays (treatment participants only), and 2–3 weeks later. Reading the information had small- to medium-sized effects on multiple indicators of participants' cognitive and affective engagement with global warming, especially among people who are politically moderate and somewhat conservative; some of these changes persisted 2–3 weeks later. Some impacts were seen as more novel and worrisome, including illnesses from contaminated food, water, and disease-carrying organisms. Our findings provide the most definitive evidence to date about the importance of raising awareness about the health impacts of global warming. While participants believed all of the essays as offered valuable information, educational efforts might most productively focus on impacts that are relatively less familiar and more emotionally engaging, such as food-, water-, and vector-borne illnesses.

Plain Language Summary Many people in the United States tend to see global warming as a distant threat despite the fact that it poses significant risks to public health. In this study, we found that informing people about the health implications of global warming can increase public engagement with the issue and reduce differences in opinion across political lines. Additionally, we found that people view certain health impacts from global warming differently from others. Notably, participants viewed information about illnesses from contaminated food and water, and disease-carrying organisms as more worrisome and novel compared to other types of health impacts from global warming.

1. Introduction

Climate change poses significant and varied risks to human health nationwide. As the climate continues to change, many associated health impacts are becoming more frequent, increasing in severity, and spreading over broader geographical regions. Documented health impacts include the spread of infectious diseases such as Lyme disease, injuries and deaths from extreme weather, and asthma and other lung conditions exacerbated by increased temperatures, decreased air quality, and longer allergy seasons. Some populations—especially children, older adults, those suffering from chronic illness, and people who live in low-income communities—are particularly at risk (U.S. Global Change Research Program, 2016).

Despite a large body of literature demonstrating climate-related health risks and the fact that the health consequences of climate change are arguably the most relevant aspect of the issue to most people (Maibach et al., 2010), most Americans appear to be largely unaware of the health impacts of climate change and who are most at risk (Leiserowitz et al., 2014; Maibach et al., 2015). This may be a consequence of the fact that there has been relatively little media coverage of the health harms of climate change, and this reporting has generally focused on a broad discussion of health implications, with little attention to specific categories of impacts, and to how specific climate- and weather-related factors affect human health (Weathers, 2013; Weathers & Kendall, 2016).

A bedrock principle of public health practice is to inform people of the risks they face so that they can be productively involved in decisions about how best to manage those risks (Institute of Medicine, 2015; Maibach et al., 2007). Regrettably, partisan news coverage and misinformation campaigns about climate change created to protect the interests of fossil fuel companies have led to a stark polarization between liberals and conservatives about the issue, which in turn has led to political gridlock on climate solutions and is indirectly seriously harming the public's health (Dunlap et al., 2016; Dunlap & McCright, 2011; Feldman et al., 2012, 2014; Merkley & Stecula, 2018). Ironically, many approaches to informing the American public about climate change, such as framing it as an environmental or complex scientific issue, have likely contributed to this polarization. Framing theory posits that the way information about an issue is framed—giving greater weight to certain dimensions of the issue over others—can shape the way people think and feel about the issue. Frames in communication can increase the salience and perceived applicability of certain considerations for audiences when forming attitudes about that issue, resulting in an emphasis framing effect (Chong & Druckman, 2007). Decades of psychological research on duel process models of persuasion have demonstrated that perceived personal relevance of the information is a key contributor to attitude formation (Johnson & Eagly, 1989; Petty & Cacioppo, 1986). Yet research shows that the dominant images Americans associate with climate change are melting ice and threats to non-human nature, impacts that are distant from the everyday experiences of Americans (Leiserowitz, 2006; Smith & Leiserowitz, 2012). Focusing on these aspects of the topic reinforces the perception that the threat of climate change is temporally and spatially distant, which in turn makes it difficult for many people—particularly on the conservative end of the political spectrum—to see the personal relevance of the issue (Feinberg & Willer, 2013; Nisbet, 2009; Spence et al., 2012). Lastly, framing climate change as an environmental issue is vulnerable to a common counterargument among opponents of action that there is a tradeoff between protecting the environment and growing the economy such that societal efforts to address climate change would have severe economic consequences (Nisbet, 2009).

Previous research suggests that health-framed information about climate change—information that conveys the relevance of climate change and related energy choices to people's health—may have the potential to reduce political polarization and foster public engagement with the issue in a manner beneficial to both personal and collective risk management decisions (Maibach et al., 2010; Myers et al., 2012; Petrovic et al., 2014). These previous studies, however, are limited by the use of convenience samples (Maibach et al., 2010; Petrovic et al., 2014), or by a narrow range of outcome measures, such as a focus on only emotional responses (Myers et al., 2012). Therefore, in this study we sought to expand on previous research by using a higher-quality sample to measure the impact of providing climate and health information and by assessing a broader array of key beliefs that are predictive of risk perceptions (van der Linden, 2015), support for policies to address global warming (Ding et al., 2011), and behavioral engagement on the issue (Roser-Renouf et al., 2014). We specifically hypothesized that exposure to information about the different health impacts of global warming would increase key indicators of personal engagement with the issue, including (a) affective assessment that global warming is bad for people's health and certainty in this assessment, (b) perceived personal importance of global warming, (c) worry about global warming, (d) perceived personal harm from global warming, (e) perceived harm to future generations from global warming, and (f) injunctive beliefs about global warming (i.e., the view that society should respond to the problem).

Moreover, we sought to assess how audiences evaluate information about *specific categories* of health impacts from global warming, important information that has not been assessed in prior research. When developing educational strategies, it is important to understand prior perceptions and reactions to information about the topic. Certain subjective reactions—such as perceived relevance and novelty of the information, ease of understanding, and perceived temporal significance—can affect people's receptivity to the information (O'Keefe, 2015; Spence et al., 2012). Therefore, we sought to assess how people evaluate eight different essays—each about a specific category of health effects from global warming—in terms of five important subjective reactions: (a) perceived relevance of the information, (b) perceived novelty of the information, (c) ease of understanding, (d) negative emotional response, and (e) perceived timing of the impacts.

Finally, we sought to explore whether reactions to information about the health effects of global warming differ depending upon audience characteristics. Epidemiologic research has shown that certain populations are more vulnerable to the negative effects of global warming, including people with preexisting medical conditions (U.S. Global Change Research Program, 2016), and that these vulnerable groups are more likely

to feel like they are already at risk from global warming (Akerlof et al., 2015). Additionally, attitudes toward global warming are highly polarized in terms of political ideology, with liberals being more concerned and supportive of action to address global warming relative to conservatives (Dunlap et al., 2016; McCright & Dunlap, 2011). Therefore, we examined whether the effects of information about the health impacts of global warming are moderated by (a) political ideology and/or (b) presence of a chronic health condition. Specifically, we sought to determine if the information reduces political polarization among liberals and conservatives and has a larger impact on individuals with a chronic conditions given that they are more vulnerable.

2. Materials and Methods

2.1. Participants

Participants were a demographically diverse group of American adults who were quota sampled (balanced on gender, age, education, income, Hispanic ethnicity, race, and political ideology) to approximate a nationally representative sample. Recruitment was conducted in Winter 2017 by P2Sample, a vendor that maintains a nationwide nonprobability panel of individuals who have agreed to participate in online surveys (for more information about P2Sample, see their website: https://try.p2sample.com/). A total of 2,254 people participated in the first wave of data collection. Two to three weeks later, participants were contacted again to answer additional questions; 1,331 (59%) participated in this second wave of data collection.

To determine whether there were systematic patterns in whether people participated in the second survey, we regressed participation in the second survey (T3) on race, gender, age, education, income, Hispanic identity, political ideology, presence of a chronic condition, and experimental condition and on all outcome variables measured at T1. This analysis revealed that individuals who were older were more likely to participate in the second survey, but no other variables were significantly associated with participation in the second survey (see Table S24 in the supporting information).

2.2. Study Design

We conducted a randomized experiment with a longitudinal design (Shadish et al., 2002). In the initial data collection, participants were randomly assigned to one of two groups after responding to six pretest questions about their global warming beliefs (referred to here as T1 data collection; see details below). Control group participants did not receive any information about the health impacts of global warming; they only answered questions about the issue ($N_{\text{Wave 1}}$ = 401). Treatment group participants ($N_{\text{Wave 1}}$ = 1853) read eight short essays about health impacts of climate change (approximately 150 words each), in random order, that were based on information contained in the 2016 National Climate and Health Assessment (Note: The sample size of the treatment group was larger so that we could make within-subject comparisons to explore how people differentially evaluated the eight different essays). Each essay asked and briefly answered three questions about a category of health impacts: What's happening? (i.e., How is our climate changing?) How does that harm our health? and Who is being harmed? The health impact categories were extreme heat; poor air quality; extreme weather events; diseases spread by insects, ticks, and rodents; contaminated water; contaminated food; hunger and malnutrition; and mental health problems (see Text S2 for the essays).

After reading each essay, individuals were asked to answer a number of questions about the information they had read (see details below). These questions were repeated a total of eight times, once after each essay. Following exposure to all eight essays, individuals in the treatment group were asked the pretest questions again (referred to here as T2 data collection). The median time to complete the initial survey was 19.3 min in the treatment group and 5.1 min in the control group; the treatment condition contained more survey questions than the control condition. We did not record the time spent reading each essay.

Two to three weeks later, in the second wave of data collection, treatment participants ($N_{\text{Wave 2}}$ = 1,104; 60% of Wave 1 treatment participants responded) and control group participants ($N_{\text{Wave 2}}$ = 227; 57% of Wave 1 control participants responded) received the same set of questions about their global warming beliefs (referred to here as T3 data collection; details below). No further treatments were administered.

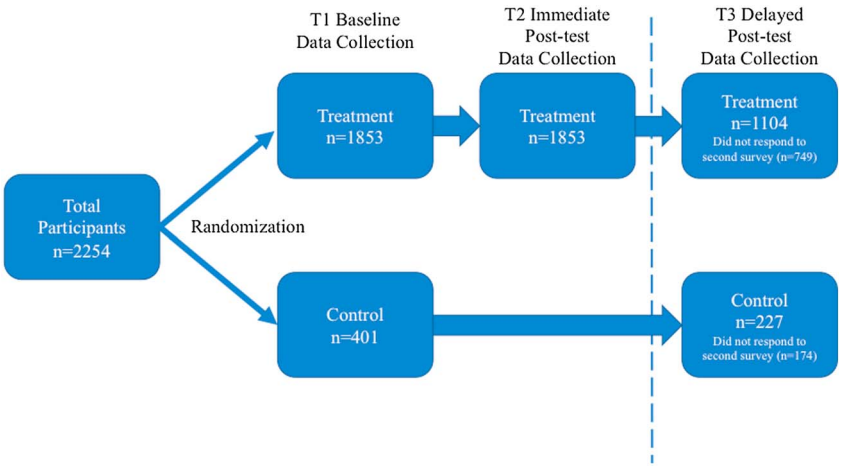

Figure 1. Visual description of study design, participant recruitment, and retention.

Figure 1 presents a visual representation of the study design. Written consent was obtained from all participants both at the beginning of the initial data collection and at the beginning of the second wave of data collection.

2.3. Dependent Variables: Global Warming Beliefs

All participants answered questions to assess six dependent variables at the beginning of the first data collection (i.e., T1) and during the second wave of data collection (i.e., T3, delayed posttest). Treatment group participants also answered these questions at the end of the first data collection (i.e., T2, immediate posttest). An additional dependent measure—injunctive beliefs—was measured at T3 only for all participants.

2.3.1. Affective Assessment of the Health Impact of Global Warming

An affective assessment of how good or bad global warming is for human health was measured with a single 11-point item: "On a scale from −5 (very bad) to +5 (very good), do you think global warming is bad or good for the health of people in your community?"

2.3.2. Affective Assessment Certainty

Certainty in the affective assessment was measured with a single 7-point item: "How certain (or uncertain) are you about your answer to the previous question regarding how bad or good you think global warming is for the health of people in your community?" The scale was anchored at three points: 1 (*very uncertain*), 4 (*neither uncertain nor certain*), and 7 (*very certain*).

2.3.3. Personal Issue Importance

Personal issue importance of global warming was measured with a single 5-point item: "How important is the issue of global warming to you personally?" The scale was anchored at three points: 1 (*not at all important*), 3 (*somewhat important*), and 5 (*extremely important*).

2.3.4. Worry About Global Warming

Worry about global warming was measured with a single 4-point item: "How worried are you about global warming?" (1 = *not at all worried*; 4 = *very worried*).

2.3.5. Perceived Harm to Self

Perceived harm to self from global warming was measured with a single 4-point item that included an additional "Don't know" response option: "How much do you think global warming will harm you personally?" (1 = *not at all*; 4 = *a great deal*). Respondents that chose "Don't know" were excluded from analysis (5.8% at T1, 4.6% at T2, and 4.1% at T3).

2.3.6. Perceived Harm to Future Generations

Perceived harm to future generations from global warming was measured with a single 4-point item that included an additional "Don't know" response option: "How much do you think global warming will harm future generations of people?" (1 = *not at all*; 4 = *a great deal*). Respondents that chose "Don't know" were excluded from analysis (3.6% at T1, 3.0% at T2, and 2.6% at T3).

Table 1
Means and Standard Errors for Global Warming Beliefs by Political Ideology at Time 1 and Time 2

		Affective assessment		Affective assessment certainty		Issue importance		Worry about global warming		Perceived harm to self		Perceived harm to future generations	
Group	Time	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Total	T1	−1.96	0.06	5.18	0.04	3.59	0.03	3.01	0.02	2.80	0.03	3.38	0.02
	T2	−2.49	0.07	5.36	0.05	3.62	0.03	3.11	0.02	2.94	0.02	3.42	0.02
Very liberal	T1	−2.33	0.17	5.52	0.11	4.29	0.07	3.50	0.06	3.30	0.07	3.69	0.06
	T2	−2.64	0.18	5.60	0.12	4.21	0.08	3.54	0.06	3.39	0.06	3.70	0.06
Somewhat	T1	−2.79	0.15	5.19	0.10	3.94	0.06	3.36	0.05	3.02	0.06	3.78	0.05
liberal	T2	−3.05	0.16	5.38	0.11	3.94	0.07	3.43	0.05	3.13	0.06	3.76	0.05
Moderate	T1	−2.24	0.10	5.02	0.07	3.62	0.04	3.07	0.03	2.89	0.04	3.54	0.03
	T2	−3.01	0.10	5.31	0.07	3.73	0.04	3.22	0.03	3.04	0.04	3.61	0.03
Somewhat	T1	−1.58	0.13	4.89	0.08	3.19	0.05	2.71	0.04	2.50	0.05	3.17	0.05
conservative	T2	−2.43	0.13	5.10	0.09	3.27	0.06	2.85	0.04	2.73	0.05	3.30	0.04
Very	T1	−0.88	0.15	5.28	0.10	2.93	0.06	2.41	0.05	2.30	0.06	2.70	0.05
conservative	T2	−1.35	0.16	5.41	0.11	2.93	0.07	2.51	0.05	2.41	0.06	2.74	0.05

Note. *SE* = standard error.

2.3.7. Injunctive Beliefs

Injunctive beliefs about how much effort should be made to address global warming was measured with five 7-point items that asked whether the following entities should be doing more or less to protect people from health problems caused by global warming: The President, The U.S. Congress, Federal agencies, Your state government, and Your local government. (1 = *much less*; 4 = *about the same*; 7 = *much more*). Cronbach's ? = 0.97.

2.4. Essay Evaluations

Respondents in the treatment group were asked a series of 12 evaluative questions after each essay. Descriptive statistics for these measures are presented in Table 1; information about scale reliability within each impact category (where relevant) is presented in Table S2.

Our construction of the measures for perceived relevance, perceived novelty of the information, and the ease of understanding the information was informed by an exploratory factor analysis because these items were all asked within the same question block. We also used exploratory factor analysis to inform our construction of the scale for the negative emotional response variable because all of the emotional response items were assessed in the same question block. Further details about these factor analyses can be found in Text S1 in the supporting information.

2.4.1. Perceived Relevance

Perceived essay relevance was measured with four 7-point bipolar semantic differential items: uninteresting/interesting, useful/useless, doesn't apply to me/does apply to me, and worth sharing with others/not worth sharing with others. Average Cronbach's ? = 0.84 across all eight categories (Min ? = 0.83, Max ? = 0.86).

2.4.2. Perceived Novelty of the Information

Perceived novelty of the information was measured with two 7-point bipolar semantic differentials: unsurprising/surprising and familiar to me/unfamiliar to me. We used the Spearman-Brown coefficient to assess reliability of this measure because it has been recommended as the most appropriate statistic for two item scales (Eisinga et al., 2013). Average Spearman-Brown coefficient = 0.48 across all eight categories (Min Spearman-Brown coefficient = 0.43, Max Spearman-Brown coefficient = 0.50).

2.4.3. Ease of Understanding the Information

Perceived ease of understanding the information was assessed with a single 7-point bipolar semantic differential: hard to understand/easy to understand. Higher values indicate that the information was easier to understand.

2.4.4. Negative Emotional Response

Emotional responses to the information were assessed with four 7-point items: "How much did you feel the following emotions while reading about the health effects of [IMPACT] caused by global warming?" (1 = *not*

at all; 4 = *a moderate amount*; 7 = *a great deal*). The emotions were fear, helplessness, anger, and disgust. Average Cronbach's ? = 0.93 across all eight health impact categories (Min ? = 0.92, Max ? = 0.94).

2.4.5. Timing of the Impacts

Perceived timing of the impacts described in each essay was measured with a single 6-point item: "When do you think global warming will begin to make health problems from [IMPACT] worse for people in your community?" Response options were 1 (*this is happening already*), 2 (*in 10 years*), 3 (*in 25 years*), 4 (*in 50 years*), 5 (*in 100 years*), and 6 (*never*).

2.5. Moderator Variables

2.5.1. Political Ideology

Political ideology was measured with a single 5-point item (1 = *very liberal*; 2 = *somewhat liberal*; 3 = *moderate, middle of the road*; 4 = *somewhat conservative*; 5 = *very conservative*).

2.5.2. Presence of Chronic Health Conditions

Participants were asked to indicate whether they had the following conditions: coronary heart disease, diabetes, obesity, lung illness (including asthma), or a physical or mental disability. If participants indicated that they had at least one of these conditions, they were coded as having a chronic health condition (39.6% of the sample at Wave 1 and 40.0% at Wave 2). Otherwise, if participants did not possess any of these conditions they were coded as not having a chronic health condition (60.4% at Wave 1 and 60% at Wave 2).

2.6. Analysis

To examine the short-term effects of reading the essays, we ran mixed design analyses of variance, with time (T1: pretest vs. T2: immediate posttest) as a within-subjects factor and political ideology and presence of a chronic condition as between-subjects factors. These two sets of analyses relied solely upon responses from the treatment group because only individuals in the treatment group received the essays and had their global warming beliefs measured at T1 and T2. A Bonferroni adjustment was used for all pairwise comparisons.

To examine the longer-term effects of the essays at T3 (delayed posttest), we conducted between-subject analyses of covariance with experimental condition (control vs. treatment), political ideology, and presence of a chronic condition as between-subject factors. Baseline (T1) global warming beliefs were included as covariates in these models, except for the model examining effects on injunctive beliefs, because this variable was only measured at T3. Age, gender, education, income, Hispanic ethnicity, and race were used as covariates in these models. A Bonferroni adjustment was used for all pairwise comparisons.

Effect size estimates for specific contrasts are provided in terms of Pearson's *r*. The effect size descriptors—small, medium, and large—are specific to communication research and were derived from a quantitative review of meta-analyses (Weber & Popova, 2012). A small effect refers to a Pearson's *r* value of less than 0.10, a medium effect refers to values of *r* between 0.10 and 0.25, and a large effect refers to values of *r* greater than 0.25 (Weber & Popova, 2012).

To explore how people evaluated the impact essays, we conducted a series of mixed design analyses of variance with impact category as a within-subjects factor and political ideology and presence of a chronic condition as between-subject factors. Again, a Bonferroni adjustment was used for all pairwise comparisons.

To assess the impact of sample mortality from the first wave of data collection to the second, we regressed participation in the second survey (T3) on race, gender, age, education, income, Hispanic identity, political ideology, presence of a chronic condition, and experimental condition and on all outcome variables measured at T1.

Missing data were excluded listwise from all analyses because less than 1% of data were missing on all variables, with the exception of perceived harm to self and perceived harm to future generations. For these two variables, the slightly larger proportion of missing data was due to some respondents choosing the "Don't know" response option that was available for these two questions, which we treated as missing data. Because we consider a "Don't know" to be an intentional and valid response, it would be inappropriate to use alternative methods for handling these missing cases, such as data imputation. SPSS Version 24 was used for all analyses.

Table 2a
Immediate Posttest Treatment Effects for Global Warming Beliefs by Political Ideology (Time 1 vs. Time 2)

	Affective assessment				Affective assessment certainty				Issue importance			
Group	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*
Total	−0.53	0.05	0.00	0.24	0.18	0.05	0.00	0.09	0.02	0.02	0.25	0.03
Very liberal	−0.31	0.13	0.02	0.02	0.07	0.12	0.55	0.01	−0.08	0.05	0.11	0.04
Somewhat liberal	−0.26	0.12	0.03	0.05	0.19	0.11	0.08	0.04	0.00	0.05	0.95	0.00
Moderate	−0.77	0.08	0.00	0.23	0.28	0.07	0.00	0.10	0.11	0.03	0.00	0.09
Somewhat conservative	−0.85	0.10	0.00	0.20	0.22	0.09	0.02	0.06	0.08	0.04	0.03	0.05
Very conservative	−0.47	0.12	0.00	0.09	0.13	0.11	0.21	0.03	−0.01	0.05	0.90	0.00

Note. SE = standard error.

3. Results

3.1. Short-Term Essay Treatment Effect (Immediate Posttest)

After reading information about the health effects of global warming participants revised their affective assessment of the health impact of global warming, rating it as worse for health (specifically, more "bad"), as compared to their baseline rating, $F(1, 1840) = 111.87$, $p < 0.001$, $r = 0.24$ (see Table 1 for means and standard errors). This effect was moderated by political ideology, $F(4, 1840) = 6.40$, $p < 0.001$, such that moderate and somewhat conservative participants demonstrated a medium effect size, while those who were very liberal, somewhat liberal, and very conservative demonstrated a small effect size (see Table 2a). The treatment effect was also moderated by presence of a chronic condition, $F(1, 1840) = 4.71$, $p = 0.03$, such that the effect was larger among those with a chronic condition compared to those without one (see Tables 3 and 4a).

Moreover, participants became more certain about their affective assessments after reading the essays $F(1, 1844) = 15.61$, $p < 0.001$, $r = 0.09$ (see Table 1). This effect was not moderated by political ideology but was moderated by the presence of a chronic condition, $F(1, 1844) = 13.00$, $p < 0.001$, such that only individuals with a chronic health condition increased the certainty of their assessment (see Tables 3 and 4a).

Reading the essays did not have a significant main effect on perceived personal importance of global warming, $F(1, 1844) = 1.32$, $p = 0.25$, $r = 0.03$; however, there was a significant interaction with political ideology, $F(4, 1844) = 3.77$, $p = 0.005$ (see Table 1) and presence of a chronic condition $F(1, 1844) = 16.86$, $p < 0.001$ (see Table 3). Participants who were politically moderate and those who were somewhat conservative showed a small but significant increase in perceived importance of global warming, while liberal and very conservative participants did not (see Table 2a). Participants with a chronic condition rated global warming as more important after reading the essays whereas those without a chronic condition rated global warming as less important (see Table 4a).

There was also a significant main effect of treatment on worry about global warming, $F(2, 1843) = 38.85$, $p < 0.001$, $r = 0.14$, such that after reading the essays participants reported being more worried about global warming—demonstrating a medium effect size (see Tables 1 and 2b).

Table 2b
Immediate Posttest Treatment Effects for Global Warming Beliefs by Political Ideology (Time 1 vs. Time 2)

	Worry about global warming				Perceived harm to self				Perceived harm to future generations			
Group	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*
Total	0.10	0.02	0.00	0.14	0.14	0.02	0.00	0.18	0.05	0.02	0.00	0.07
Very liberal	0.04	0.04	0.33	0.02	0.09	0.05	0.06	0.05	0.01	0.04	0.82	0.01
Somewhat liberal	0.06	0.04	0.09	0.04	0.11	0.04	0.01	0.06	−0.01	0.04	0.68	0.01
Moderate	0.14	0.02	0.00	0.14	0.14	0.03	0.00	0.12	0.07	0.02	0.00	0.07
Somewhat conservative	0.14	0.03	0.00	0.10	0.24	0.04	0.00	0.16	0.13	0.03	0.00	0.10
Very conservative	0.10	0.04	0.01	0.06	0.12	0.04	0.01	0.07	0.04	0.04	0.29	0.03

Note. SE = standard error.

Table 3
Means and Standard Errors for Global Warming Beliefs by Presence of a Chronic Condition at Time 1 and Time 2

		Affective assessment		Affective assessment certainty		Issue importance		Worry about global warming		Perceived harm to self		Perceived harm to future generations	
Group	Time	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Total	T1	−1.96	0.06	5.18	0.04	3.59	0.03	3.01	0.02	2.80	0.03	3.38	0.02
	T2	−2.49	0.07	5.36	0.05	3.62	0.03	3.11	0.02	2.94	0.02	3.42	0.02
No chronic condition	T1	−1.91	0.08	5.28	0.05	3.61	0.03	3.00	0.03	2.80	0.03	3.36	0.03
	T2	−2.34	0.08	5.30	0.06	3.56	0.04	3.08	0.03	2.90	0.03	3.37	0.03
Chronic condition	T1	−2.02	0.10	5.08	0.06	3.58	0.04	3.02	0.03	2.81	0.04	3.40	0.03
	T2	−2.65	0.10	5.42	0.07	3.67	0.04	3.14	0.03	2.98	0.04	3.47	0.03

Note. SE = standard error.

We also observed a significant main effect of treatment on increased perceived personal harm from global warming—with a medium effect size, $F(1, 1690) = 57.65$, $p < 0.001$, $r = 0.18$ (see Table 1). This effect was not moderated by political ideology but was moderated by presence of a chronic condition, $F(1, 1690) = 4.19$, $p = 0.041$, such that participants with a chronic condition had a larger increase in perceived personal harm compared to those without one (see Tables 3 and 4a). Moreover, we observed a small but significant main effect of treatment resulting in an increase in perceived harm to future generations, $F(1, 1748) = 9.16$, $p = 0.003$, $r = 0.07$. This effect was moderated by political ideology, $F(4, 1748) = 2.89$, $p = 0.021$, and presence of a chronic condition, $F(1, 1748) = 4.16$, $p = 0.042$ (see Tables 1 and 3). Specifically, only politically moderate and somewhat conservative participants (Table 2b), and those with a chronic condition (Table 4b), showed an increase in perceived harm to future generations.

3.2. Longer-Term Essay Treatment Effects (2- to 3-Week Posttest)

Two to three weeks later, in a between-group comparison of the treatment versus the control group, there was no evidence of a treatment effect on affective assessment of the health impact of global warming, $F(1, 1312) = 1.75$, $p = 0.186$, $r = 0.04$ (see Table 5). However, we did find a small and significant main effect such that individuals in the treatment condition were more certain that global warming is *bad* for health compared to control $F(1, 1312) = 7.80$, $p = 0.005$, $r = 0.08$ (see Table 5).

Similarly, there was no between-group main effect of treatment on personal issue importance of global warming $F(1, 1312) = 0.15$, $p = 0.70$, $r = 0.01$; however, there was a significant interaction with political ideology $F(4, 1312) = 4.02$, $p = 0.003$ (see Table 5). Participants who were somewhat conservative showed a small but significant increase in personal issue importance relative to control, while very conservative participants showed a small but significant decrease in personal issue importance compared to control (see Table 6a).

There also was no significant main effect of treatment on worry about global warming $F(1, 1311) = 0.001$, $p = 0.978$, $r = 0.001$. However, there was a significant interaction with political ideology $F(4, 1311) = 3.68$, $p = 0.005$, such that political moderates demonstrated a small but significant increase in worry about global warming relative to control. There was no change in worry among respondents in other political subgroups (see Tables 5 and 6b).

Table 4a
Immediate Posttest Treatment Effects for Global Warming Beliefs by Presence of a Chronic Condition (Time 1 vs. Time 2)

	Affective assessment				Affective assessment certainty				Issue importance			
Group	Mean Diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*
Total	−0.53	0.05	0.00	0.24	0.18	0.05	0.00	0.09	0.02	0.02	0.25	0.03
No chronic condition	−0.43	0.06	0.00	0.16	0.03	0.06	0.64	0.01	−0.05	0.02	0.03	0.05
Chronic condition	−0.63	0.07	0.00	0.19	0.33	0.07	0.00	0.11	0.10	0.03	0.00	0.08

Note. SE = standard error.

Table 4b
Immediate Posttest Treatment Effects for Global Warming Beliefs by Presence of a Chronic Condition (Time 1 vs. Time 2)

	Worry about global warming				Perceived harm to self				Perceived harm to future generations			
Group	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*
Total	0.10	0.02	0.00	0.14	0.14	0.02	0.00	0.18	0.05	0.02	0.00	0.07
No chronic condition	0.07	0.02	0.00	0.09	0.10	0.02	0.00	0.11	0.02	0.02	0.37	0.02
Chronic condition	0.12	0.02	0.00	0.12	0.18	0.03	0.00	0.15	0.08	0.02	0.00	0.08

Note. *SE* = standard error.

There was no between-group treatment effect at T3 on personal issue importance $F(1, 1316) = 1.15$, $p = 0.28$; perceived harm to self $F(1, 1209) = 2.40$, $p = 0.122$; perceived harm to future generations $F(1, 1241) = 0.12$, $p = 0.728$; or injunctive beliefs $F(1, 1313) = 0.18$, $p = 0.67$.

3.3. Essay Evaluations

The essays differed with regard to participant's evaluations of perceived relevance, $F(6.73, 12375) = 36.97$, $p < 0.001$. Mental health impacts were seen as less relevant than all other impact categories ($p < 0.001$). Hunger and malnutrition impacts were also viewed as less relevant than the other impact categories ($p < 0.01$), except extreme heat, extreme weather events, and mental health problems (see Table 7). These evaluations did not differ among participants based on their political ideology, but there was a significant interaction based on the presence of a chronic condition, $F(6.73, 12375) = 4.32$, $p < 0.001$. Participants with a chronic condition tended to see information about each of the impacts as more personally relevant compared to those without one, especially poor air quality and mental health problems (see Table S22).

The essays also differed with regard to perceived novelty of the information, $F(6.51, 11943) = 125.81$, $p < 0.001$. Specifically, information about the health effects of vector-borne illness, contaminated water, contaminated food, hunger and malnutrition, and mental health problems caused by global warming were seen as more novel than information about extreme heat, poor air quality, and extreme weather events ($p < 0.001$; see Table 7). Furthermore, information about contaminated food, hunger and malnutrition, and mental health problems were viewed as more novel than information about vector-borne illness and contaminated water ($p < 0.001$). Finally, information about mental health problems caused by global warming were seen as more novel than information about contaminated food and hunger and malnutrition ($p < 0.001$).

Essay evaluations also differed with regard to negative emotional responses generated, $F(6.81, 12511) = 30.49$, $p < 0.001$. Information about contaminated water and contaminated food elicited a more

Table 5
Means and Standard Errors for Global Warming Beliefs by Political Ideology for Control and Treatment Groups

		Affective assessment		Affective assessment certainty		Issue importance		Worry about global warming		Perceived harm to self		Perceived harm to future generations		Injunctive beliefs	
Group	Time	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Total	Control	−2.11	0.15	5.05	0.11	3.63	0.05	3.08	0.04	2.80	0.05	3.44	0.04	5.42	0.11
	Treatment	−2.32	0.07	5.39	0.05	3.65	0.02	3.08	0.02	2.89	0.02	3.45	0.02	5.37	0.05
Very Liberal	Control	−2.50	0.41	5.06	0.30	3.64	0.14	3.29	0.12	2.82	0.14	3.49	0.12	6.26	0.30
	Treatment	−2.75	0.19	5.63	0.14	3.74	0.06	3.12	0.05	3.01	0.06	3.57	0.05	5.93	0.14
Somewhat liberal	Control	−2.43	0.33	4.92	0.24	3.62	0.11	3.22	0.09	2.86	0.11	3.49	0.09	5.91	0.24
	Treatment	−2.54	0.16	5.38	0.12	3.73	0.05	3.15	0.04	2.93	0.05	3.51	0.04	5.95	0.12
Moderate	Control	−1.86	0.22	4.77	0.17	3.56	0.07	2.85	0.06	2.88	0.07	3.44	0.06	5.62	0.16
	Treatment	−2.50	0.10	5.34	0.07	3.66	0.03	3.07	0.03	2.90	0.03	3.46	0.03	5.59	0.07
Somewhat conservative	Control	−1.64	0.29	4.87	0.22	3.43	0.10	2.93	0.08	2.69	0.10	3.35	0.08	4.94	0.22
	Treatment	−2.03	0.13	5.27	0.10	3.65	0.04	3.07	0.04	2.93	0.04	3.44	0.04	4.95	0.10
Very conservative	Control	−2.09	0.36	5.61	0.27	3.92	0.12	3.12	0.10	2.77	0.12	3.41	0.10	4.38	0.27
	Treatment	−1.80	0.16	5.31	0.12	3.50	0.05	2.98	0.05	2.67	0.05	3.28	0.05	4.42	0.12

Note. *SE* = standard error.

Table 6a
Delayed Posttest (2–3 Weeks Later) Treatment Effects for Global Warming Beliefs by Political Ideology (Control vs. Treatment)

	Affective assessment				Affective assessment certainty				Issue importance				Worry about global warming			
Group	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size r	Mean diff.	*SE*	*p* Value	Effect size *r*
Total	−0.22	0.17	0.19	0.04	0.34	0.12	0.01	0.08	0.02	0.05	0.70	0.01	0.00	0.05	0.98	0.03
Very Liberal	−0.25	0.45	0.57	0.02	0.57	0.33	0.08	0.05	0.10	0.15	0.49	0.02	−0.17	0.13	0.18	0.04
Somewhat liberal	−0.11	0.36	0.77	0.01	0.47	0.27	0.08	0.05	0.11	0.12	0.37	0.02	−0.07	0.10	0.52	0.02
Moderate	−0.64	0.24	0.01	0.07	0.57	0.18	0.00	0.09	0.10	0.08	0.23	0.03	0.22	0.07	0.00	0.09
Somewhat conservative	−0.39	0.32	0.23	0.03	0.39	0.24	0.10	0.05	0.22	0.11	0.04	0.06	0.14	0.09	0.11	0.04
Very conservative	0.29	0.40	0.46	0.02	−0.30	0.29	0.30	0.03	−0.42	0.13	0.00	0.09	−0.14	0.11	0.21	0.03

Note. SE = standard error.

negative emotional response than extreme heat, poor air quality, extreme weather events, hunger and malnutrition, and mental health problems caused by global warming ($p < 0.05$; see Table 7). Vector-borne illness generated a more negative emotional response than extreme heat, extreme weather events, and mental health problems ($p < 0.01$). Poor air quality and hunger and malnutrition caused a greater negative emotional response than extreme heat and mental health problems ($p < 0.05$). Finally, extreme heat and extreme weather events produced more negative emotional reactions than information about mental health problems caused by global warming ($p < 0.05$).

Participants also evaluated the essays differently in terms of ease of understanding, $F(6.85, 12553) = 17.99$, $p < 0.001$. Extreme heat, poor air quality, and contaminated water were all viewed as easier to understand than contaminated food, hunger and malnutrition, and mental health problems ($p < 0.01$, see Table 7). Additionally, information about mental health problems was rated as more difficult to understand relative to all other categories of impacts ($p < 0.01$).

We also observed differences in terms of the perceived timing of the impacts, $F(6.65, 12230) = 29.88$, $p < 0.001$. Contaminated food, hunger and malnutrition, and mental health problems were expected to begin farther in the future relative to all other impact categories ($p < 0.001$, see Table 7), and mental health problems were seen as happening farther in the future than contaminated food and hunger and malnutrition ($p < 0.05$). There was also a significant interaction between impact category and political ideology, $F(26.60, 12230) = 2.05$, $p < 0.001$. Individuals on the conservative end of the political spectrum tended to see each of the impacts as more temporally distant compared to those on the liberal end; however, these differences were less pronounced for vector-borne illness and contaminated water and more pronounced for mental health problems caused by global warming (see Table S23).

4. Discussion

Our findings contribute to the growing literature on the importance of framing global warming as a public health issue. We found that a single exposure to eight brief essays about the different health impacts

Table 6b
Delayed Posttest (2–3 Weeks Later) Treatment Effects for Global Warming Beliefs by Political Ideology (Control vs. Treatment)

	Perceived harm to self				Perceived harm to future generations				Injunctive beliefs			
Group	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*	Mean diff.	*SE*	*p* Value	Effect size *r*
Total	0.08	0.06	0.12	0.04	0.02	0.05	0.73	0.01	−0.05	0.12	0.67	0.01
Very liberal	0.19	0.15	0.19	0.04	0.08	0.13	0.53	0.02	−0.32	0.33	0.33	0.03
Somewhat liberal	0.07	0.12	0.53	0.02	0.02	0.10	0.81	0.01	0.05	0.27	0.86	0.00
Moderate	0.01	0.08	0.86	0.01	0.02	0.07	0.78	0.01	−0.03	0.18	0.86	0.00
Somewhat conservative	0.24	0.11	0.03	0.06	0.09	0.09	0.31	0.02	0.01	0.24	0.96	0.00
Very conservative	−0.10	0.13	0.45	0.02	−0.13	0.11	0.23	0.01	0.04	0.29	0.88	0.00

Note. SE = standard error.

Table 7
Means and Standard Errors for Message Reactions Across Impact Types

	Personal relevance		Novelty of info		Negative affect		Ease of understanding		Timing of impacts	
Impact	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Extreme heat	5.32	0.04	2.94	0.04	4.04	0.05	5.70	0.04	2.00	0.04
Poor air quality	5.38	0.04	3.00	0.04	4.14	0.04	5.72	0.04	1.97	0.04
Extreme weather events	5.32	0.04	3.00	0.04	4.09	0.05	5.65	0.04	2.02	0.04
Vector-borne illness	5.33	0.03	3.25	0.04	4.19	0.04	5.64	0.04	2.01	0.04
Water-borne illness	5.38	0.03	3.32	0.04	4.25	0.04	5.72	0.04	2.05	0.04
Food-borne illness	5.35	0.04	3.57	0.04	4.23	0.04	5.56	0.04	2.17	0.04
Hunger and malnutrition	5.24	0.04	3.61	0.04	4.13	0.05	5.55	0.04	2.20	0.04
Mental health problems	5.05	0.04	3.85	0.04	3.94	0.05	5.42	0.04	2.26	0.04

Note. SE = standard error.

of global warming produced small- to medium-sized effects across a variety of indicators of cognitive and affective engagement with the issue, in the short term. Although most of these impacts were not found in between-group analyses 2–3 weeks after exposure, people who read the essays were more certain about their assessment about how bad (or in rare cases, good) global warming is for human health than were people who had not read the information. In addition, political moderates exposed to the essays were more worried about global warming 2–3 weeks later than political moderates not exposed to the essays, and participants who were somewhat conservative and read the essays felt the issue was more personally important than those who were somewhat conservative and had not read the essays. Although we did not test the treatment effect on injunctive beliefs—the belief that various government actors (the President, Congress, federal agencies, state government, and local government) should take more action to protect people from the health problems caused by global warming—at immediate posttest, there was no between-group difference on this measure 2–3 weeks after reading the essays. It would appear, therefore, that reading information about the health harms of global warming once can have a considerable immediate impact on personal engagement in the issue of global warming as an immediate response, although the effect may not persist.

We also identified a number of interesting differences in how people evaluated the information about the eight health impacts from global warming. It is notable that extreme heat, poor air quality, extreme weather events, and food-, water-, and vector-borne illnesses were viewed as more personally relevant than mental health problems and hunger and malnutrition. We also found that mental health problems, hunger and malnutrition, and contaminated food were seen as more difficult to understand and more temporally distant than other impact categories. This pattern of findings suggests that individuals may see themselves as relatively less vulnerable to mental health and food-related impacts from global warming.

Perhaps not surprisingly, information about the health effects of contaminated food and water, vector-borne illness, hunger and malnutrition, and mental health problems was viewed as more novel than information about extreme heat, poor air quality, and extreme weather events. This finding is consistent with past research that found that global warming tends to be strongly associated with heat-related imagery (Leiserowitz, 2006; Smith & Leiserowitz, 2012) and that health problems from respiratory illness and extreme weather events caused by global warming tend to be more salient compared to other health impacts (Maibach et al., 2015). This may be partly attributable to the fact that heat- and weather-related impacts have received relatively more attention in news coverage about the health implications of global warming (Weathers & Kendall, 2016).

Interestingly, we found that information about contaminated food and water—and to a slightly lesser degree, vector-borne illness—generated more negative emotional responses than other categories of health impacts. This has important implications for communication given that affective and emotional responses can greatly influence risk perception and behavior (Marx et al., 2007). Information about these three health problems may have activated moral concerns about purity, which are strongly associated with the emotion of disgust (Clifford & Wendell, 2016). If true, these specific impacts may be particularly relevant for politically conservative audiences since moral concerns about purity tend to resonate with them (Feinberg & Willer,

2013). We also found less ideological polarization in the perceived timing of health impacts from vector- and water-borne illnesses. Moreover, food-, water-, and vector-borne illnesses associated with global warming have received relatively little media attention in recent years, making these topics ripe for increased public discussion (Weathers & Kendall, 2016).

Given that some treatment effects were more pronounced among political moderates and those who lean conservative, it is reasonable to wonder whether this is attributable to a ceiling effect among liberals versus something in the content of the essays that specifically resonated with moderates and conservatives. We believe that these two explanations are not mutually exclusive and that both may be partially responsible for the pattern of results we observed. It is true that liberals tend to have higher baseline engagement with climate change relative to moderates and conservatives, but given the fact that we observed some significant attitudinal changes even among the most liberal participants suggests they still have room to improve on some measures of engagement. However, a growing body of literature suggests that focusing on moral concerns related to purity can increase conservatives' support for political attitudes and policy positions that are more typically held by liberals (Clifford & Wendell, 2016; Day et al., 2014; Feinberg & Willer, 2013; Kam & Estes, 2016; Wolsko, 2017; Wolsko et al., 2016). Health-framed information about climate change may engage the moral concerns of conservatives—like purity—more directly than environmentally framed information. Nevertheless, more research is needed to understand exactly why health messages about climate change seem to be especially effective with moderates and conservatives.

Our findings also contribute to a relatively small but developing literature on the persistence of framing effects. The fact that many of the effects we initially observed at immediate posttest had decayed 2 to 3 weeks later is largely consistent with prior research that finds that framing effects tend to rapidly decay without reinforcement through repetition (Hill et al., 2013; Lecheler & Vreese, 2016). More research is needed on how to increase the durability of framing effects in science communication. For example, some have suggested that using episodic frames (e.g., focusing on concrete events or individuals) or visual (as opposed to text-based) stimuli may increase the strength and durability of framing effects (Aarøe, 2011; Lecheler & Vreese, 2016).

Our study has several limitations that should be considered. First, given the longitudinal component to our research design, our study is susceptible to sensitization and mortality effects. Although there tend to be more advantages than disadvantages associated with pretests (Shadish et al., 2002), it is possible that the presence of pretests in the treatment condition-sensitized participants to the topic of the study, which may have artificially increased the treatment effects we observed in the within-subject analyses. However, these potential threats to validity are largely addressed by the presence of a control group in the between-subject assessment of longer-term treatment effects. Sample mortality is also a concern given that we surveyed subjects at multiple points in time. If there was a systematic loss of sample between the first and second surveys, then that could bias our analysis. However, given that attrition was not correlated with the treatment, there is a relatively minimal risk of mortality-related bias, although our analysis of longer-term treatment effects may be less generalizable to younger populations.

We intentionally asked participants to answer questions about each essay they read so as to assess how they evaluated different categories of health impacts. Moreover, this questioning was intended to encourage participants to engage in more effortful processing of the essay content. Because more effortful processing of information can lead to stronger and longer-lasting framing effects (Lecheler & Vreese, 2016), it is possible that a more naturalistic delivery of the information would have less dramatic and persistent effects on audiences. Additional research could be done to isolate the treatment effects of climate and health information versus the sheer cognitive task of reading and evaluating multiple short essays about climate change.

The dependent measures in our study focused on cognitive and affective outcomes, not behavioral ones. One recent study found that messages about the health effects of global warming can increase concern about the issue, while simultaneously depressing engagement in political behaviors to express that concern (Levine & Kline, 2017). Future research is necessary to identify the conditions under which messages about the health implications of global warming can motivate protective actions to mitigate and adapt to the problem. Additionally, our stimuli were text based, somewhat long, and didactic in tone. More research is needed to ascertain how presenting this information in more dynamic, engaging, and realistic formats in field settings may affect responses to the messages (Han & Stenhouse, 2015; Stenhouse, 2017). Our study was also

limited to Americans; therefore, it provides little evidence as to the potential value of information about the health impacts of climate change for other populations. Given that climate change represents a global threat to human health, more research is needed to understand how individuals in other countries respond to this risk information.

Climate change is already affecting human health in communities around the United States and is likely to become a health threat of historic proportions. Our study suggests that brief, informative essays about how climate change is affecting our health and who is being most harmed can stimulate positive engagement with the issue. Importantly, we find that certain health impacts are less familiar and more worrisome than others in the minds of Americans. Given the widespread lack of awareness about the public health implications of climate change among Americans, more effective outreach about the entire range of health risks is called for. However, public health officials may wish to strengthen public engagement specifically about illnesses caused by contaminated food and water and by disease-carrying pests. Information about these impacts was viewed as both relatively novel and particularly troublesome compared to other impacts. Additionally, it is worth noting that information about mental health problems caused by global warming was perceived as the most temporally distant, unfamiliar, and difficult to understand impact as well as the least personally relevant and disturbing. This underscores the importance of actions to help the public appreciate the serious yet often complicated effects of climate change on mental well-being.

5. Conclusion

Our study takes the first step toward understanding how Americans evaluate information about different categories of health impacts from climate change and significantly extends the emerging evidence about how providing this information can be helpful. We hope the results of this study will help to mobilize the public health community and catalyze additional research to figure out how to optimally target and tailor this information for a wide variety of audiences in order to reduce our collective vulnerability to the wide-ranging health threats from climate change.

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