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ADDRESSING GLOBAL WARMING DENIALISM
THE EFFICACY OF MECHANISM-BASED EXPLANATIONS IN CHANGING GLOBAL WARMING BELIEFS

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Abstract Despite the scientific consensus concerning the current causes and future effects of anthropogenic global warming, there has been little to no improvement in public opinion, attitudes, or behavior related to its mitigation. This article examines how different information conveyance strategies affect belief in global warming. Three experiments reveal that a fundamental understanding of the underlying mechanism of global warming—the greenhouse gas effect—is integral to belief in the existence of global warming. Specifically, the current research demonstrates that persuasive messaging incorporating an explanation of the mechanism (versus consequences) underlying global warming leads to belief change (study 1); that this effect is moderated by political orientation, such that the effect of mechanism-understanding on global warming belief is greater for conservatives (study 1, 2, and 3); that understanding of the mechanism underlying global warming affects willingness to engage in sustainable activities and buying socially conscious products (study 2); and that the effect persists over time and can influence actual donation behavior (study 3). Social, public policy, and marketing implications for this strategy are discussed.

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> "Insisting on the authority of science does not always help [. . .] especially when it identifies global changes, challenges, and disrupts some of the most cherished social, economic, and psychological investments societies have made in their own future."
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> —Dryzek, Norgaard, and Schlosberg's (2013) *Climate Challenged Society*

> "Any fool can know. The point is to understand."
>
> —Albert Einstein (as cited in Simmons 2003)

While scientific consensus concerning the current causes and future effects of global warming has become increasingly unified (if not entirely resolute), this consensus has not resulted in substantive change or shift in public opinion or attitudes toward the mitigation of global warming in the United States and elsewhere (Gallup 2014). Further, communication efforts that attempt to persuade the public by framing the argument around the consequences of global warming, or by focusing on scientific consensus, have been ineffective and perhaps even counterproductive (Feygina, Jost, and Goldsmith 2010; Feinberg and Willer 2011; Kahan et al. 2012; Painter 2013). Of greatest concern, the populations of the largest emitters of greenhouse gases (the United States, Europe, and China) are consistently the *least* worried about the current and future effects of global warming (Gallup 2014; Pew 2015). In the United States, public belief in global warming decreased from 79 percent in 2007 to 68 percent in 2015, with only 46 percent rating it as a "very serious" problem (Pew 2015). Further, as ideological differences increase within the population (Fiorina and Abrams 2008; Lelkes 2016; Boxell, Gentzkow, and Shapiro 2017), any message culturally or politically tailored to one side of a contentious issue is likely to alienate the other side. In light of this prior research and current levels of polarization, is there a communication strategy than can persuade individuals unconvinced that global warming is real?

Using theory grounded in motivated and teleological reasoning, we build on previous persuasion research (e.g., Ajzen and Fishbein 1977; Petty and Cacioppo, Petty and Cacioppo 1986; Kunda 1990; Koehler 1991) and suggest that the answer to this question lies in the specific type of information presented. Across three studies, we empirically test the ability of a *mechanism-based communication strategy* to persuade unconvinced individuals that anthropogenic global warming is occurring, where the *mechanism* underlying global warming (the greenhouse gas effect) is communicated. Results suggest that when exposed to the mechanism underlying global warming, rather than just statistics describing the potential consequences of global warming, individuals are significantly more likely to believe in its existence. Further, this effect is driven by increased understanding of that mechanism. We find this strategy is relatively more effective for politically conservative message recipients, whom prior

research (e.g., Kahan et al. 2012; Kidwell, Farmer, and Hardesty 2013) suggests are most uncertain about global warming and hardest to persuade. Finally, these effects persist over time, and can affect environmentally conscious consumption and real donation behavior. Taken together, these results inform a potential strategy for policy makers trying to change beliefs and behavior related to global warming by emphasizing *understanding the mechanism underlying the phenomenon* rather than implementing more common consequence-driven strategies. We conclude with policy and research implications of the present work.

Factors Affecting the Persuasiveness of Global Warming–Related Communication

The *Motivated Reasoning Model* (MRM; Kunda 1990; Redlawsk 2002; Kahan 2013; Cook et al. 2016) suggests that, regardless of quality or source expertise, strongly held beliefs and identities can predispose individuals to discount the validity of new information deemed inconsistent with strongly held beliefs (Goidel, Shields, and Peffley 1997; Nisbet 2005). This increases polarization and decreases the likelihood of adopting a science-based viewpoint (Mutz 2008). The MRM has been successfully applied in numerous domains, including political decision-making (Redlawsk 2002), opinions about emergent technologies (Druckman and Bolsen 2011), and the polarization of beliefs on a variety of scientific issues (Drummond and Fischhoff 2017). In politically charged contexts, people primarily use information that reinforces their worldview (Dusso and Kennedy 2015), with factual information having little persuasive power (Druckman and Bolsen 2011).

Further, extant research demonstrates that greater scientific literacy and knowledge does *not* attenuate these effects, but instead accentuates them. For example, conservatives with greater scientific literacy are more likely to doubt global warming (Kahan et al. 2012), in part because they are better able to form creative and complex counterarguments to resist cognitive dissonance (Lord, Ross, and Lepper 1979; Kahan et al. 2012). As a consequence, these individuals tend to most resolutely deny global warming (Kahan et al. 2012).

Additionally, given that the future consequences surrounding global warming cannot be expressed with absolute certainty, scientific communication concerning global warming often uses phrases such as "very likely," leading many individuals to interpret the underlying science as having less certainty than intended, making global warming easier to deny (Budescu, Broomell, and Por 2009). For example, take one of the most popular persuasive statements related to global warming: "97% of scientists agree on global warming" (Cook et al. 2016). While this statement is meant to imply the certainty of global warming, those motivated to do so can interpret this statement as "global warming is not 100% certain," counterproductively introducing evidence supporting global warming uncertainty.

Ultimately, if greater knowledge and education does not lead to greater persuasion and belief in polarized issues, how might scientists and/or educators reach these uncertain individuals and convince them otherwise? We suggest that *the type of information* conveyed to these individuals is vital. Specifically, presenting unconvinced individuals with the *mechanism* underlying global warming, rather than statistics or outcomes, should lead to greater understanding and subsequent belief.

How a Mechanism-Based Information Strategy Can Reduce Climate Change Denialism

Humans tend to seek out causal information and generally prefer it to correlational information (Ahn et al. 1995), even for unique events that are unlikely to provide any predictive ability about the future (Keil 2006). Philosophers and psychologists have argued that causal explanations allow us to better understand the world and better control our futures (Kitayama, Markus, and Kurokawa 2000; Williams and Lombrozo 2010). This tendency to infer causal relationships is vital for learning and is present even in young infants (Hassin, Bargh, and Uleman 2002; Sobel, Tenenbaum, and Gopnik 2004; Keil 2006). Further, understanding causality is a primary factor determining comprehension, with individuals more likely to believe something when they are also able to explain it (Koehler 1991; Graesser, Singer, and Trabasso 1994; Roscoe and Chi 2007; Wellman and Liu 2007). For example, individuals who are instructed to explain why a particular football team will win a match subsequently believe their version of events is more likely (Sherman et al. 1983; Koehler 1991; Graesser et al. 1994; Roscoe and Chi 2007; Wellman and Liu 2007). Koehler (1991) suggests that explanations provide "persuasive inertia," with relevant evidence appearing more coherent with the focal hypothesis, while alternative hypotheses become more difficult to consider. In the context of global warming, framing its existence in terms of its *mechanism* (the greenhouse effect) should have greater efficacy in changing beliefs because it appeals to *understanding causality,* as opposed to simply parroting statistics or potential outcomes.

Understanding is a key construct for measuring layperson comprehension of scientific ideas. In contrast to memorization, which promotes retention, understanding reflects an ability to make sense of that information and apply it to new problems. For example, after a physics lesson, a memorization test might include questions to write out specific formulas, whereas a test for understanding might ask students to apply these formulas to solve novel problems (Mayer 2002). Understanding can range from "an elementary idea of what something means (or how it works) to a deep professional understanding of a concept of construct in the full context of its field" (Miller 2004, p. 274).

In the current context, this body of research has demonstrated that people may believe (or disbelieve) in global warming, despite not understanding why or how it happens (Kempton 1997).

To provide initial evidence that greater understanding of the greenhouse effect will result in greater belief, a pretest ($N = 104$) was conducted. Participants were asked to report their current belief in global warming and answer an open-ended question about their own understanding of how greenhouse gases cause global warming. Limited previous research measuring public understanding of the greenhouse gas effect (Kempton 1997) used open-ended questions, allowing nuanced interpretation of why people do or do not understand the greenhouse gas effect. Further, these responses can still be transformed into quantitative data with the help of coders. Two coders with postgraduate education were provided coding instructions (see Supplementary Appendix A) and coded responses from 1 (no understanding) to 5 (excellent understanding). We utilized a negotiated coding methodology due to our responses containing sophisticated concepts and requiring sensitivity where differences in knowledge are pertinent (see Garrison et al. 2006; Campbell et al. 2013).[1] Following independent coding, the coders were asked to negotiate toward consensus. The coders achieved good interrater reliability before negotiation (Krippendorff's $\alpha = 0.82$) and after negotiation (Krippendorff's $\alpha = 0.92$). These scores were averaged to create a single *mechanism understanding* measure. Belief in global warming was significantly correlated with understanding of the underlying mechanism ($r = 0.24$, $p = 0.01$). Education level was also assessed but was not significantly correlated with belief in global warming. ($r = 0.14$, $p = 0.15$). Further, when belief in global warming was regressed on both mechanism understanding and education level, the standardized effect of mechanism understanding on belief was 0.22 ($p < 0.04$) while the effect of education level (0.06) remained non-predictive ($p = 0.57$).[2]

These preliminary results, coupled with past research describing the effectiveness of causal and explanation-based information on persuasion, suggest that persuasive efforts based on understanding the underlying mechanism of global warming may result in greater subsequent belief in global warming. Stated formally:

H1: The effect of a mechanism-based explanation on belief in global warming will be mediated by one's understanding of that mechanism.

1. Negotiated coding has been widely used across a number of domains to quantify complex qualitative data collected from respondents about their understanding of a phenomena after an intervention, particularly when involute data makes agreement between coders challenging. Nevertheless, there are limitations to this method, which we discuss in detail.

2. Please see https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/BC3CPN for all specific materials, scale items, codebooks, and data.

The Moderating Effect of Scientific Literacy and Political Conservativism on Message Persuasiveness

Prior research suggests that increased scientific literacy can lead to greater disbelief in opposing viewpoints within contentious domains, as individuals are better equipped to rationalize away dissonance related to belief-inconsistent persuasion (Hamilton 2011; Kahan et al. 2012). However, we suggest that mechanism-based persuasive strategies potentially avoid activating these rationalization strategies by presenting an explanation of a particular phenomenon relatively devoid of political or other contentious attributes. Specifically, the mechanism underlying global warming (i.e., the *greenhouse gas effect,* whereby greenhouse gases act like a blanket, absorbing radiation and trapping warm air in Earth's atmosphere) is a well-understood and accepted phenomenon, even by those most skeptical of global warming models. Further, because individuals have a greater tendency to believe something when they are able to explain it (Koehler 1991; Graesser, Singer, and Trabasso 1994; Roscoe and Chi 2007; Wellman and Liu 2007), understanding the greenhouse gas effect should make the phenomena of global warming more coherent while making alternative hypotheses more difficult to counterargue.

Importantly, belief in global warming varies by political orientation: those on the more liberal end of the political spectrum tend to believe that global warming is real, human-made, and ongoing, while those on the more conservative end of the spectrum do not (e.g., 3 percent of liberals, but 40 percent of conservatives in the US, believe that global warming will never happen; Pew 2015). As previously noted, the downstream consequences of global warming cannot be expressed with absolute scientific certainty, and as such, a disbeliever will be motivated to interpret any uncertainty in a way that is consistent with their worldview. In contrast, those who already believe will discount the uncertainty, opting to maintain their confidence that global warming is occurring regardless of their specific knowledge on the topic.

Thus, we argue that liberals will tend to believe in global warming as a function of the shared beliefs of their political in-group, and subsequently, understanding the underlying mechanism of global warming will have little additional effect. Conservatives, on the other hand, tend to be skeptical of global warming, and are motivated to interpret any uncertain future consequences of global warming in a way that is consistent with their worldview. However, when presented with the mechanism underlying global warming, conservatives should be more constrained in their ability to counterargue, due to general agreement that the greenhouse gas effect exists and has no obvious political or cultural meaning. Thus, the effect of understanding the mechanism on belief in global warming should be stronger for conservatives than liberals. Stated formally:

H2: A mechanism-based understanding of global warming will interact with political orientation, such that the positive effect of understanding on global warming belief will be greater for conservatives (versus liberals).

Finally, research suggests that uncertainty and ignorance are two primary factors that contribute to unsustainable behavior (Hine and Gifford 1996; de Kwaadsteniet et al. 2007; Gifford 2011). Specifically, individuals utilize uncertainty to rationalize inaction (Gifford 2011) by justifying that selfish behavior is easier because there is a possibility that one's behavior will not lead to negative consequences (de Kwaadsteniet et al. 2007). However, when the positive effects of sustainable behavior appear more certain, individuals will have greater difficulty justifying selfish behavior and tend to act more prosocially by preferring sustainable activities and products (de Kwaadsteniet et al. 2007; Gifford 2011). Assuming that individuals tend to show greater certainty in global warming's occurrence when they better understand the mechanism underlying the greenhouse gas effect, mechanism-based persuasion efforts should result in greater sustainable and prosocial behavior. Formally:

H3: An increased understanding of the greenhouse gas effect will positively affect belief in the existence of global warming, which will lead to an increase in willingness to engage in sustainable activities.

We test our hypotheses across three studies, demonstrating that a fundamental understanding of the mechanism underlying global warming leads to increased belief in global warming and subsequent sustainable activities. Study 1 provides initial evidence, demonstrating that persuasive messaging related to the mechanism underlying global warming drives greater belief change, and illustrates the moderating effect of political orientation. Study 2 demonstrates that this increase in belief affects one's willingness to engage in sustainable activities, while study 3 shows that this sustainability effect persists over time, affecting real donation behavior. Finally, we utilize both text (study 1) and videos (studies 2 and 3) as stimuli, extending our results across different messaging media.

Study 1: Belief in Global Warming Is Stronger After Viewing a Mechanism-Based Message

METHOD AND PROCEDURE

One hundred fifty participants were recruited via Amazon's Mechanical Turk to complete an online survey. Ten participants failed an attention check[3]

3. Those who failed the attention check did not differ on demographic characteristics (e.g., age, gender, belief in global warming, knowledge measure, or political orientation; all p's > 0.38). However, respondents who failed the attention check tended to self-report a slightly greater understanding change (5.56 vs. 4.36 $p = 0.05$), although this effect was driven primarily by the consequences condition (6.00 vs. 4.08, $p = 0.08$).

embedded in the study, resulting in a total of 140 participants. Participants were assigned to one of three conditions: *mechanism, consequences*, or a *control*. In the mechanism and consequences conditions, participants read either a vignette that described the mechanism underlying the greenhouse gas effect adapted from a report from the Australian Government Department of the Environment and Energy (2020) or a vignette that described the consequences of global warming adapted from Feinberg and Willer (2011). Both are reproduced in Supplementary Appendix B. The two vignettes were matched for length and processing difficulty. In addition, time spent on the page was recorded. No information was given in the control condition, with those participants moving immediately to the next section. Table 1 compares selected characteristics of subjects in all three studies and (for comparison) respondents to a nationally representative survey by Leiserowitz et al. (2018).

Participants then completed a single-item measure of understanding change (*This study has changed my understanding of the underlying process of global warming*; 1 = strongly disagree, 7 = strongly agree), as well as their belief in global warming (e.g., *I currently believe that humans are, at least in part, responsible for global warming* and *The world is warming, in part, due to human influence*; 1 = strongly disagree, 7 = strongly agree). Afterward, in order to assess whether the manipulation actually changed understanding, participants completed a 10-item multiple-choice mechanism knowledge questionnaire to confirm whether participants were, on average, reading the text (Supplementary Appendix C). Finally, participants completed a single-item measure of political orientation (1 = Very Liberal, 7 = Very Conservative), reported basic demographics, were thanked for their participation, and were debriefed.

Results

MANIPULATION CHECK

The *control* condition and *consequences-based* condition did not significantly differ on either the manipulation check mechanism knowledge questionnaire, nor the understanding change measure. Further, mechanism knowledge did not relate to political orientation ($r = –0.04$, $p = 0.68$). Given that the *consequence-based* condition and the *control* condition did not differ, the two conditions were combined (code = 0) and contrasted to the *mechanism-based* condition (code = 1).

An ANOVA confirmed a significant effect of condition on the mechanism knowledge measure (see table 2). Post hoc tests revealed that those in the *mechanism-based* condition scored higher on the mechanism knowledge measure (compared to participants in the *consequences-based* and *control* conditions).

Table 1. Demographic breakdown of all samples compared to US population

	Pretest (n = 104) MTurk %	Study 1[a] (n = 140) MTurk %	Study 2 (n = 270) Students %	Study 3, T_1 (n = 149) MTurk %	Study 3, T_2 (n = 92) MTurk %	US population Leiserowitz et al. (2018) %
Belief in global warming						
Score above scale midpoint	59	87	83	79	84	73
Sex						
Female	47	54	42	46	49	52
Education						
No college	4	–	4	20	16	39
Race						
White	–	–	69	73	73	61
Age (>19)						
Under 30	48	36	99	39	32	13
30–60	50	57	1	57	65	56
> 60	2	4	0	3	2	31

[a]The pretest did not include a measure of race. Study 1 did not include a measure for education or race.

Table 2. Effect of experimental condition on understanding change, belief, and knowledge (study 1)

	Understanding change	Belief in global warming	Mechanism knowledge
Means (SDs)			
Control	4.22 (1.75)	6.00 (1.25)	6.80 (1.47)
Consequences	4.08 (1.18)	5.79 (1.34)	6.54 (1.62)
Mechanism	4.80 (1.75)	5.91 (1.18)	7.80 (1.36)
ANOVA (original)			
F	2.20	0.327	9.31
(df)	(2, 137)	(2, 137)	(2, 137)
p	0.12	0.72	<0.001
ANOVA (collapsed)			
F	4.29	0.01	17.92
(df)	(1, 138)	(1, 138)	(1, 138)
p	0.04	0.93	<0.001

NOTE.—There were no significant differences between the consequences and control condition on either the mechanism knowledge quiz ($p = 0.40$) or the understand change measure ($p = 0.71$). There were significant correlations between belief in global warming with the mechanism knowledge questionnaire ($r = 0.19$, $p = 0.02$) and understanding change ($r = 0.33$, $p < 0.001$).

MEDIATING EFFECT OF UNDERSTANDING ON BELIEF

The two questions on belief were strongly correlated ($r = 0.88$, $p < 0.001$) and were averaged into a single belief variable. Table 2 shows that understanding change differed significantly between the experimental condition and the two control conditions. Political orientation was not correlated with understanding *change* ($r = –0.02$, $p = 0.82$). A mediation analysis was conducted to explore the mediating effect of understanding change on belief in global warming, using the PROCESS macro (Hayes 2013; model 4[4]) with a bootstrapping procedure (5,000 resamples) to construct bias-corrected confidence intervals. A mediating effect of understanding change on belief in global warming was observed (see table 3). That is, reading the mechanism-based vignette (compared to the consequence-based or control vignette) increased participants' self-reported change in understanding of the greenhouse gas effect, and the magnitude of that change predicted an increased belief in global warming.

4. Model numbers refer to the statistical models associated with the Hayes PROCESS Macro in SPSS to provide readers with more context on the specific analyses performed. In the context of this manuscript, model 1 refers an interaction with two independent variables, model 4 refers to mediation, and model 6 refers to serial mediation. Models can be viewed online at http://www.personal.psu.edu/jxb14/M554/specreg/templates.pdf, or see Hayes (2013) for more information.

Table 3. Mediation results on belief in global warming (study 1)

	B	SE	LCI	UCI
Condition -> Understanding change	0.157	0.099	0.008	0.391
Condition -> Understanding change -> Belief (controlling for age and gender)	0.175	0.106	0.021	0.432

NOTE.—*B* represents the unstandardized regression coefficient for the indirect mediating effect (*ab*). LCI and UCI reflect the 95 percent upper and lower confidence interval.

MODERATING EFFECT OF POLITICAL ORIENTATION

Consistent with prior research, correlational analysis reveals a negative relationship between political orientation and belief in global warming ($r = –0.47$, $p < 0.001$). While there was no relationship between understanding change and political orientation, there was a significant interactive effect of understanding change and political orientation (table 4) on belief in global warming (one participant did not state their political affiliation and was excluded from analysis).

Table 4. Moderation results at relatively more liberal (–1 SD) and conservative (+1 SD) of political orientation on belief in global warming (study 1)

	B	SE	*p*	*F* (*df*)
Political orientation	–0.337	0.054	<0.001	
Understanding × Political orientation	0.109	0.026	<0.001	17.90 (1, 135)
Understanding × Political orientation (Liberals, –1 SD)	0.071	0.062	0.25	
Understanding × Political orientation (Conservatives, +1 SD)	0.507	0.078	<0.001	
Understanding × Political orientation (controlling for age and gender)	0.114	0.026	<0.001	19.16 (1, 133)
Understanding × Political orientation (Liberals, –1 SD) (controlling for age and gender)	0.066	0.062	0.29	
Understanding × Political orientation (Conservatives, +1 SD) (controlling for age and gender)	0.523	0.080	<0.001	

NOTE.—The *B* (unstandardized regression coefficient) of Understanding × Political Orientation at +/– 1 SD reflects the effect of mechanism understanding on belief in global warming for those who identify as relatively more liberal (16th percentile) and conservative (84th percentile). That is, for those who identify as more liberal there is no significant effect of understanding on belief, but there is a relatively strong and significant effect for those who identify as more conservative.

Figure 1 provides a graphical representation of the interaction at +/– 1 standard deviation from the mean on political orientation and understanding change. Moderation analysis using the PROCESS macro (Hayes 2013; model 1, see footnote 5) examined the conditional indirect effect of understanding change on belief at +/– 1 standard deviation from the mean on the political orientation measure. Analysis revealed that for individuals who were relatively liberal (–1 SD), there was no effect of understanding change on belief, while the effect of understanding change on belief for individuals who were relatively conservative reflects understanding change significantly predicting increased belief.

Study 1 Discussion

The findings in study 1 support hypotheses 1 and 2. Participants who read a vignette that explained the mechanism underlying the greenhouse gas effect (as opposed to its consequences or a control) were more likely to report an increased understanding of that effect and subsequently exhibit greater belief in global warming (H1). Responses in the control condition did not differ from those in the consequences-based condition, suggesting that our effects were not driven by a negative response to the consequences-based condition. This is in contrast to previous research that suggests that focusing on the consequences of global warming can lead to a backfire effect (e.g., Feinberg and Willer 2011). Finally, supporting H2, we find that political

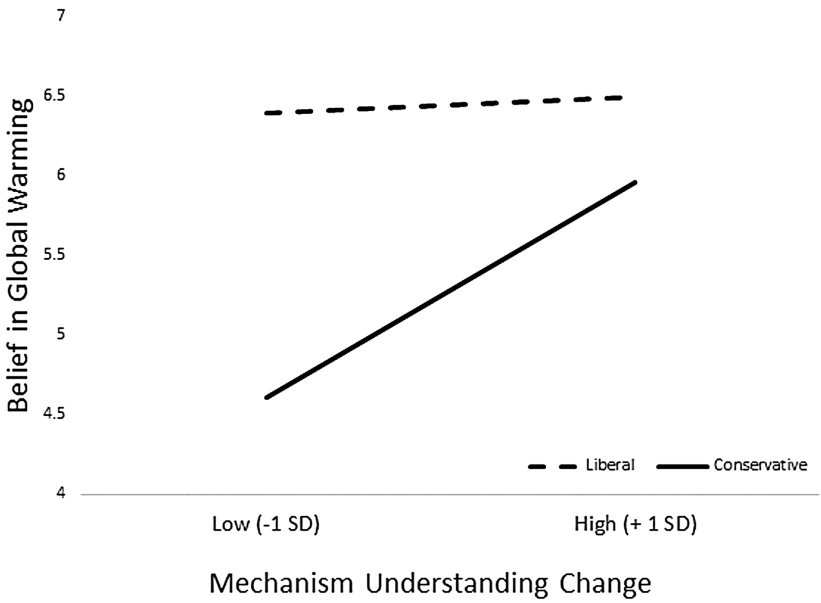

Figure 1. The effect of understanding change (+/– 1 SD) on belief in global warming for liberals and conservatives (study 1).

orientation moderates the relationship between message type and change in belief in global warming. Specifically, while more liberal individuals tend to believe in global warming independently of their understanding of the mechanism underlying the greenhouse gas effect, a significant change in conservatives' understanding of that mechanism led to a significant increase in subsequent belief in global warming.

Study 2: Changes in Belief in Global Warming Influences Environmentally Conscious Behavior

Study 2 extends our inquiry by examining the relationship between understanding the greenhouse gas effect and environmentally conscious consumption behavior. Specifically, we were interested in whether understanding the mechanism underlying the greenhouse gas effect (and its downstream effect on belief in global warming) would lead to positive changes in sustainable behavior attitudes. From a policy and managerial perspective, changes in belief are not very impactful until they manifest in consumption preferences and practices that reduce emissions.

In addition, study 2 aimed to rule out the possibility that our effects are being driven by individual differences in scientific analysis. Prior research suggests that increased scientific literacy can lead to greater disbelief in opposing viewpoints, as individuals are better equipped to rationalize away dissonance related to exposure to counterarguments (Kahan et al. 2012). Consequently, the most resolute climate denialism is featured among conservatives highest in scientific literacy (Kahan et al. 2012). However, the current research hypothesizes that mechanism-based persuasion presents an apolitical explanation of a phenomenon by focusing on causality—a primary factor determining comprehension and belief (Koehler 1991; Graesser, Singer, and Trabasso 1994; Roscoe and Chi 2007; Wellman and Liu 2007). Thus, in order to better rule out these alternative explanations, we explore the moderating effect of mechanistic understanding and contrast it with general scientific literacy.

Method and Procedure

Three hundred fifty-eight participants were recruited from a large university in the Northwestern United States and were randomly assigned to participate in either a *mechanism-based* or *consequence-based* video treatment. Seventy-eight participants failed an attention check[5] and an additional 10 participants did not write about their understanding, leaving a total of 270 participants.

5. Those who failed the attention check did not differ on age, gender, education level, or belief in global warming (all P's > 0.52). There was an effect on political leaning (4.33 vs. 3.88, $p = 0.02$). Somewhat unsurprisingly, those who failed the attention check scored significantly lower than those who did not on the science measure (6.81 vs. 6.19, $p = 0.001$).

Participants were first asked to describe in their own words (and regardless of their belief) how greenhouse gases cause global warming on an open-ended question (time 1). Participants then watched a *mechanism-based* video or a *consequence-based* video about the correlation between increased emissions, global warming, and the disastrous effects it could cause (see Supplementary Appendix D). After the video, participants again described their understanding of the greenhouse gas effect on an open-ended question (time 2). Participants then answered the same two questions related to climate change belief as study 1. Participants next completed a series of items assessing behavioral intent to perform six sustainable behaviors such as recycling to reduce consumption of products contributing to global warming ($a = 0.92$; adapted from Feygina, Jost, and Goldsmith 2010; see Supplementary Appendix E for full question wording). Next, to assess scientific literacy and political orientation, participants responded to a series of science-related questions (adapted from Kahan et al. 2012 and reproduced in Supplementary Appendix F) and the same single-item political orientation measure as study 1. Finally, after completing basic demographic questions, participants were thanked and debriefed.

Results

INITIAL DATA CODING

As in the pretest, two independent coders rated responses of the open-ended measure of understanding the greenhouse gas effect. Upon discussion, the coders achieved perfect consensus (Krippendorff's $\alpha = 1$) for both time 1 and time 2 (prior to negotiation, intercoder reliability was 0.59 for time 1 and 0.62 for time 2). Finally, the correct answers on the scientific literacy test were aggregated as a measure of each participant's scientific expertise.

MECHANISM UNDERSTANDING

After watching the videos, an ANOVA confirmed a significant change in understanding of the greenhouse gas effect for participants in the mechanism-based condition relative to the consequences-based condition. A repeated measures analysis revealed a significant understanding (time 1 and 2) by condition effect. As shown in table 5, those in the consequences condition increased their understanding from a mean of 1.99 to 2.54,[6] while in the mechanism condition, understanding was significantly greater, increasing from 1.98 to 3.18.

6. Although the differences between time 1 and time 2 in the consequences condition was significantly less compared to the mechanism condition, it was still was statistically significant. This was likely due to the fact that coding at time 2 took into account understanding at time 1 and was incorporated into their overall understanding. Ostensibly, participants did not report everything they knew about the greenhouse gas effect at time 1 and/or the consequences video served to prime some additional information that participants knew but did not readily recall.

Table 5. Effect of condition on understanding previdео, postvideo, and understanding change (study 2)

	Understanding (previdео)	Understanding (postvideo)	Understanding change
Means (SDs)			
Consequences	1.99 (0.78)	3.18 (0.96)	0.55 (0.68)
Mechanism	1.98 (0.73)	2.54 (0.88)	1.20 (0.83)
ANOVA			
F	0.014	31.95	42.21
(df)	(1, 268)	(1, 268)	(1, 268)
p	0.91	<0.001	<0.001

MEDIATION ANALYSIS

To examine the mediating effect of increased understanding between video condition and belief in global warming, we used the PROCESS macro (Hayes 2013; model 4, see footnote 5) to conduct mediation analysis with a bootstrapping procedure (5,000 resamples) to construct bias-corrected confidence intervals. The bootstrapping procedure revealed significant mediation, controlling for understanding at time 1 (see table 6). That is, consistent with study 1, the *mechanism-based* video significantly increased participants' understanding of the greenhouse

Table 6. Mediation analysis of understanding the greenhouse gas effect on belief in global warming and sustainable behaviors (study 2)

	B	SE	LCI	UCI
Condition ->Understanding ->Belief (controlling for T_1)	0.152	0.072	0.020	0.304
Condition ->Understanding ->Belief (controlling for T_1, age, gender, ethnicity, and education)	0.165	0.073	0.037	0.329
Condition ->Understanding ->Sustainable behaviors (controlling for T_1)	0.162	0.077	0.020	0.321
Condition ->Understanding -> Sustainable behaviors (controlling for T_1, age, gender, ethnicity, and education)	0.177	0.075	0.046	0.344

NOTE.—*B* represents the unstandardized regression coefficient for the indirect mediating effect (*ab*). LCI and UCI reflect the 95 percent upper and lower confidence interval.

gas effect, resulting in greater belief in global warming, while the *consequence-based* video had no measurable effect. Further, this result holds while controlling for gender, age, and ethnicity, and education. Interestingly, gender significantly predicted belief, with women reporting greater belief than men ($F(1, 268) = 9.43$, $p = 0.002$). However, this does not impact the overall pattern of results.

Finally, we assessed the effect of increased mechanism understanding on participant intent to engage in sustainable activities. Consistent with our theorizing, increased understanding of the mechanism underlying the greenhouse gas effect significantly mediated participants' increased belief in global warming, which in turn drives intent to engage in environmentally pro-social activities (table 5).

MODERATING EFFECT OF POLITICAL ORIENTATION

Consistent with study 1, political orientation was negatively correlated with belief in global warming and unrelated to scientific literacy (see table 6). Next, we replicated the polarization effect found by Kahan and colleagues (2012), finding that scientific knowledge and political affiliation interact to predict belief in global warming. Specifically, liberal participants (–1 SD) exhibited a positive (though non-significant) effect of scientific knowledge on belief in global warming, while conservative participants (+1 SD) exhibited a negative relationship between scientific knowledge and belief in global warming. Importantly, the opposite effect is obtained when examining the relationship between political orientation and understanding the mechanism underlying the greenhouse gas effect (table 7).

Table 7. Moderating effect of political orientation at relatively more liberal (–1 SD) and conservative (+1 SD) political orientation and scientific knowledge on belief in global warming (study 2)

	B	SE	*p*	*F* (*df*)
Political orientation (main effect)	–0.375	0.043	<0.001	
Scientific knowledge	0.016	0.050	0.75	
Scientific knowledge × Political orientation	–0.060	0.027	0.02	5.12 (1, 267)
Scientific knowledge × Political orientation (Liberals, –1 SD)	0.110	0.068	0.10	
Scientific knowledge × Political orientation (Conservatives, +1 SD)	–0.131	0.071	0.06	

NOTE.—The *B* (unstandardized regression coefficient) of Understanding × Political Orientation at +/– 1 SD reflects the effect of mechanism understanding on belief in global warming for those who identify as relatively more liberal (16th percentile) and conservative (84th percentile). That is, for those who identify as more liberal there is a marginal significant effect of scientific knowledge on belief, but there is a marginal negative effect for those who identify as more conservative.

Specifically, consistent with study 1, there was no statistically significant effect of *mechanism understanding* on belief in global warming for liberal participants, whereas there is a significant effect for conservative participants (see table 8). That is, when conservatives understand the mechanism underlying the greenhouse gas effect, they are significantly more likely to believe in global warming. This effect remains consistent when controlling for age, gender, race, and education (see figures 2a and 2b).

Finally, to demonstrate that the understanding scores reflected a change in understanding and not simply rote memorization and parroting of the information in the video, we utilized text-analysis to compare participant responses at time 2 to the transcript of the video. The text-analysis revealed that less than 1 percent of the text (0.7 percent) was identical to the transcript.

Table 8. Moderating effect at relatively more liberal (–1 SD) and conservative (+1 SD) of political orientation and mechanism understanding on belief in global warming (study 2)

	B	SE	*p*	*F* (*df*)
Political orientation (main effect)	–0.375	0.043	<0.001	
Understanding × Political orientation	0.085	0.039	0.03	4.66 (1, 266)
Understanding × Political orientation (Liberal, –1 SD)	0.145	0.100	0.15	
Understanding × Political orientation (Conservative, +1 SD)	0.483	0.108	<0.001	
Understanding × Political orientation (controlling for age, gender, ethnicity, and education)	0.081	0.040	0.04	4.22 (1, 259)
Understanding × Political orientation (Liberal, –1 SD) (controlling for age, gender, ethnicity, and education)	0.173	0.102	0.09	
Understanding × Political orientation (Conservative + 1 SD) (controlling for age, gender, ethnicity, and education)	0.498	0.109	<0.001	

NOTE.—The *B* (unstandardized regression coefficient) of Understanding × Political Orientation at +/– 1 SD reflects the average effect of mechanism understanding on belief in global warming for those who identify as relatively more liberal (16th percentile) and conservative (84th percentile). That is, for those who identify as more liberal there is no/marginal significant effect of understanding on belief, but there is a relatively strong and significant effect for those who identify as more conservative.

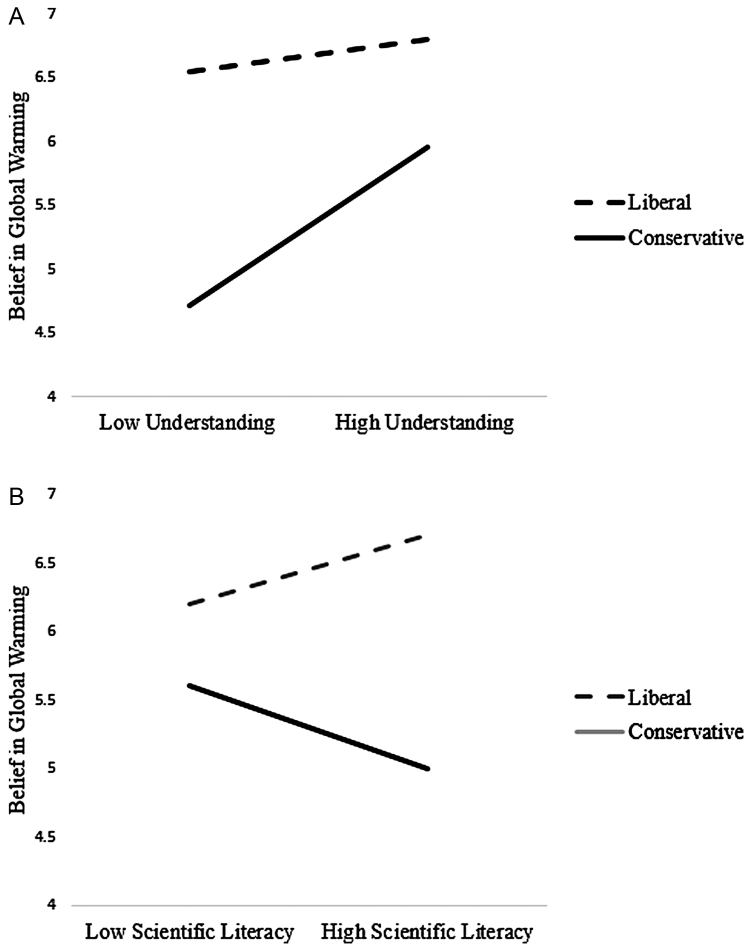

Figure 2. The effect of low and high (+/– 1 SD) understanding of the greenhouse gas effect (figure 2a) and scientific literacy (figure 2b) on belief in global warming for liberals and conservatives (study 2).

Study 2 Discussion

Study 2 further establishes evidence for H1 and H2, while illustrating that underlying change in understanding of the greenhouse gas effect results in not only a subsequent increase in belief in global warming, but, importantly, a shift in intent toward more sustainable consumption (H3).

However, study 2 leaves open two important questions: are these effects temporary and fleeting, or robust over time, and do they predict actual behavior?

If participants are indeed learning the mechanism underlying global warming, as we propose, that information should be learned, processed, committed to memory, and subsequently impact behavior. Thus, in study 3 we attempt to demonstrate that the effect of the mechanism-based manipulation on understanding persists over time and affects actual donation behavior.

Study 3: Does Mechanism-Based Learning Affect Belief in Global Warming Over Time?

Studies 1 and 2 provide evidence that understanding the underlying causes of global warming predicts greater subsequent belief in global warming and that exposure to mechanism-based (versus consequence-based) explanations leads to greater belief change, with the effect being strongest on the most uncertain participants. However, it is possible that this effect is only temporary and individuals presented with a mechanism-based explanation can rationalize away or dismiss these ideas over time. To examine this question, study 3 was designed to assess the longer-term effects of a mechanism-based persuasion strategy. Further, while study 2 found that exposure to mechanism-based explanations led to greater belief in global warming and subsequent changes in individuals' desire to behave in socially positive or sustainable ways, intentions do not always predict real-world behavior. Thus, study 3 incorporated a real-world behavioral choice (making a charitable donation).

Method and Procedure

One hundred and seventy nine participants were recruited via Amazon's Mechanical Turk and were paid $1.00 as compensation to participate in a two-factor *(video type: mechanism-based* versus *consequence-based)* between-subject study. The study consisted of two separate sessions separated by a six-week time delay. Thirty participants did not write responses or simply copied the question, leaving a total of 149 participants.[7]

SESSION 1

Session 1 was identical to study 2. As in the previous studies, two independent coders rated the responses. Upon discussion, the two coders achieved good

7. With the exception of one, participants excluded did not complete writing explanations and subsequently did not complete the rest of the study, including the demographics. As such, no analyses can be performed. Importantly, there were no differences between those who took the study during the second session and those who did not. Specifically, there were no differences on understanding change or belief, nor on what condition they were assigned to (all P's > 0.45). Further, there were no differences in gender, age, ethnicity, or education (all P's > 0.11)

interrater reliability (Krippendorff's $\alpha = 0.95$; Krippendorff's $\alpha = 0.96$) for time 1 and 2, respectively (prior to negotiation, intercoder reliability was 0.72 for time 1 and 0.69 for time 2). After completing all measures, participants were asked if they would like to be included in a follow-up study in six weeks' time. Those interested were asked to provide an email address.

SESSION 2

Ninety-two participants from the first experiment responded to an email request to participate in session 2. Participants were matched using a unique code provided by participants during session 1 and session 2. Instead of writing an explanation of the greenhouse gas effect (as they had during the first session), participants were given a 10-question multiple-choice questionnaire (see Supplementary Appendix G) to assess their understanding of the mechanism underlying the greenhouse gas effect (we refer to this as *knowledge* to draw a distinction from the measure of understanding in session 1). Participants were then again asked about their belief in global warming. Finally, participants were asked if they would like to donate part of their compensation for taking the study to a carbon-offset program (1 = Yes, 2 = No; Supplementary Appendix H). After completing a set of basic demographic questions, including the same single-item political orientation measure as in previous studies, participants were thanked, debriefed, and paid.

Results

MECHANISM UNDERSTANDING

After watching the videos, an ANOVA confirmed a significant change in understanding of the greenhouse gas effect for participants in the *mechanism-based* condition relative to the *consequences-based* condition ($F(1, 148) = 19.79$, $p < 0.001$; see table 9).

MEDIATION ANALYSIS

To examine whether increased understanding mediates belief in global warming, mediation analysis was conducted (Hayes 2013; model 4, see footnote 5) with a bootstrapping procedure (5,000 resamples) to construct bias-corrected confidence intervals. The bootstrapping procedure revealed significant mediation controlling for understanding during session 1. This effect remains while controlling for age, gender, and ethnicity. That is, consistent with our previous studies, viewing the mechanism-based video significantly increased participants' understanding of the greenhouse gas effect relative to session 1, resulting in greater belief in global warming.

Table 9. Effect of condition on understanding prevideo, postvideo, and understanding change (study 3)

	Understanding (prevideo)	Understanding (postvideo)	Understanding change
Means (SDs)			
Consequences	2.17	2.31	0.14
	(0.98)	(0.96)	(0.54)
Mechanism	1.98	2.56	0.58
	(0.87)	(1.06)	(0.67)
ANOVA			
F	1.65	2.30	19.79
(df)	(1, 148)	(1, 148)	(1, 148)
p	0.20	0.13	<0.001

Session 2

While not all participants in session 1 responded to the email request to participate in the second session, analysis comparing individuals who took part in the second session versus those who did not revealed no significant differences across session 1 on belief in global warming, understanding, or their randomly assigned condition (all *P*'s > 0.1), suggesting no systematic differences in individuals who opted to take part in session 2.

PRIMARY RESULTS

First, we examined whether understanding of the greenhouse gas effect from session 1 predicted knowledge about global warming in session 2. Results indicate a significant correlation between the two measures ($r = 0.44$, $p < 0.001$). Further, session 1 understanding and session 2 knowledge predicted belief in global warming ($r = 0.27$, $p = 0.01$, $r = 0.29$, $p = 0.01$) and session 2 belief in global warming significantly predicted donation agreement (coded as 1 = yes, 2 = no, $r = –0.33$, $p = 0.001$), as did session 2 knowledge (coded as 1 = yes, 2 = no, $r = –0.21$, $p < 0.05$). Importantly, serial mediation (Hayes 2013; model 6, see footnote 5) exploring the indirect effect of the *mechanism-based video* condition on donation through session 1 understanding and session 2 belief demonstrated a significant mediating effect (table 10). As illustrated by figure 3, participants who saw the mechanism-based video reported greater subsequent understanding and then greater belief and subsequent donation behavior six weeks later.

Table 10. Mediation analysis of understanding the greenhouse gas effect on belief in global warming and donation (study 3)

	B	SE	LCI	UCI
Condition ->Understanding T_2 → Belief T_2 (controlling for understanding T_1)	0.188	0.098	0.021	0.403
Condition ->Understanding T_2→ Belief T_2 (controlling for understanding T_1, age, gender, ethnicity, and education)	0.186	0.101	0.005	0.401
Condition ->Understanding T_2→ Belief T_3 → Donation (controlling for understanding T_1)	–0.122	0.091	–0.366	–0.010
Condition ->Understanding T_2→ Belief T_3 → Donation (controlling for understanding T_1, age, gender, ethnicity, and education, 90% CI)	–0.092	0.097	–0.300	–0.004

NOTE.—*B* represents the unstandardized regression coefficient for the indirect mediating effect (*ab*). LCI and UCI reflect the 95 percent upper and lower confidence interval.

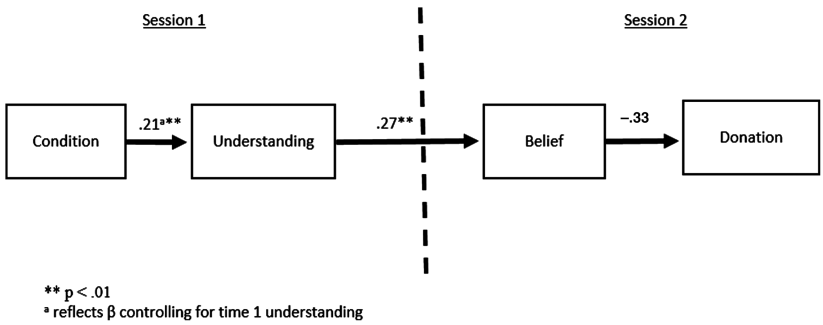

Figure 3. Path model of the effect of condition (consequence vs. mechanism) on donation agreement (coded as 1 = yes, 2 = no) through understanding at session 1 and belief at session 2 (study 3).

MODERATING ROLE OF POLITICAL ORIENTATION

Consistent with studies 1 and 2, we assessed the moderating effect of political orientation on the relationship between understanding and belief. The interaction revealed a marginally significant interaction (table 11).

Table 11. Correlational and moderated effects at relatively more liberal (–1 SD) and conservative (+1 SD) of political orientation on belief in global warming (study 3, session 2)

	B	SE	*p*	*F (df)*
Political orientation (main effect)	–0.489	–0.077	<0.001	
Understanding × Political orientation	0.142	0.075	0.06	3.58 (1, 88)
Understanding × Political orientation (Liberal, –1 SD)	0.003	0.171	0.99	
Understanding × Political orientation (Conservative, +1 SD)	0.571	0.232	0.02	
Understanding × Political orientation (controlling for age, gender, ethnicity, and education)	0.224	0.076	0.004	8.66 (1, 81)
Understanding × Political orientation (Liberal, –1 SD) (controlling for age, gender, ethnicity, and education)	–0.272	0.181	0.14	
Understanding × Political orientation (Conservative, +1 SD) (controlling for age, gender, ethnicity, and education)	0.625	0.231	0.008	

NOTE.—The *B* (unstandardized regression coefficient) of Understanding × Political Orientation at +/– 1 SD reflects the average effect of mechanism understanding on belief in global warming for those who identify as relatively more liberal (16th percentile) and conservative (84th percentile).

Consistent with the previous studies, assessing the conditional effects at +/– 1 SD, reveals that for more liberal participants (–1 SD), there was no effect of understanding on belief, whereas for more conservative participants (+1 SD), there was a stronger, statistically significant effect. Finally, as in study 2, text-analysis revealed that only 1.2 percent of the text provided by participants was identical to the text provided in the study and less than 1 percent reflected minor deviations from the text provided in the study.

Study 3 Discussion

The results of study 3 provide support for our central argument that understanding the greenhouse gas effect relates positively to subsequent belief in global warming. In addition, study 3 adds two important contributions. First, we demonstrate that the effect of mechanism-based persuasion persists over time: viewing the mechanism-based video not only changed immediate understanding of the mechanism underlying the greenhouse gas effect

and subsequent belief in global warming, but showed consistent effects six weeks later. Second, we demonstrated that greater understanding of the mechanism underlying the greenhouse gas effect and subsequent belief in global warming impacted real-world donation behavior six weeks after viewing the mechanism-based video.

General Discussion

Pro-social interventions in psychology and marketing have primarily focused on normative and implicit interventions (Goldstein, Cialdini, and Griskevicius 2008; Thaler and Sunstein 2008; Peloza, White, and Shang 2013). However, these interventions are unlikely to affect views on global warming or other ideologically laden beliefs with the same effectiveness as spurring the reuse of towels or sustainable consumption of coffee. Spurring belief in global warming requires a more explicit intervention capable of not just changing, but reversing, publicly held beliefs and attitudes. In the present research, we demonstrate the effectiveness of a mechanism-based explanation that explains why global warming is happening (the greenhouse gas effect). The resulting explicit intervention is effective, particularly with conservatives, and has important implications for pro-social communications and marketing interventions.

Public Policy and Managerial Implications

Arguably, no problem in contemporary public policy poses a greater potential threat to society and the world than global warming. Global warming is in a category of social and environmental problems that policy makers have never experienced in the past, combining a distant temporal nature, outcome uncertainty, and imperfect solutions requiring tremendous cost to current taxpayers who may be deceased before any benefits are realized (Gardiner 2011). Politically, global warming policy carries with it explicit incentives to shirk. At an international level, it creates trade disadvantages; at a national level, it weakens one state or province economically relative to another; at an individual level, there are considerable tangible and intangible transaction costs to changing lifestyles (Stern 2007; Gardiner 2011).

Consequently, inspiring the collective action needed to ameliorate the effects of global warming requires communication strategies effective in persuading those who may not believe global warming is happening due to lack of understanding the underlying science and/or a conflict between their ideological, cultural, or religious beliefs. The present research illustrates a strategy with the potential to break through this morass of ideology and culture. Specifically, contexts where this strategy would seem most likely to find success are those where simple, apolitical explanations can be used to understand

seemingly complicated scientific phenomena. One example already in practice regards human interaction with sensitive habitats: in Hanauma Bay Nature Preserve in Hawaii, visitors must watch a supervised video (<10 minutes) on how coral reefs function before being allowed into the preserve. Because even the gentlest touch from humans can contaminate and destroy coral due to the oils naturally in human skin, the video serves as an educational tool to protect sensitive habitats by focusing on mechanism and without engaging in any sort of political debate.

Mechanism-based persuasion strategies might yield positive outcomes in motivating vaccinations, accepting genetically modified organisms in food, and reducing the overuse of antibiotics. Because each has a relatively simple explanation (i.e., *"when you get a vaccine, it sparks your immune response, helping your body fight off and remember the germ so it can attack it if the germ ever invades again";* U.S. Department of Health and Human Services 2019) and generally lacks political associations (i.e., the influenza vaccine is not seen as liberal nor conservative), mechanism-based persuasion strategies could potentially aid in changing public opinion and help spur public action.

Limitations and Future Directions

Mechanism-based persuasion strategies may not be effective in all conditions, and more research is needed to understand the boundaries of its effectiveness. For example, in contexts inseparable from emotional, religious, or cultural meaning while lacking a simple scientific explanation (i.e., stem cell research, euthanasia, or sex education), mechanism-based strategies could backfire. As an example, an explanation of how euthanasia works may inspire even greater opposition because the debate is normative and not rooted in empirical claims. Consequently, future research should help identify boundary conditions for mechanism-based persuasive strategies.

It is also important to note that our effects were indirect and are dependent on the extent to which participants showed greater understanding of the mechanism. Although we controlled for prior understanding in our analyses, some participants may have been resistant to new information, and thus would not exhibit any understanding and subsequent belief or behavior change (indeed, some of the open-ended responses explicitly informed us that they did not waste their time on our "propaganda"). Relatedly, we excluded a number of participants who failed attention checks or did not write responses, suggesting that these participants were likely the least motivated to process the provided information systematically. On the other hand, those participants that were receptive to the information provided in our studies reported an overall increase in their understanding of the greenhouse gas effect, resulting in a significant change in belief in anthropogenic global warming. Identifying the individual

differences between these two groups of respondents is critical in reducing global warming denialism.

Further, it is important to note that while our manipulations directly drive a change in understanding the mechanism underlying global warming, both this mediating variable and our dependent variables are measured and not randomly assigned. As such, the relationship between the mediator and the dependent variable is ultimately correlational, thus understanding the mechanism underlying global warming is only assumed to causally affect belief that global warming is occurring (see Pirlott and MacKinnon 2016). As such, future research should seek to explore interventions that spur open-mindedness toward new information (e.g., the trustworthiness of the information source) as well as utilize designs that experimentally manipulate any mediating variables.

In addition, our focal dependent variable, understanding of the greenhouse gas effect, was quantified using the negotiated coding methodology, a popular strategy across domains when quantifying qualitative data (e.g., Coomber et al. 2017; Skillman et al. 2019; Judina and Platonov 2019), particularly when the data reflects participant understanding of complex topics in foundational research, making coder agreement challenging. However, this methodology is not without limitation. As rightfully noted by an anonymous reviewer, reproducing the data with different coders may be difficult, due to inherent differences in how different coders might interpret the open-ended responses. However, the instructions utilized to train reviewers (Supplementary Appendix A) and transparently reporting the K_{alpha} at each stage of coding (Supplementary Appendix K) should mitigate some of these concerns. In keeping with this, future research should seek to develop an improved instrument and coding instructions to ensure greater reliability and subsequent reproducibility of the data. In doing so, this may also provide better-nuanced insights into the specific aspects of understanding and how they lead to greater belief change in global warming or other domains.

Finally, we would like to reiterate that the nature of our effects should be interpreted alongside known limitations to our data sources. However, while MTurk samples tend to be different from the general population in predictable ways (Levay et al. 2016), extent research comparing the applicability of MTurk samples to those used by the American National Election Studies (ANES) suggests that "the same values and personality traits that motivate ideological differences in the mass public also divide liberals and conservatives on MTurk" (Clifford, Jewell, and Waggoner 2015, p. 7). Similarly, while there are meaningful differences between student samples and the general population, extent research examining similarities and differences among college students as samples for politically relevant research suggests that "students and the non-student general population, are, on average, indistinguishable when it comes to partisanship . . . [in terms of both] partisan direction and intensity" (Druckman and Kam 2011, p. 51). Nevertheless, there are still likely meaningful differences in the motivations and other psychological

variables between MTurk workers, students, and the general population. As such, the external validity of these findings would be enhanced by replicating these effects in a probability-based survey.

Supplementary Data

Supplementary data are freely available at *Public Opinion Quarterly* online.

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