



# Systems thinking as a pathway to global warming beliefs and attitudes through an ecological worldview

Matthew T. Ballew<sup>a,1</sup>, Matthew H. Goldberg<sup>a</sup>, Seth A. Rosenthal<sup>a</sup>, Abel Gustafson<sup>a</sup>, and Anthony Leiserowitz<sup>a</sup>

<sup>a</sup>Yale Program on Climate Change Communication, Yale School of Forestry & Environmental Studies, Yale University, New Haven, CT 06511

Edited by Arild Underdal, University of Oslo, Oslo, Norway, and approved March 8, 2019 (received for review November 26, 2018)

Prior research has found that systems thinking, the tendency to perceive phenomena as interconnected and dynamic, is associated with a general proenvironmental orientation. However, less is known about its relationship with public understanding of climate change and/or whether this relationship varies across people with different political views. Because climate change is a highly politicized issue, it is also important to understand the extent to which systems thinking can foster acceptance of climate science across political lines. Using an online sample of US adults ( $n = 1,058$ ), we tested the degree to which systems thinking predicts global warming beliefs and attitudes (e.g., believing that global warming is happening, that it is human-caused, etc.), independent of an ecological worldview (i.e., the New Ecological Paradigm). We found that although systems thinking is positively related to global warming beliefs and attitudes, the relationships are almost fully explained by an ecological worldview. Indirect effects of systems thinking are consistently strong across political ideologies and party affiliations, although slightly stronger for conservatives and Republicans than for liberals and Democrats, respectively. We did not find evidence of the converse: Systems thinking does not seem to mediate the relationship between an ecological worldview and global warming beliefs and attitudes. Together, these findings suggest that systems thinking may support the adoption of global warming beliefs and attitudes indirectly by helping to develop an ecological ethic that people should take care of and not abuse the environment.

systems thinking | New Ecological Paradigm | climate change | attitudes | climate change communication

The challenges associated with environmental protection today are multifaceted and affected by many interacting factors. The challenges operate on various, often large, spatial scales, unfold on long temporal scales, and usually have global implications (for example, carbon dynamics, nutrient cycles, and ocean acidification). Dealing with these problems will require systems thinking and integrated multidisciplinary science.

US National Research Council (ref. 1, p. 13)

Systems thinking refers to a “cognitive paradigm that involves an implicit tendency to recognize various phenomena as a set of interconnected components that interact with one another to make a dynamic whole” (2). It involves the understanding that the social, economic, and natural worlds are part of an interconnected system that is constantly changing, and that humans, including oneself, are members of this dynamic system (3).

In the environmental domain, systems thinking is viewed as fundamental to understanding and addressing environmental problems such as climate change. In 2012, the US National Research Council urged the Environmental Protection Agency to apply a systems thinking approach, rather than a traditional “siloeed, disciplinary” approach (ref. 1, p. 36), to understanding environmental issues. Systems thinking is also gaining attention in educational settings. At this time, the US K-12 Next Generation Science Standards emphasizes “crosscutting concepts” as one of the core dimensions of scientific learning including topics on system models, patterns, and stability and change (4–6).

Although systems thinking is often emphasized as central to learning about and understanding climate science and other environmental issues (e.g., natural resource management) (7), research on the effects of systems thinking as a cognitive framework or ability is nascent. For example, prior research suggests that systems thinking is associated with proenvironmental tendencies including connectedness to the natural world, environmental behavior, perceptions that climate change is a serious threat, and support for climate policies such as energy taxes (3, 8, 9). One recent study found that systems thinking was more strongly linked to an ecological worldview (i.e., the New Ecological Paradigm) (10) than were other measures of environmental attitudes; specifically, connectedness to nature and biospheric environmental concern (3). It is perhaps not surprising the two are strongly correlated: systems thinking is a cognitive paradigm of viewing the world as a set of interconnected parts and processes (2), and the New Ecological Paradigm refers to an ecological worldview or value system that humans are part of the natural world, with strong responsibilities to protect it for both humans and nonhuman species (10). Indeed, one of the central themes of the New Ecological Paradigm emphasizes the interrelation between humans and the environment; specifically, “beliefs about humanity’s ability to upset the balance of nature” (ref. 10, p. 427).

Given that systems thinking is increasingly viewed as central to understanding climate science, but empirical research on its effects is limited, it is important to assess the predictive strength of systems thinking in explaining climate change beliefs and attitudes, and to do so in relation to a conceptually similar construct, the New

## Significance

Systems thinking is recognized as vital to understanding climate science and addressing climate change. Understanding how systems thinking influences the public’s beliefs and attitudes about climate change has important implications for climate change education and communication. Our findings indicate that across the political spectrum, systems thinking may facilitate an ecological ethic or value system that humans should preserve and protect the natural world rather than exploit it. This, in turn, may strengthen proclimate views and understanding of climate change (e.g., that global warming is happening, is human-caused, etc.). The findings contribute to systems thinking theory and indicate the importance of promoting systems thinking to support proclimate science beliefs, attitudes, and behaviors across political lines.

Author contributions: M.T.B., S.A.R., and A.L. designed research; M.T.B. performed research; M.T.B. and M.H.G. analyzed data; and M.T.B., M.H.G., S.A.R., A.G., and A.L. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

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Data deposition: The data reported in this paper have been deposited in the Open Science Framework, <https://osf.io/zc7q5/>.

<sup>1</sup>To whom correspondence should be addressed. Email: matthew.ballew@yale.edu.

This article contains supporting information online at [www.pnas.org/lookup/suppl/doi:10.1073/pnas.1819310116/-DCSupplemental](http://www.pnas.org/lookup/suppl/doi:10.1073/pnas.1819310116/-DCSupplemental).

Published online April 8, 2019.

Ecological Paradigm, a widely used measure of a proenvironmental orientation (11). Understanding the unique predictive strength of systems thinking on views about climate change has practical implications for climate change education and communication, in addition to theory development. Thus, we hypothesize that systems thinking predicts global warming beliefs and attitudes, and uniquely predicts views independent of an ecological worldview or value system. Specifically, we focus on the relation of systems thinking and the New Ecological Paradigm to the following: belief that global warming is happening and human-caused, worry about global warming, perceptions that it is a serious threat, issue importance, and knowledge of the scientific consensus about human-caused global warming.

It is also plausible that an ecological worldview mediates, at least in part, the relationship between systems thinking and global warming beliefs and attitudes. Several theoretical perspectives on systems thinking support this process; for example, “that an ecological worldview emerges from an awareness of the interdependencies all biological life forms share” (ref. 3, p. 578). More recent research also suggests that systems thinking may activate a tendency to “value, care for and feel connected to entities that extend distally beyond the self” (ref. 12, p. 224), supporting other perspectives and previous research (8, 9, 13). Further, by definition, systems thinking refers to a general cognitive paradigm of viewing phenomena as interconnected and dynamic; it is not limited to the environmental domain, but includes other systems such as society and the economy (2, 3). On the basis of these theoretical perspectives, systems thinking may facilitate proenvironmental values that then shape more specific beliefs and attitudes about climate change. However, given the limited research on the effects of systems thinking, we also test the alternative explanation that a general proenvironmental orientation activates systems thinking, which then influences views about climate change. Understanding this distinction can help educators and science communicators develop strategies targeting systems thinking and help researchers and scholars better understand the psychological processes involved in systems thinking and public understanding of climate change.

We also explore whether relationships between systems thinking, worldview, and beliefs and attitudes vary by political ideology and/or party affiliation. Because climate change is a deeply politicized issue (14, 15), approaches are needed that encourage the adoption of views aligned with climate science across political lines. Prior research has found that compared with conservatives, liberals have more openness to complexity and more tolerance for ambiguity and uncertainty (16, 17). Systems thinking has also been found to correlate with a liberal political ideology (8). Although we expect that systems thinking positively correlates with proclimate views across the political spectrum, we also predict that there will be stronger relationships between systems thinking and an ecological worldview, as well as global warming beliefs and attitudes, for liberals and Democrats relative to conservatives and Republicans,

respectively. Understanding these relationships will provide insight on the extent to which promoting systems thinking in education and communication can help close political gaps in climate opinion.

### Study Overview

Using an online sample of US adults (TurkPrime’s Prime Panels;  $n = 1,058$ ), the present research examines the extent to which systems thinking predicts global warming beliefs and attitudes, the degree to which ecological worldview (i.e., the New Ecological Paradigm) (7) explains (mediates) relationships between systems thinking and global warming beliefs and attitudes (or vice versa), and whether these relationships differ by political ideology and/or party affiliation.

To measure systems thinking, respondents completed the 15-item Systems Thinking Scale Revised (3). As a measure of ecological worldview, respondents also completed the 15-item New Ecological Paradigm Revised (10). To measure global warming beliefs and attitudes, toward the end of the survey, respondents answered several questions adapted from survey instruments used in *Climate Change in the American Mind*, a semiannual nationally representative survey of US public opinion about climate change (18).

Respondents also completed measures of political ideology and party affiliation. For political group comparisons, political ideology was recoded into a binary variable to refer to liberals (coded as 0) versus conservatives (coded as 1), and political party affiliation was recoded into Democrats (coded as 0) versus Republicans (coded as 1). For simplicity, respondents identifying as ideologically moderate or Independent were not considered in the present analyses used for political group comparisons (although results were essentially the same when considering them in the models; *SI Appendix*).

Respondents also completed several sociodemographic questions (i.e., gender, age, education level, annual income, race/ethnicity). Because previous research documents variation in global warming beliefs and attitudes across gender, race, education, and income (19), as well as age (20, 21), we reproduced the present analyses while statistically controlling for these variables to test the robustness of effects (*SI Appendix*).

### Results

Correlation analyses found that, as predicted, systems thinking was positively related to beliefs that global warming is happening and human-caused, worry about and perception of risk from global warming, issue importance, and knowledge of scientific consensus ( $r$ s ranged from 0.169 to 0.311;  $P < 0.001$ ); Table 1). Systems thinking was also strongly related to an ecological worldview ( $r = 0.545$ ;  $P < 0.001$ ), consistent with previous research (3). The relationships between ecological worldview and global warming beliefs and attitudes were also generally strong ( $r$ s ranged from 0.378 to 0.539;  $P < 0.001$ ). Next, multiple regression models assessed the extent to which systems thinking

**Table 1. Correlation matrix ( $n = 1,058$ )**

Variable	1	2	3	4	5	6	7	8	9
1. Systems thinking									
2. Ecological worldview	0.545								
3. GW is happening	0.311	0.525							
4. GW is human-caused	0.169	0.394	0.607						
5. Worry about GW	0.280	0.539	0.695	0.553					
6. Risk perceptions	0.262	0.502	0.670	0.558	0.757				
7. Issue importance	0.259	0.508	0.693	0.539	0.802	0.747			
8. Scientific consensus	0.276	0.378	0.539	0.483	0.503	0.506	0.488		
9. Political ideology	-0.234	-0.316	-0.429	-0.400	-0.400	-0.353	-0.373	-0.392	
10. Party affiliation	-0.159	-0.284	-0.359	-0.312	-0.328	-0.272	-0.299	-0.319	0.559

All  $P$  values  $< 0.001$ . Sample size of risk perceptions was  $n = 917$  as a result of omitting “Don’t know” responses. Political ideology is measured on a 5-point scale from 1 (“Very liberal”) to 5 (“Very conservative”) and party affiliation is coded as 0 = “Democrat,” 1 = “Independent,” and 2 = “Republican.”

GW, global warming.

predicted beliefs independent of ecological worldview. Once worldview was included in the model, however, the relationships between systems thinking and global warming beliefs and attitudes became nonsignificant across almost every outcome, with the exception of scientific consensus (Table 2, Model 2). Results were similar across all models when statistically controlling for gender, age, education, income, and race (SI Appendix, Table S3). Contrary to our prediction, these results indicate that systems thinking does not uniquely or directly predict beliefs and attitudes independent of ecological worldview. Rather, these findings suggest that systems thinking may have an indirect effect: ecological worldview may fully mediate the relationship between systems thinking and global warming beliefs and attitudes.

Using Hayes's PROCESS modeling software to test for mediation, we found, as posited, that ecological worldview significantly explains the relationship between systems thinking and global warming beliefs and attitudes (22). The direct effects of systems thinking dropped to nonsignificance with worldview in the models for most outcomes, and the 95% confidence intervals of indirect effects did not contain zero. There were significant standardized indirect effects (95% CIs) for belief that global warming is happening (0.275; 0.263–0.318), belief that global warming is human-caused (0.234; 0.193–0.275), worry (0.299; 0.261–0.336), perceived risk (0.289; 0.247–0.331), issue importance (0.284; 0.246–0.323), and scientific consensus (0.176; 0.133–0.220). Indirect effects were similar in strength when controlling for sociodemographic variables, including political ideology (SI Appendix).

To express these relationships in practical terms, we used unstandardized regression coefficients to estimate the percentage change in global warming beliefs and attitudes associated with a change of 1 point on the systems thinking and ecological worldview measures (23). On average, for every 1-point increase on the systems thinking scale, global warming beliefs and attitudes increased about 5–11%, and ecological worldview increased about 10% (SI Appendix, Table S2). For every 1-point increase in the ecological worldview measure, global warming beliefs and attitudes increased about 12–20%.

We also tested the alternative model using Hayes's PROCESS, that systems thinking mediates the relationship between ecological worldview and global warming beliefs and attitudes. However, we found a lack of support for this model. This is evidenced by nonsignificant indirect effects for almost all outcomes (standardized indirect effects ranged from –0.035 to 0.020). The one exception is scientific consensus (standardized indirect effect, 0.055; 95% CI, 0.016–0.094). Using a procedure to test for differences in effect sizes, we conducted Z-tests to determine whether indirect effect coefficients for systems thinking were significantly stronger than those for ecological worldview (24). Results show that the indirect effects of systems thinking through an ecological worldview are significantly stronger than the indirect effects of the converse across all outcomes (belief that global warming is happening,  $Z = 8.668$  [ $P < 0.001$ ]; belief it is human-caused,  $Z = 9.397$  [ $P < 0.001$ ]; worry,

$Z = 11.685$  [ $P < 0.001$ ]; risk perceptions,  $Z = 10.068$  [ $P < 0.001$ ]; issue importance,  $Z = 11.139$  [ $P < 0.001$ ]; and scientific consensus,  $Z = 4.038$  [ $P < 0.001$ ]).

We also tested whether the mediation models varied depending on political ideology and party affiliation; that is, the degree to which political views moderate the relationships in the mediation models. Because we found that worldview consistently mediated relationships between systems thinking and global warming beliefs and attitudes, for parsimony, we formed a single composite of the six dependent measures by standardizing the distributions and averaging the measures together. A principal components analysis supported this decision (SI Appendix, Fig. S2 and Table S8). For simplicity, we limited the analyses to dichotomous moderators: conservatives versus liberals, and Republicans versus Democrats. The results were similar when testing each dependent variable separately, and also remained similar when we included political moderates and/or Independents in the models (SI Appendix, Figs. S3 and S4 and Tables S9 and S10).

Overall, the findings were comparable to the results from the simple mediation models (Fig. 1). There were strong standardized indirect effects (95% CIs) of ecological worldview for both conservatives (0.373; 0.261–0.490) and liberals (0.212; 0.117–0.273), as well as Republicans (0.347; 0.241–0.454) and Democrats (0.245; 0.185–0.307). The indices of moderated mediation suggested that the indirect effect of worldview was stronger for conservatives compared with liberals (index, 0.161; 95% CI, 0.037–0.287); however, the difference between Republicans and Democrats was marginal (index, 0.102; 95% CI, –0.021 to 0.220). Further, systems thinking and ecological worldview together explained more variance in overall global warming beliefs and attitudes for conservatives (37.11%) and Republicans (34.41%) than for liberals (20.41%) and Democrats (24.41%). Results were similar when controlling for sociodemographic variables, except the difference in indirect effects between conservatives and liberals became marginal (SI Appendix, Fig. S1).

Differences in indirect effects are explained, at least in part, by the (unexpected) stronger relationship between ecological worldview and global warming beliefs and attitudes for conservatives and Republicans compared with liberals and Democrats, as indicated by the significant interactions (respectively,  $b = 0.463$  [ $P < 0.001$ ] and  $b = 0.359$  [ $P < 0.001$ ]; see Table 3). In other words, ecological worldview more strongly explains differences in beliefs and attitudes among the political Right ( $b$ s ranged from 0.904 to 0.946) than the political Left ( $b$ s ranged from 0.343 to 0.411), as shown in Fig. 1. Results were similar when controlling for sociodemographic variables (SI Appendix, Table S4). Further, contrary to our predictions, political views did not consistently moderate the relationships between systems thinking and either worldview or overall global warming beliefs and attitudes (SI Appendix, Tables S11 and S12). Collectively, these results indicate that the relationships between systems thinking and both ecological worldview and global warming

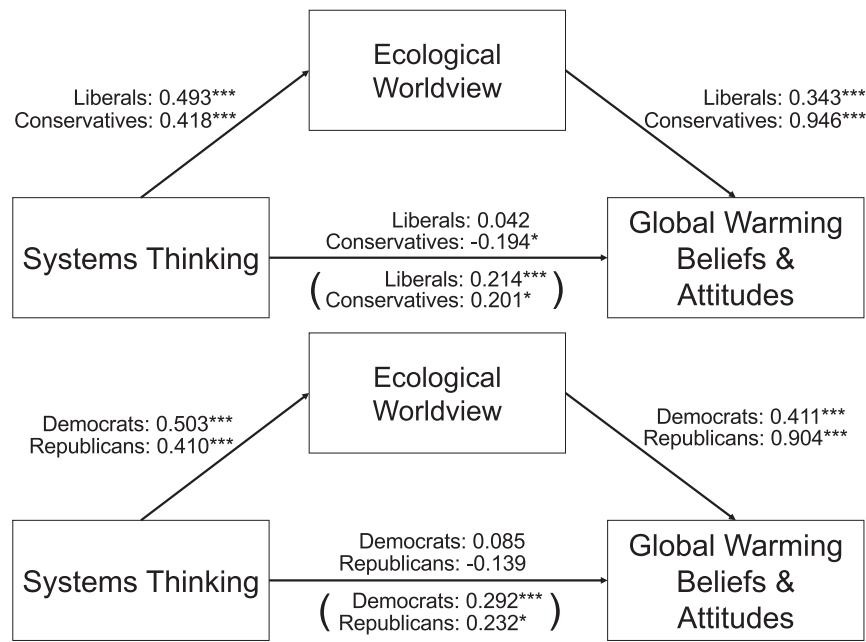
**Table 2. Systems thinking and ecological worldview predicting global warming beliefs and attitudes**

Predictor	Happening	Human-Caused	Worry	Risk Perceptions	Issue Importance	Scientific Consensus
<b>Model 1</b>						
Systems thinking	0.752*** (0.071)	0.370*** (0.066)	0.365*** (0.039)	0.314*** (0.038)	0.422*** (0.048)	8.780*** (0.941)
<i>F</i>	113.382***	31.184***	89.925***	67.240***	76.082***	87.158***
<i>R</i> <sup>2</sup>	0.097	0.029	0.079	0.069	0.067	0.076
<b>Model 2</b>						
Systems thinking	0.087 (0.075)	–0.141 (0.074)	–0.024 (0.040)	–0.033 (0.041)	–0.041 (0.051)	3.182** (1.076)
Ecological worldview	1.387*** (0.086)	1.066*** (0.084)	0.812*** (0.046)	0.712*** (0.047)	0.965*** (0.058)	11.677*** (1.222)
<i>F</i>	202.066***	99.348***	215.734***	154.749***	184.217***	92.930***
<i>R</i> <sup>2</sup>	0.277	0.159	0.290	0.253	0.259	0.150

Unstandardized *b*-values of predictors are presented with SEs in parentheses. Model 2 *P* values of systems thinking ranged from 0.056 to 0.547, except for scientific consensus ( $P = 0.003$ ). Sample size of risk perceptions analysis was 917 as a result of omitting "Don't know" responses.

\*\* $P < 0.01$ .  
\*\*\* $P < 0.001$ .





**Fig. 1.** Systems thinking predicts overall global warming beliefs and attitudes through an ecological worldview across political groups. Path coefficients refer to unstandardized *b*-values from separate mediation model tests with each political group: conservatives (*n* = 269), liberals (*n* = 316), Republicans (*n* = 235), and Democrats (*n* = 343). Coefficients in parentheses refer to direct effects of systems thinking on beliefs and attitudes without ecological worldview in the model. \*\*\**P* < 0.001; \*\**P* < 0.01; \**P* < 0.05.

beliefs and attitudes are relatively similar across people with different political views and party affiliations.

**Discussion**

Systems thinking, a cognitive framework in which individuals perceive phenomena as interconnected and dynamic (e.g., understanding that changes in one system, such as the environment, can permanently alter other systems, such as the economy; recognizing that systems fluctuate but in patterned and cyclical ways) (3, 8) is consistently associated with global warming beliefs and attitudes in the present research. In a large sample of US adults, higher-scoring systems thinkers are more likely than those who score lower to think global warming is happening, to think it is human-caused, and to worry about it, perceive it as a serious risk, value it as a personally important issue, and understand that most climate scientists are convinced that human-caused global warming is happening.

Systems thinking, however, may have a distal and indirect influence, rather than a proximate and direct influence, on climate change beliefs and attitudes. Our analyses suggest that having an ecological worldview (as characterized by the New Ecological

Paradigm; e.g., believing people should take care of and not abuse the environment) (10) consistently explains the positive relationship between systems thinking and global warming beliefs and attitudes, as indicated by strong indirect effects across mediation models. The predictive strength of systems thinking drops to nonsignificance across almost all outcomes, except knowledge of the scientific consensus, when ecological worldview is included as a mediator. Thus, systems thinking seems to be an important stepping stone: it may lead people to adopt a general proenvironmental value system, which then influences more specific beliefs and attitudes about climate change. Although this study is correlational, we did not find evidence that systems thinking, alternatively, mediates the relationship between worldview and beliefs and attitudes. In other words, our data suggest it is less likely that a general proenvironmental orientation shapes climate change beliefs and attitudes via systems thinking. Rather, it is more likely that the tendency to see the world as interconnected activates an ecological worldview, which in turn promotes the acceptance of basic conclusions of climate science. These findings support theoretical perspectives and the basic conceptualization of systems thinking as a general cognitive paradigm of viewing phenomena as interconnected and dynamic, serving as a foundation to a proenvironmental orientation (2, 3, 8, 9).

**Table 3. Systems thinking, ecological worldview, and political ideology/party predicting overall global warming beliefs and attitudes**

Predictor	Political ideology ( <i>n</i> = 585)	Party affiliation ( <i>n</i> = 578)
Systems thinking	-0.062 (0.043)	-0.007 (0.044)
Ecological worldview	0.643*** (0.049)	0.633*** (0.052)
Political group	-0.579*** (0.054)	-0.434*** (0.055)
Worldview × political	0.463*** (0.083)	0.359*** (0.087)
<i>F</i>	145.581***	115.480***
<i>R</i> <sup>2</sup>	0.501	0.446

The six measures of global warming beliefs and attitudes were standardized and averaged to form a composite. Unstandardized *b*-values of mean-centered predictors are presented with SEs in parentheses. Political group refers to liberals (coded as 0; *n* = 316) versus conservatives (coded as 1; *n* = 269) in the political ideology model, and Democrats (coded as 0; *n* = 343) versus Republicans (coded as 1; *n* = 235) in the political party model. \*\*\**P* < 0.001.



Further, we find that the pathway from systems thinking to global warming beliefs and attitudes through an ecological worldview applies to people across political ideologies and party affiliations. There is also evidence that the pathway may be stronger for conservatives compared with liberals, and to a lesser extent, Republicans compared with Democrats. For instance, systems thinking and ecological worldview explained differences in overall beliefs and attitudes about global warming for conservatives (about 37% of variance explained) and Republicans (34%) more strongly than for liberals (20%) and Democrats (24%). According to statistical standards, these are considered medium to large effect sizes, and are particularly large for the political Right (25). Further, the indirect effects of systems thinking on understanding climate change are also considered medium to large (26, 27). We find these effects to be similar in strength even when statistically controlling for socio-demographics, including political ideology (*SI Appendix*). These predictive effects across the political spectrum suggest that systems thinking may be an effective mechanism to help the public engage with the issue of climate change, given that climate change is highly politicized in the United States, and political views play a strong role in shaping climate change opinions (15, 28). Thus, strengthening systems thinking may be a useful strategy to help narrow gaps in global warming beliefs and attitudes via an ecological ethic that the natural world should be valued, preserved, and protected.

In the context of theory and research on differences in partisan value systems, engaging the values and worldviews of the political Right (e.g., moral values of purity and sanctity) may be a particularly effective strategy in facilitating proclimate views (29, 30). For instance, one study found that communicating climate change with terms such as “contamination” and “purity” were more effective than terms like “harm” and “care” in promoting proenvironmental attitudes among conservatives (29). It is, thus, plausible that there is some overlap between the political Right’s value orientations (e.g., sensitivity to purity and sanctity) and an ecological ethic that could partially explain the differences we found between partisan groups. The findings of this study are encouraging, given that factors that facilitate proclimate views in the general population can, conversely, negatively influence climate attitudes for conservatives and Republicans in the United States (e.g., higher education; refs. 31–33). Adding to research in this area (29, 30, 34, 35), our data suggest that systems thinking may be one pathway to encourage conservatives and Republicans to adopt a more ecological worldview, which may then bolster acceptance and understanding of climate change.

Taken together, the evidence from this study supports theoretical perspectives and scientific and educational efforts to foster systems thinking as a means to promote climate change beliefs, attitudes, and behaviors. There are some important limitations of this research, however. First, this study focused on the general US population, in which climate change is highly politicized, and thus, the results may not generalize to other populations. Second, this study is correlational. Although we found our results to be generally consistent, robust, and aligned with current theory on the effects of systems thinking in the environmental domain (3, 8, 9, 12), we cannot establish causation. Future research should design and evaluate interventions to experimentally (and longitudinally) test the extent to which they enhance systems thinking and affect downstream outcomes such as climate change beliefs, attitudes, and behaviors across different populations. Future experimental work should also specifically test the mediation model identified in this study to assess causality, as well as the strength of effects across the political spectrum and relative to other drivers of climate change attitudes. Because the political differences we found were unexpected, future empirical work should assess whether these findings replicate in other contexts and with other methods. Rigorous empirical assessment of current interventions is also important, given that some scientific and educational settings include systems thinking as a core component to climate science and learning (1, 2, 4–6, 36). Scholars argue that “a systems thinking mindset is malleable and can be enhanced by a variety

of kinds of interventions: both intensive educational training and more subtle framing manipulations” (ref. 8, p. 754). Despite this, however, calls for empirical research on the effects of systems thinking in applied settings have not been adequately answered (3, 37, 38). Further, more research is needed on which core systems thinking skills should be acquired and how they can be enhanced through learning and teaching strategies (39).

More research is also needed on how to encourage systems thinking in climate change communication and to assess the extent to which these approaches can support the adoption of beliefs aligned with the conclusions of climate science. For example, the public is generally unaware of the complex and multifaceted process by which natural resources are used (e.g., energy use) because these systems are typically invisible to people (40). Similarly, basic misconceptions of global climate change and its causes (e.g., greenhouse gas emissions, energy consumption, deforestation) are also common (41). This lack of awareness and knowledge poses barriers to public engagement because many people do not understand how resource consumption influences the sustainability of natural systems (9, 42, 43). Communication that makes invisible systems visible and describes the interrelation between human action, the natural environment, and other domains such as public health and the economy (including the cobenefits of a sustainable natural environment) may help to promote systems thinking and an ecological worldview, and thus, proclimate views and behavior (44).

To address environmental issues such as climate change, “we need populations equipped to conceptualize dynamic and complex problems, to work with transformational change, and to innovate solutions to emerging threats and disturbances” (ref. 2, p. 1). Climate change is a serious threat to ecosystems and human populations and represents one of the most complex systems problems society faces (36, 45). This study finds that systems thinking can encourage the adoption of an ecological worldview, which in turn can foster acceptance and understanding of climate change across people with different political views.

## Materials and Methods

**Participants.** Respondents were recruited via Prime Panels, an online sampling platform consisting of a diverse panel of about 20 million workers in the United States. The study fell under an exemption granted by the Yale University Institutional Review Board. The final sample consisted of 1,058 adults living in the United States. The final sample is disproportionately female ( $n = 707$ , 66.8%) and ages ranged from 18 to 86 y old (Mean = 46.3,  $SD = 17$ ). The majority of respondents identified as White, non-Hispanic ( $n = 791$ , 74.8%) followed by Hispanic ( $n = 101$ , 9.5%); Black, non-Hispanic ( $n = 97$ , 9.2%); and other or multiracial ( $n = 69$ , 6.5%). Most respondents had some college ( $n = 405$ , 38.3%) or a Bachelor’s degree or higher ( $n = 327$ , 30.9%). Also, the majority earned an annual household income of less than \$50,000 ( $n = 652$ , 61.7%; two respondents skipped this question). For more information, see *SI Appendix, Table S1* for demographic information. Data are available on the Open Science Framework (46).

**Procedure and Materials.** Respondents completed the Systems Thinking Scale Revised (3) by rating 15 statements such as “All the Earth’s systems, from the climate to the economy, are interconnected”; “Adding just one more, small farm upstream from a lake can permanently alter that lake”; and “Social problems, environmental problems, and economic problems are all separate issues” (reverse coded) on a 7-point scale ranging from 1 (“Strongly disagree”) to 7 (“Strongly agree”) in a randomized order ( $\alpha = 0.71$ ; Mean = 4.90;  $SD = 0.70$ ). After this, respondents completed the 15-item New Ecological Paradigm Revised (10) (e.g., “Plants and animals have as much right as humans to exist”; “We are approaching the limit of the number of people the Earth can support”; “Humans have the right to modify the natural environment to suit their needs” [reverse coded]) on a 5-point scale ranging from 1 (“Strongly disagree”) to 5 (“Strongly agree”) also in a randomized order ( $\alpha = 0.82$ ; Mean = 3.58;  $SD = 0.62$ ).

Respondents then completed the six measures of global warming beliefs and attitudes in the following order: (i) “How strongly do you believe that global warming is or is not happening?” rated on a scale from 1 (“I strongly believe global warming is NOT happening”) to 7 (“I strongly believe global warming IS happening”; Mean = 5.50;  $SD = 1.70$ ); (ii) “Assuming global warming IS happening: How much of it do you believe is caused by human

activities, natural changes in the environment, or some combination of both?" rated on a 7-point scale ranging from 1 ("I believe global warming is caused entirely by natural changes in the environment") to 7 ("I believe global warming is caused entirely by human activities"; Mean = 4.92; SD = 1.54); (iii) "How worried are you about global warming?" rated on a 4-point scale from 1 ("Not all worried") to 4 ("Very worried"; Mean = 2.96; SD = 0.92); (iv) two risk perception questions, "How much do you think global warming will harm you personally?" and "How much do you think global warming will harm future generations of people?" rated on a 4-point scale from 1 ("Not at all") to 4 ("A great deal"), as well as a "Don't know" option ("Don't know" responses were considered missing and not included in the mean composite of the two items,  $n = 141$ , 13.3%;  $r = 0.66$ ; Mean = 3.01; SD = 0.86); (v) "How important is the issue of global warming to you personally" rated on a 5-point scale 1 ("Not at all important") to 5 ("Extremely important"; Mean = 3.57; SD = 1.44); and (vi) "To the best of your knowledge, what percentage of climate scientists have concluded that human-caused global warming is happening?" with a 0–100% slider scale to measure knowledge of the scientific consensus about human-caused global warming. In our sample, about one in five of respondents (20%) understood that more than 90% of climate scientists are convinced that human-caused global warming is happening (Mean = 69.95%; SD = 22.36%), which is equivalent to the proportion that understand this in the general US population (20%) (18).

After these questions, respondents completed demographic questions on age, gender, race, education, income, political ideology, and party affiliation. Political ideology was measured on a 5-point scale (1 = "Very liberal," 2 =

"Somewhat liberal," 3 = "Moderate, middle of the road," 4 = "Somewhat conservative," 5 = "Very conservative"; Mean = 2.96; SD = 1.18), and political party affiliation was measured with five response options (25.0% identified as Republican, 35.5% Democrat, 26.7% Independent, 11.2% no party/not interested in politics, and 1.5% other).

We used Hayes's PROCESS macro (22) Model 4 with 10,000 bootstrapped resamples and bias-corrected estimates to test the simple mediation models. To test whether the relationships among systems thinking, ecological worldview, and global warming beliefs and attitudes were moderated by political ideology and/or party affiliation, we used the following PROCESS models: (i) Model 58 to test whether paths (a) from systems thinking to ecological worldview and/or (b) from ecological worldview to global warming beliefs and attitudes were moderated by political ideology and/or party affiliation, and whether indirect (mediation) effects were significantly different across political groups; (ii) Model 1 to test whether the relationship between systems thinking and global warming beliefs and attitudes was moderated by political ideology and/or party affiliation; and (iii) Model 4 to test the simple mediation model for each of the four political groups, as shown in Fig. 1. Predictors were mean-centered, using PROCESS for the moderation tests. The standardized mean composite of global warming beliefs and attitudes was tested for parsimony; however, each outcome was also examined separately (SI Appendix, Figs. S3 and S4).

**ACKNOWLEDGMENTS.** This project was supported by the Heising-Simons Foundation, the 11th Hour Project, the TomKat Foundation, the Energy Foundation, and the MacArthur Foundation.

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