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Local Warming: Daily Temperature Change Influences Belief in Global Warming

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Abstract

Although people are quite aware of global warming, their beliefs about it may be malleable; specifically, their beliefs may be constructed in response to questions about global warming. Beliefs may reflect irrelevant but salient information, such as the current day's temperature. This replacement of a more complex, less easily accessed judgment with a simple, more accessible one is known as attribute substitution. In three studies, we asked residents of the United States and Australia to report their opinions about global warming and whether the temperature on the day of the study was warmer or cooler than usual. Respondents who thought that day was warmer than usual believed more in and had greater concern about global warming than did respondents who thought that day was colder than usual. They also donated more money to a global-warming charity if they thought that day seemed warmer than usual. We used instrumental variable regression to rule out some alternative explanations.

Keywords

judgment, environmental effects

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A recent poll found that a majority of the world's population (including 97% of the United States) is aware of global warming (Pugliese & Ray, 2009), perhaps as a result of extensive media coverage and campaigns to increase awareness. The Alliance for Climate Protection, for instance, has spent $300 million in advertising to change people's opinions on the subject (Revkin, 2008). Despite this high level of awareness, there is reason to suspect that beliefs about global warming are malleable. Research suggests that people construct many values and beliefs in real time (Diamond & Hausman, 1994; Fischhoff, 1991; Lichtenstein & Slovic, 2006; Payne, Bettman, & Johnson, 1992; Slovic, 1995). Knowledge about climate change, we suspect, consists of a poorly integrated and mutually inconsistent amalgam of political opinion, social and situational factors, and scientific data. Thus, answering what might be seen as a scientific question about temperature requires integrating a complex belief structure formed by many diverse and conflicting inputs. This may cause transient factors that are present only at the time of measurement to inappropriately influence people's beliefs. By analogy, when asked about the state of the national economy, someone might look at the amount of money in his or her wallet, a factor with only trivial relevance.

Our concern about the malleability of global-warming beliefs arose from reactions to the record East Coast snowfalls in 2010 that deposited heavy snow in the Washington, D.C., area and the subsequent news reports expressing skepticism of global warming. Could daily temperature abnormalities influence beliefs in global warming—a phenomenon that required extensive measurements taken over long periods and broad geographical areas to establish (Solomon et al., 2007)?

Although climate scientists have measured temperature trends over decades, humans are equipped with another, readily accessible source of information about the environment: an exquisite sensitivity to relative changes in temperature. A memorable example of this was pointed out by the philosopher George Berkeley (1713/1988), who argued that a person's perception of the temperature of water depends on whether the hand being used to test it is hot or cold. When two hands, the left hot and the right cold, are put into the same room-temperature water, the water seems cold to the left hand and hot to the right.

We propose that when people are asked about global warming, their sensitivity to relative temperature is recruited through a process of *attribute substitution* (Kahneman & Frederick,

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2002). Attribute substitution occurs when the target attribute is "relatively inaccessible; and . . . a semantically and associatively related candidate attribute is highly accessible" (Kahneman & Frederick, 2002, p. 54). When asked about the reality of global warming, a complex and sometimes contentious topic, respondents may substitute their judgments about whether the weather on the current day is colder or warmer than expected, a far easier quantity to evaluate.

The focus of our study was similar to the aim of past studies—to show that transient weather affects global-warming beliefs—but our emphasis was on relative temperature deviation rather than absolute temperature deviation, which the previous studies examined (Joireman, Truelove, & Duell, 2010; Schuldt & Schwarz, 2008). We believe that changes from a recent reference temperature are more salient and accessible than absolute temperature and that people adapt to absolute temperature, naturally expecting, for example, winter to be colder than summer. Consequently, this research using absolute temperature has produced a mixed pattern of relatively weak results.

The relationship between relative temperature deviation and global-warming beliefs finds support from political scientists who have related objective temperature deviation to poll results concerning global warming (Egan & Mullin, 2010). Their analysis showed that this relationship is stronger for people who are less educated and have weaker partisan ties than for people with greater education and stronger partisan ties. Taking their analysis one step further, we proposed that the mechanism producing this effect is the attribute substitution of recent, local temperature deviation for global warming over longer time periods. By using instrumental variable regression—an econometric tool commonly used to analyze natural experiments—we were also able to control for reverse causality and omitted variable biases. This approach also showed that actual temperature deviations account for only part of the effect of perceived temperature deviations on global-warming beliefs: We found a stronger effect of perceived deviations than actual deviations on such beliefs. Finally, we verified the robustness of the effect across geographies and seasons, and we added a meaningful behavioral measure.

To summarize, we hypothesized that highly accessible perceptions of local temperature deviations from historical daily averages are recruited to answer difficult questions concerning beliefs about global warming. To examine this notion, we conducted three Internet-based studies that asked diverse samples of respondents about their belief in and concern about global warming. We also asked whether respondents perceived their local temperature that day to be colder or warmer than usual.

Studies 1a and 1b

Method

Participants in Study 1 volunteered for a "quick 3-minute survey" via a Web-site link. We recruited participants from the United States and Australia, respectively, for Studies 1a and 1b. (See the Supplemental Material available online for details of the two samples.)

In Study 1a, we asked 582 Americans to report how convinced they were "that global warming is happening" and how much they "personally worried about global warming." We labeled these responses *belief* and *concern*, respectively. Response options ranged from 0 (*not at all convinced/worried*) to 3 (*completely convinced/a great deal worried*). These global-warming questions and the response scales were adapted from prior public-opinion studies about global warming (Leiserowitz, Shome, Marx, Hammer, & Broad, 2008).

We also asked participants whether the local temperature on the day they completed the survey was colder or warmer than usual for that time of year. They responded using a 5-point scale that ranged from −2 (*much colder*) to 2 (*much warmer*). We labeled this response *perceived deviation* because it is related to but psychologically distinct from the actual deviation from the usual temperature. Participants also provided their postal code and basic demographic information, including their political affiliation.

To gather this data not just during local winter conditions but also during local summer conditions, we conducted Study 1b within 1 week of Study 1a. In Study 1b, we asked 290 residents of Australia the same questions that we asked Americans in Study 1a using the same response scales.[1]

We counterbalanced the order of the global-warming and temperature questions. Past researchers have reasoned that if a participant was asked two seemingly unrelated questions, he or she may nonetheless recognize that the answer to the first might influence his or her response to the second. The participant would then consciously avoid this influence (Schwarz & Clore, 1983). Manipulating the order of the global-warming and temperature questions allowed us to assess whether people were aware of the influence of local temperature deviation on their global-warming attitudes. If they were aware, we expected a weaker effect of perceived deviation on attitudes toward global warming when participants answered questions about temperature before questions about global warming than vice versa.

Results

Figure 1 plots the relationship between mean perceived deviations from the usual temperature and the mean levels of belief and concern about global warming. Belief and concern correlated significantly in both Study 1a ($r = .73$, $p < .0001$) and Study 1b ($r = .69$, $p < .0001$). Although there were differences in mean levels of belief and concern between the two countries,[2] the effect of perceive deviation was similar; therefore, we combined the two sets of data (see the Supplemental Material). The results showed a striking relationship: People who thought the current day's temperature was warmer than usual were more likely to believe in and worry about global warming than people who thought the current day's temperature was

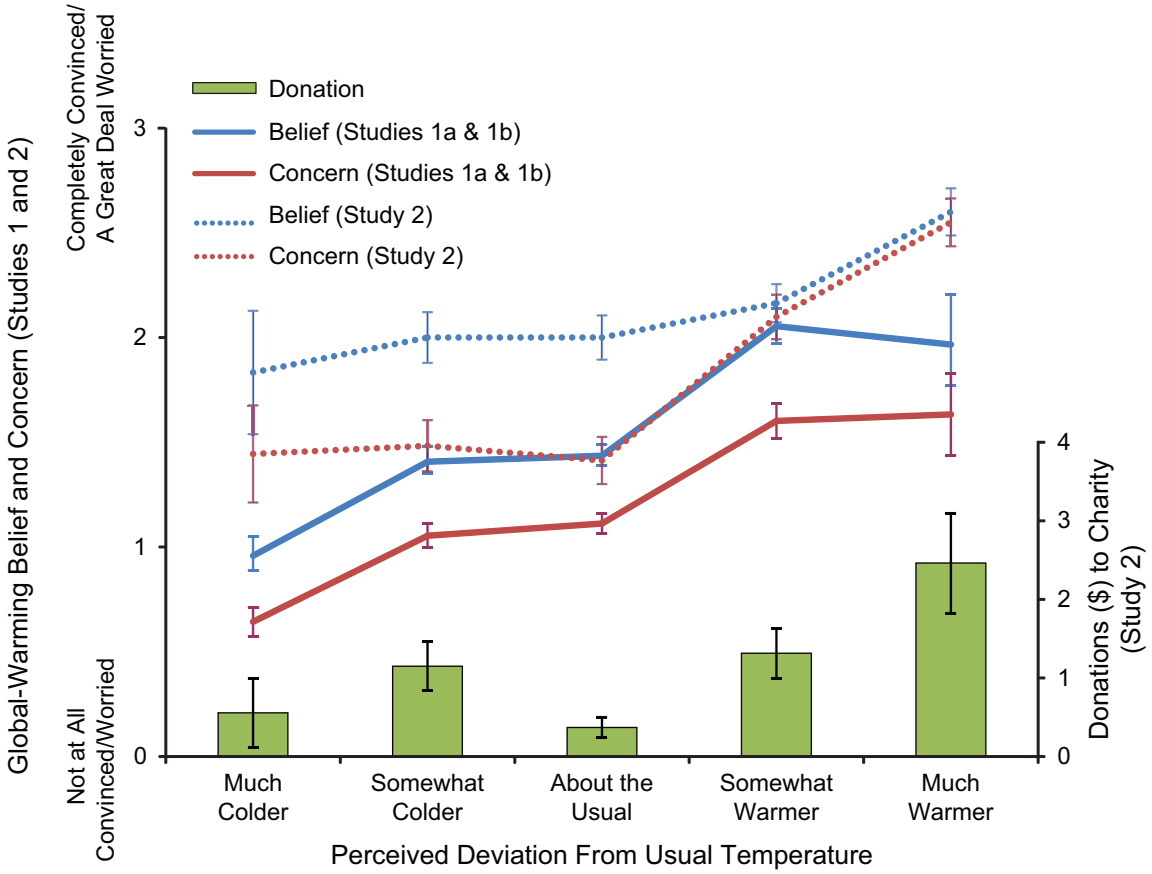

Fig. 1. Belief in and concern about global warming (left *y*-axis; Studies 1 and 2) and amount of donations to charity (right *y*-axis; Study 2) as a function of perceived deviation from the usual temperature. Error bars denote ±1 *SEM*.

colder than usual. For the two temperature extremes, the difference in perceived deviation resulted in a one-point difference (on a 4-point scale) in both belief and concern. Simple linear regressions showed significant effects of perceived deviation on both belief, $\beta = 0.28$, $t(872) = 7.86$, $p < .0001$, and concern, $\beta = 0.25$, $t(872) = 8.61$, $p < .0001$. Nonparametric tests using ordered logistic regressions showed similar effects for both belief, $\beta = 0.50$, $z = 7.86$, $p < .0001$, and concern, $\beta = 0.55$, $z = 8.43$, $p < .0001$. It is important to note that question order had little impact on the size of the effect, though it was directionally higher when the global-warming questions came before the local-temperature questions than when they came after (see the Supplemental Material). This finding suggests that respondents' conscious awareness of the effect of question order was limited.

Although striking, these results are correlational and subject to two classes of alternative interpretations. The first is reverse causation: Perhaps belief in global warming actually causes people to perceive the temperature as warmer than usual (Weber, 1997). The second class of alternative explanation is that an omitted variable may affect both perceived deviation and attitudes toward global warming. Omitting this variable from the regression would overstate the effect of perceived temperature deviation. For example, perhaps global-warming skeptics are also more aware of temperatures that are colder than usual.

To address these concerns, we employed instrumental variable regression, an econometric technique widely used in economics to help establish causality in observational data when randomized experiments are not possible (Sargan, 1958). Following this technique, we modeled the effect of the purported causal variable (perceived temperature deviation) on a dependent variable (global-warming attitudes) using a third, *instrumental* variable that was related to but not caused by the causal variable. We followed previous work by using weather as an instrumental variable (Miguel, Satyanath, & Sergenti, 2004; Paxson, 1992) and used actual temperature deviation as an instrumental variable for the perceived deviation. We reasoned that although actual temperature deviations can affect perceived deviations, the reverse case—that peoples' beliefs influence actual temperature deviations—cannot be true.

Estimates for instrumental variables were calculated using two-stage least squares regression. The first-stage regression used actual temperature deviation to generate predicted values of perceived deviation. These predicted values of perceived deviation, free of any effects of belief on perceived deviation, were then used to estimate effects on belief and concern. Thus, perceived temperature deviation was regressed on actual

temperature deviation, which generated predicted values for perceived deviations; we then ran regressions estimating belief and concern as functions of the predicted values of perceived deviation. Because this new predictor was a function of only actual deviation, this procedure eliminated concerns about reversed causality and omitted variables (Angrist & Krueger, 2001).

We used respondents' postal codes to collect actual temperatures on the day of the study and historical averages for their city, and then we calculated actual deviations by taking the difference between these two measures.[3] Actual deviation was correlated with perceived deviation ($r = .49$, $p < .0001$), as well as both belief in global warming ($r = .18$, $p < .0001$) and concern about global warming ($r = .14$, $p < .001$).[4] It is important to note that actual deviation did not correlate with the residuals from the original explanatory equations ($r = .05$ and .01, respectively, for belief and concern, n.s.); that is, it was an exogenous variable and satisfied the sufficient conditions to be an instrumental variable. The first-stage regression showed that actual deviation accounted for 24% of the variance in perceived deviation. The second-stage regression confirmed our central result: The predicted values of perceived deviation obtained from the first-stage regression had highly significant effects on both belief, $\beta = 0.41$, $z = 4.36$, $p < .0001$, and concern, $\beta = 0.26$, $z = 3.38$, $p < .001$. Thus, perceived deviation from the usual temperature, at least in part, causes changes in global-warming attitudes.

Note that perceived deviations can be alternatively considered as fully mediating the effect of actual deviations on belief and concern in global warming, actual deviation, direct: $t(576) = 4.28$, actual deviation, mediated: $t(575) = 1.25$, bootstrapped Sobel's $Z = 5.80$, $p < .0001$. However, mediation analysis demonstrates consistency with a hypothesized process, but it does not test causality.

We also conducted a number of additional regressions that directly controlled for objective temperature measures (actual temperature and deviation from the historical average) as well as demographic factors (gender, education, age, and political affiliation). Because the political parties differ in the United States and Australia, we ran these regressions separately for each country. Actual temperature and deviation did not have significant effects except through the effect of perceived deviation. Although party affiliation, gender, and age had significant effects on belief in global warming, the effect of perceived deviation remained highly significant in the presence of these controls (see the Supplemental Material for additional details of these analyses).

Study 2

Overall, Studies 1a and 1b demonstrated a basic relationship between perceived local temperature deviations and attitudes toward global warming, controlling for a number of other factors. However, these studies were limited, as we did not observe any consequential behavior that might follow from respondents' global-warming attitudes.

Method

In Study 2, we asked 251 different individuals to participate in a Web-based study that used the same questions and methodology as in Study 1. These participants were drawn from the Center for Decision Sciences Virtual Lab database. Study 2 also added a behavioral measure that asked participants whether they would donate part of the fee they were awarded for completing the study to Clean Air-Cool Planet (http://www.cleanair-coolplanet.org). All donations were actually given to this charity. As an additional robustness check, Study 2 separated the two questions by unrelated research tasks that took 18 min on average (in Study 1, the global-warming and temperature questions were adjacent). Finally, because presentation order had no effect in the prior studies, the global-warming questions always preceded the temperature questions.

Results

As Figure 1 shows, the data from Study 2 replicated the effect of perceived temperature deviations on global-warming belief, $\beta = 0.15$, $t(249) = 2.68$, $p < .01$, and concern, $\beta = 0.26$, $t(249) = 4.78$, $p < .0001$, that we observed in Study 1. These two measures again showed a significant correlation ($r = .70$, $p < .0001$). The key result of Study 2, however, was that participants who thought that the day of the study was warmer than usual donated a larger amount of their earnings to Clean Air-Cool Planet than those who thought that the day of the study was colder than usual, $\beta = 0.25$, $t(249) = 2.00$, $p < .05$. Participants who thought the temperature was much colder than usual donated an average of only \$0.48 (SD = \$1.74; 24% of participants donated), whereas those who thought the temperature was much warmer than usual donated an average of \$2.04 (SD = \$2.43; 63% of participants donated). Participants in the latter group donated almost 25% of their earnings. As in Study 1, we conducted additional regressions that revealed the robustness of these effects when controlling for actual temperature and actual deviation, demographics, political affiliation, geographical region, and general environmental attitude. See the Supplemental Material for details of these analyses.

General Discussion

In the studies reported here, we found that people's belief in and concern about global warming depended on whether the local temperature on the day of the study seemed warmer or colder than usual. Such increases in belief and concern also produced higher donations to a global-warming charity. We interpret this result as attribute substitution, in which an easily accessible judgment (the current day's local temperature) is used in place of a more complex and less accessible one (global temperature trends). Furthermore, we found that the presentation order of the temperature and global-warming questions did not influence this effect, a result that suggests that the substitution occurs without awareness. If respondents

had been aware, they would have attempted to exclude the temperature information from their judgments.

These results join a growing body of work showing that irrelevant environmental information, such as the current weather, can affect judgments. A classic study showed that weather affects judgments of overall well-being (Schwarz & Clore, 1983). Similarly, exposure to a source of physical warmth, such as holding a cup of coffee, can increase the perceived interpersonal warmth of another individual (Williams & Bargh, 2008). Other studies have shown that daily weather can influence choices: Individuals tend to overweigh cold weather by purchasing but subsequently returning heavy winter clothing on days when the daily temperature is below average (Conlin, O'Donoghue, & Vogelsang, 2007). College admissions officers put more weight on applicants' academic attributes (compared with their social or athletic attributes) on cloudy days than on clear days (Simonsohn, 2007). Similarly, students were more likely to enroll in a school known for its academic strengths and recreational weaknesses if they visited during cloudy days (Simonsohn, 2010). Finally, the work of Risen and Critcher (in press) complements our results: In an experimental manipulation of temperature deviation, they found that increasing the ambient room temperature increased belief in global warming.

Our results also raise a deep question: Given that global warming has been extensively featured in the media, and large amounts of attention have been dedicated to changing public understanding and attitudes, why are beliefs in global warming so malleable that they can be affected by irrelevant daily temperatures? The lesson drawn from our results is that even for important issues like global warming, responses to survey questions are not set in stone. It is, perhaps, the issue's very complexity, and people's ambivalence toward global warming, that causes people to draw only temporary conclusions and to reconsider their beliefs each time they are surveyed. This myopic focus on their immediate experience suggests that people's beliefs can be as mercurial as the weather and raises important questions about the role of labile public opinion in the formulation of policy in complex areas. Our work suggests one mechanism that can help explain what seems to be a concrete shift in public sentiment concerning belief in global warming, but that, in reality, may be only ephemeral.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

Notes

1. We subsequently replicated the study with a different sample of Americans during a particularly hot spell during the summer of 2010. The results were virtually identical with the findings of the initial study.
2. U.S. participants reported less belief (M = 1.35) than Australian participants (M = 1.65), $t(871) = 3.92$, $p < .001$, and less concern (M = 1.00) than Australian participants (M = 1.31), $t(871) = 4.75$, $p < .0001$.
3. We also tried to use the actual change in temperature from the previous day to the day of the study as an instrumental variable but found that it was a poor predictor of perceived temperature deviation ($r = .08$).
4. We restricted this analysis to Study 1a because our ability to determine actual temperatures from postal codes was less accurate for Australian participants.

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