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PEER-REVIEWED ARTICLE

Using Interactive Maps to Reveal the Content of Second-Order Climate Change Beliefs

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Although there is extensive research on first order climate change beliefs, second-order beliefs (perceptions about what others believe) are an understudied and potentially highly influential factor tied to a lack of climate policy action. This map reading study employs a pre- and post-map observational design to investigate how interactive maps can reveal and update second-order climate change beliefs. Participants first completed a pre-map survey detailing their climate change beliefs and estimating public support for climate policies. Participants then completed map reading tasks on an interactive web map that visualized county-level climate change opinions in North Carolina, while their eye movements were recorded with an eye tracker. A post-map survey gauged participants' reactions to the actual climate opinions, accompanied by map usability questions. The results showed a widespread underestimation of actual climate policy support among participants. Participants commonly used a set of environmental and humanistic concerns to justify the content of their own beliefs, but when asked to rationalize others' beliefs using the map, they used conspiratorial or ideological explanations to describe others who were more skeptical of climate policy. Additionally, participants exhibited egocentric bias, focusing more on their home counties and those with extreme climate change opinions when exploring the web map. The research underscores the potential of interactive maps to improve the understanding of second-order climate change beliefs and emphasizes opportunities for enhancing their ability to communicate the broad public support that exists for many climate policies.

KEYWORDS: web cartography; web map usability; climate change communication

INTRODUCTION

Maps are increasingly used to communicate information about climate change and are an important medium for disseminating messages and stories about it to the public and policymakers. However, partisan polarization remains at record levels, which has led to controversies and debates over climate policy. Despite abundant research on first-order (individual-level) beliefs, second-order beliefs (beliefs about what others believe) remain an understudied and potentially highly influential factor tied to a lack of climate policy action. Climate policy debates in the United States have been framed around Democratic support and Republican opposition, with little consideration for the heterogeneity of beliefs within those groups or the actual levels of support for different policies. While climate change opinions have been studied for the last three decades (Tuitjer et al. 2022), our study takes advantage of the growing popularity of using public opinion maps for climate change communication to understand why people believe what they do about others (Howe et al. 2015; Ballew et al. 2019; Marlon et al. 2022). We characterize the second-order beliefs about climate change among a student sample and determine how

interactive climate change opinion maps work to reveal and update the content of these beliefs. This study is guided by the following questions: (1) How do students who hold a range of opinions exhibit second-order beliefs about climate change? (2) Which types of web map interactions are most valuable for updating second-order beliefs?

BACKGROUND

The field of climate change communication was developed to address the stagnation in debate and action that has occurred over the last two decades (Moser 2016). Notably, it provided the empirical groundwork that is essential to understand group values, beliefs, and identities, and their role in supporting pro-climate social policy (Fielding and Hornsey 2016). In practice, climate change communication led to the development of tailored communication strategies that emphasize both the affective responses to climate stories and also the more traditional, quantitative presentations of scientific information to the public. Broad-level public acceptance of human-caused climate change is largely attributed to these efforts, and support for climate change policies among the American public is higher than ever—yet relatively few voters engage in political actions to reduce global warming (Leiserowitz et al. 2021). There are still many unanswered questions about how acceptance of climate change gets translated into action.

First-order beliefs are the beliefs that individuals hold. When it comes to climate change, they are driven by a combination of factors, like individual scientific knowledge, education level, race, gender, risk perception, exposure to extreme weather, general environmental attitudes, and religious or political affiliation (Lee et al. 2015; Lewis et al. 2019; Shao and McCarthy 2020). Political affiliation, in particular, is strongly correlated with climate change acceptance, risk perception, and support for mitigation policies (Hamilton et al. 2010; Hamilton and Saito 2015). In contrast, second-order beliefs, or beliefs about what others believe, remain an understudied and potentially highly influential factor in the current lack of significant climate policy action (Mildenberger and Tingley 2017). Individual positions toward a particular issue are identity-based, formed in response to the perceived positions of one's social in-groups and out-groups. Second-order beliefs are characterized by egocentric bias, or the assumption by an individual that others hold similar views to themselves, especially if those others are perceived as similar. These beliefs are also tied to the formation of the false consensus effect, whereby individuals overestimate the homogeneity of group beliefs, and the pluralistic ignorance effect, whereby individuals support positions but mistakenly assume others do not. Finally, second-order beliefs have contributed to false polarization, where individuals perceive more partisan polarization than exists (Epley et al. 2004; Epley and Gilovich 2006; Miller and McFarland 1987). The net result is a general population-level underestimation of pro-climate positions and a reinforcement of weak support for climate policies (Sparkman et al. 2022).

Researchers have largely focused on first-order beliefs because they have assumed the primary importance of the information deficit model of communication, in which factors like education and communication of scientific information operate as a gateway of belief to increasing support for pro-climate policies amongst the public (Ehret et al. 2018). For example, consensus messaging about anthropogenic climate change leads to increased support for public action because it prompts an attitudinal shift in the way the public perceives the legitimacy of scientific facts (Linden et al. 2019). Under the deficit model of communication, it is the transfer of scientific information from experts to the public that needs to be improved to prompt behavioral change related to climate solutions and policy support. However, research shows that education efforts to change first-order beliefs can result in more, not less, polarization (Hart and Nisbet 2012). This is because people who possess greater policy knowledge are also more likely to have strong partisan views (Hamilton et al. 2015; Smith and Mayer 2019). Climate change also holds different meanings across different social, cultural, and historical contexts (Hulme 2009), so understanding how diverse audiences would come to support the same policies but for different reasons remains a challenge.

Competing theories in science communication recognize the importance of more active or dialogic models for understanding how scientific information is interpreted and acted upon by the public. Specifically, under cultural cognition models, belief systems are formed by both the individual-level factors mentioned above as well as top-down factors, such as social identity, elite messaging, and

cultural concerns (Fielding and Hornsey 2016; Kahan 2012). The cultural cognition theory, along with the social identity approach (which views identity as malleable and everchanging) show that individuals filter information through the lenses of worldview and social identity (Kahan et al. 2010). Literacy and education are crucial components to the public understanding of science. However, it is important to account for the ways in which people process information through culturally transmitted values, in order to understand the complete formation of their ideological development and the prevailing attitudes toward climate change policies (Farrell 2016; Hoffman 2011).

Most cartographic research on climate change to date has focused on improving the graphic design of the presentation of scientific information for a variety of audiences, with the intent centered around the effective transfer of that information to the public (Retchless and Brewer 2016; Harold et al. 2016). This research has improved the effectiveness of maps in major media outlets and scientific reports (Fish 2020). However, it has also operated under the primary assumptions of the information deficit model of communication, with static maps passively delivering expert-derived messages about climate change to the uninformed or unconcerned public. Research agendas have subsequently broadened in scope to consider how maps can be used to mobilize the public and policymakers through storytelling (Roth 2021), the extent that mapped messages are viewed as trustworthy (Griffin 2020), and whether map designers and their audiences occupy positions of privilege that typically exclude the members of the public they are most trying to reach (Retchless et al. 2022). These examples of recent research show how the field has come to recognize the need to consider maps as more than simply a medium for the passive transfer of information.

Part of this broadening of the research paradigm is a focus on interactive maps, which offer the user the ability to manipulate a map based on a set of intended goals and specific use cases (Roth 2017; Cartwright et al. 2001). Several studies have examined how climate change information is perceived by the public when using interactive maps (Popelka et al. 2019; Retchless 2018). The results have shown that interactive maps are more effective in improving user understanding of complex subjects than static maps, although familiarity with the medium remains a challenge. Users with more interactive web map experience are more likely to understand how to navigate such maps and therefore have an easier time finding information (Davis et al. 2020). The methods of these user studies focused on both the quantitative and qualitative user reactions to geographic information and the interactions that facilitated this information transfer. The research we present in this paper uses similar methods to examine the extent to which maps can correct the mischaracterizations of others' climate change beliefs, and to further understand how interactive maps may moderate polarization, thus consolidating support for popular policies.

MATERIALS AND METHODS

DATA COLLECTION AND MAP READING EXPERIMENT

Participant Recruitment

We used an exploratory approach in this research, developing both a pre- and a post-map observational design to understand whether and how using interactive maps can reveal and update the content of map users' second-order climate change beliefs. As is common in eye tracking and other map use studies, a convenience sample (n=30) was recruited from the student population at Appalachian State University (App State), by visiting courses to announce the study and call for volunteers. Participants from the Departments of Geography and Planning, Public Health, Sociology, Business, Economics, History, and Outdoor Recreation were asked to participate in an eye-tracking research study about interactive maps and climate change beliefs. Volunteers did not receive any incentive for their participation.

Pre-map phase

The research was divided into three phases, beginning with a pre-map phase, and then followed by a map reading session, and a post-map phase. In the pre-map phase, participants completed an online survey screener using Qualtrics to collect demographic information and information about participants' climate change beliefs (Table 1). The pre-map survey also identified any participants who might be disqualified from eye-tracking research due to preexisting vision-related conditions. Before beginning

DEMOGRAPHIC ITEM	PARTICIPANTS (N)	SAMPLE PERCENTAGE
Gender		
Male	11	37%
Female	18	60%
No response	1	3%
Academic year		
1st year student	5	17%
2nd year student	9	30%
3rd year student	5	17%
4th year student	4	13%
Graduate student	7	23%
Experience with technology		
Very low experience	0	0%
Low experience	1	3%
Moderate experience	14	47%
High experience	14	47%
Very high experience	1	3%
Frequency of web map use		
Daily	16	53%
Weekly	13	43%
Monthly	1	3%
Yearly	0	0%
Political affiliation		
Very liberal	10	33%
Liberal	15	50%
Moderate	5	17%
Conservative	0	0%
Very conservative	0	0%
Climate change concern		
Alarmed	19	63%
Concerned	11	37%
Cautious	0	0%
Disengaged	0	0%
Doubtful	0	0%
Dismissive	0	0%

Table 1. Participant demographics (n = 30).

ABBREVIATION	STATEMENT
Catastrophic risk	Climate change poses a catastrophic risk to society.
Capitalist society	Climate change is a symptom of a capitalist society that has primarily prioritized economic growth and consumerism, and which has dangerously exceeded the carrying capacity of the planet.
International agreements	Sustainable economic growth can continue indefinitely with the right market-based mechanisms and international agreements.
Environmental problem	Climate change has been misdiagnosed as an environmental problem and market failure.
Carbon pricing	Climate change is a result of the failure to recognize limits to growth and can be corrected by putting a price on carbon.
Diverse policies/tech	Human ingenuity and government investment in diverse policies and technologies will lower the cost of action and protect against climate damages.
Awareness	Public awareness and acceptance of climate change are important first steps to advance climate policy.
Activism	A new public consciousness spread through grassroots activism and social protest is necessary to advance climate change solutions.
Nuclear	Government should encourage the development of nuclear energy relative to other energy sources.
Wind and solar	Government should encourage the adoption of renewables, like wind and solar, relative to other energy sources.
Natural gas	Government should encourage the development of natural gas relative to other energy sources.

Table 2. Abbreviated names of climate change statements presented to participants. Participant responses are seen in Figure 3.

the survey, participants provided informed consent and received an anonymized ID that was used to track their participation throughout the research study. This research was approved through the Appalachian State Institutional Review Board to ensure that all protocols for ethical research were followed, and participants were informed about research risks associated with the eye tracker.

The pre-map survey was designed to gather information about participants' computer proficiency, comfort with and understanding of interactive web maps, self-identified political ideologies, and climate change beliefs. This allowed us to gather baseline information on each participant's views before potentially influencing them during the rest of the study. Four questions from the Six Americas Super Short Survey (SASSY; Chryst et al. 2018) were used to measure participant levels of climate change concern, ranging from alarmed to dismissive. Participants were also asked to identify their political ideologies, ranging from very conservative to very liberal. Finally, we measured their support for different climate change policies and theories of social change, as well as their dominant views of nature, by asking participants to rate their level of agreement with a series of statements (Table 2) adapted from Nisbet (2014), on a scale of 1 (strongly disagree) to 5 (strongly agree). For example, participants were asked to rate their agreement as to whether "climate change poses a catastrophic risk to society." We also asked participants to rate their agreement with energy policy statements like "government should encourage the development of nuclear energy relative to other energy sources" and "government should encourage the adoption of renewables, like wind and solar relative to other energy sources."

Web Map Design

An interactive web map showcasing the county-level climate change opinions of North Carolinians was created using a suite of open-source programming/markup languages and libraries, including HTML, JavaScript, and CSS, as well as the Leaflet.js mapping library (Figure 1). To create the map, we collected data in 2022 from the **Yale Program on Climate Change Communication**, which provides annual climate change opinion estimates that depict the percentages of adults who support a range of statements about global warming (Howe et al. 2015). At the county level, these opinion estimates are accurate to 8 percentage points and are based on survey results from 2008–2021. They include measurements of climate change beliefs, risk perceptions, and support for different

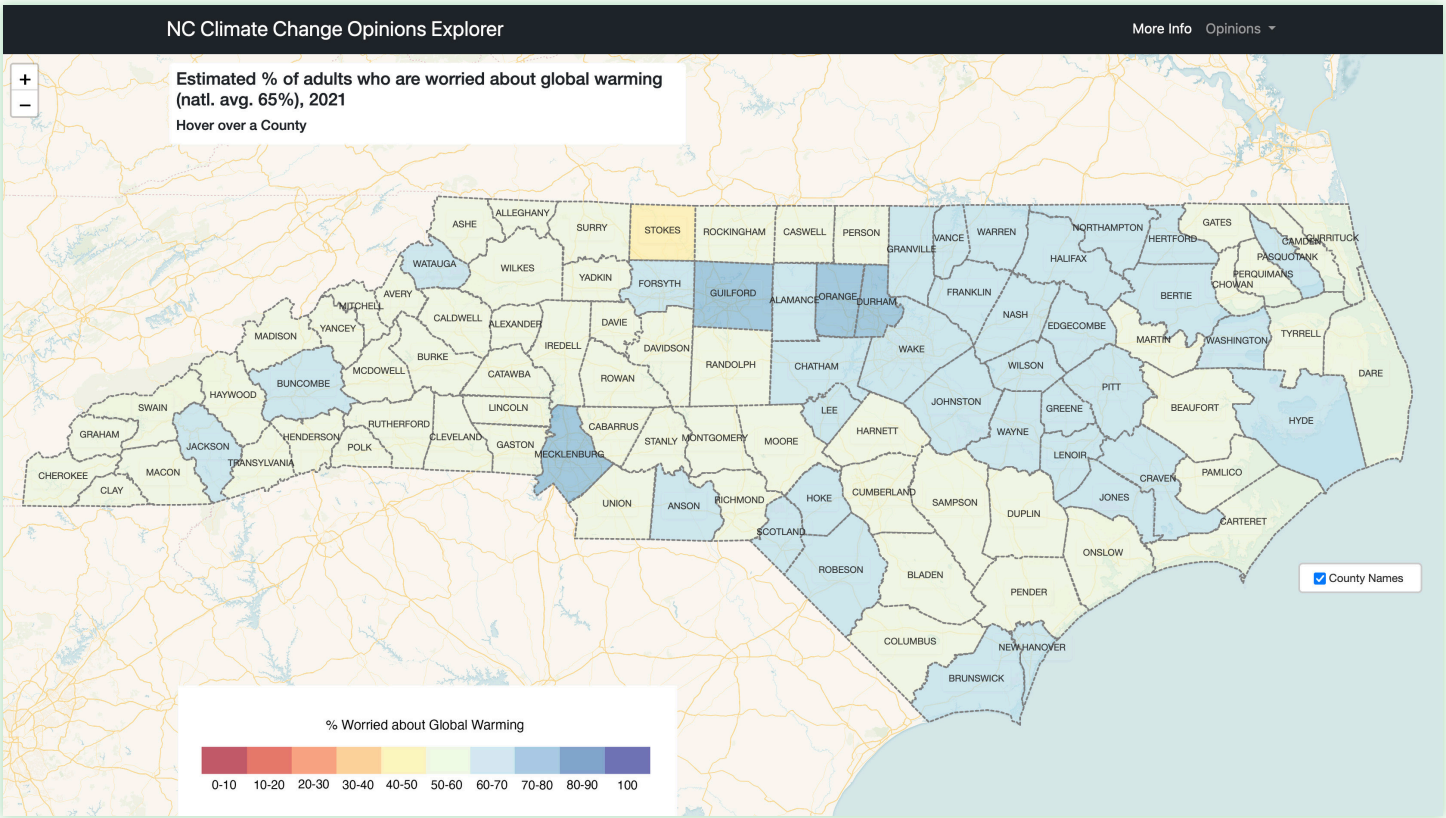

Figure 1. The NC Climate Change Opinions Explorer.

policies. Our map used three different opinion estimates. First, we used the estimated percentage of adults who are worried about climate change (a variable we will refer to as *worried*) as a baseline of general climate concern amongst North Carolinians. The second was the estimated percentage of adults who support taxing fossil fuel companies while equally reducing other taxes (*carbon tax*). Finally, we used data on the estimated percentage of adults who support the expansion of oil and gas drilling off the US coast (*offshore*). These last two datasets were chosen to relate to specific climate policies that may be considered polarizing or complex in nature, or that have been studied to be effective in mitigating climate change.

We visualized the data using choropleth symbolization. The web map also included several interactive features: a drop-down menu allowed users to toggle between the three opinion variables. They could also mouse over and highlight each county to display the name and specific percentages of opinions in that specific county, as well as for the state at large. Users could also toggle county names on and off to aid in county identification during map use.

Map Reading and Eye Tracking Session

In the second phase of the study, participants were invited to an in-person map reading and eye-tracking experiment lasting approximately 30 minutes. Participants consented to continue the research study and were given an overview of the experimental purpose and risks. Before viewing the web map, participants were asked to discuss their second-order climate change beliefs (Table 3). Specifically, participants were asked to estimate what percentage of the US population, North Carolina (NC) population, and the population within a county of their choice that they

IN-PERSON PRE-MAP READING SESSION PROMPTS
Variable
1. Worried: is worried about global warming.
2. Carbon tax: think companies should be required to pay a carbon tax.
3. Offshore drilling: support the expansion of offshore drilling for oil and natural gas off the US coast.
Second-Order Belief Estimates
1. To the best of your knowledge, what percentage of the US population. . . [variable]? Provide a number from 0 (no one) to 100 (everyone).
2. To the best of your knowledge, what percentage of the NC population. . . [variable]? Provide a number from 0 (no one) to 100 (everyone).
3. Pick a county in NC. We will record this county as part of your response. To the best of your knowledge, what percentage of this county. . . [variable]? Provide a number from 0 (no one) to 100 (everyone).
Second-Order Belief Content
1. Let's focus back on the state level. Some people in NC are/do. . . [variable], while others are not/do not. . . [variable]. We would like for you to imagine you are talking to a group of people from NC who are/do. . . [variable]. Specifically, imagine that you asked each of them why they are/do. . . [variable]. What do you think they would tell you? Please complete the following statement, focusing on what you think their responses would be. "They would say [. . .]".
2. Now, we would like for you to imagine you are talking to a group of people from NC who are not/do not. . . [variable]. Specifically, imagine that you asked each of them why they are not/do not. . . [variable]. What do you think they would tell you? Please complete the following statement, focusing on what you think their responses would be. "They would say [. . .]".

Table 3. Participants were asked to answer questions about their second-order climate change beliefs.

believe agrees or disagrees with the three variable opinion statements on climate change. Second, participants were asked to explain why they believe that groups do or do not support each statement by imagining how each group would rationalize their belief. These questions were adapted from Mildenberger and Tingley (2017) and provided a way to determine whether participants over or underestimate the population-level beliefs, while documenting the content of their beliefs about others before viewing the actual percentages on the map. The responses were audio recorded and later transcribed for content analysis. At this stage, participants completed a short training session and cognitive walkthrough of the interactive web map to familiarize them with the purpose, interactive functionality, and layout of the application. Participants were also given an overview of map reading tasks they would later be asked to complete.

This phase of the research also involved eye tracking, which provides a non-invasive way of collecting data about a user's gaze without interfering with normal viewing patterns (Holmqvist et al. 2011). User eye movements, when coupled with their verbal responses, can provide insight into how users interact with the different areas of the map and ultimately process the information being visualized and communicated (Jacob and Karn 2003). For example, fixations (points of attention) and durations (length of fixations) are tied to information processing and can thus indicate confusion or concentration over a particular element (Duchowski 2003).

We used a Tobii Pro Nano eye tracker, which records eye movements at a sampling rate of 60 Hz. Participants were seated ~65 cm from a 16-inch monitor and first completed a calibration exercise to ensure the accuracy and precision of eye movement data. Eye tracking was used to qualitatively assess participant fixations and durations across each of the mapped climate change opinion variables. The resulting gaze plots pinpoint common areas of interest or visual attention among the sample, thus providing insights into the processing of mapped spatial information. At the beginning of the experiment, a static version of the map was shown to each participant for each of the three climate opinion variables for 30 seconds. During this stage, we asked each participant to describe their reaction upon seeing the actual distribution of climate change opinions revealed on the web map. Participants were reminded of their percentage estimates of each opinion variable during this prompt.

Participants completed three map reading tasks that were developed to capture user insights on any tradeoffs between map usability, which determines how efficiently users can fulfill specific objectives with the map, and utility, which determines how well the map fulfills a specific needed function or purpose (Roth 2017). Users were prompted to engage in several objective-based interaction primitives, including identifying, ranking, and comparing, in order to facilitate user exploration of the patterns, and to allow us to document the affective user experience (Roth 2013). For example, the first map reading task asked participants to compare the percentages of adults who are worried about global warming (variable one) between two NC counties of their choice. The second task asked participants to identify the percentages who support paying a carbon tax (variable two) in Watauga County (the county in which App State is located). In the third task, participants ranked three listed counties in order of lowest to highest support for offshore drilling for oil and gas (variable three).

At the conclusion of each task, participants were prompted to verbally describe their thought process and interactions with the map using a cued retrospective think-aloud protocol, which had participants explain their use of reasoning after completing the map reading task. The use of retrospective questions is helpful, as many users struggle to complete map reading tasks while simultaneously providing full and accurate responses about their choices, especially when less experienced with interactive web map use (Atkins and McNeal 2018; Maudlin et al. 2020). In addition, think-aloud protocols can provide insights as to why a participant interacts with the map the way they do, which eye-tracking technology alone cannot provide (Popelka et al. 2019). All responses were audio-recorded and later transcribed for content analysis.

We developed a thematic content coding scheme using participant responses from the think-aloud protocol. We used **ATLAS.ti** to search for common phrases and ideas that explained participant choices in map use, areas of focus, and second-order belief content at both the county and the state level. Participant responses were organized to find similarities and differences for each question during the think-aloud protocols across map reading tasks. We gave each response at least one code, though some received more than one. Responses were then analyzed to find specific topics that participants frequently discussed

within each code. These topics provided more detail about how participants rationalized their second-order beliefs.

Post-Map Follow-up Usability Survey

During the final, post-map phase, participants completed a brief online Qualtrics survey to assess the usability of the web map and to offer their open-ended responses to the maps of climate change opinions. First, participants were asked to rank, using a Likert scale, ten measures of web map usability, including how easy the web map was to use, whether they felt confident solving tasks with the web map, and if others would be able to use the web map easily. Questions were developed from the system usability scale, which has been shown to be simple, highly accurate across different sample sizes, and particularly effective at measuring participants' attitudes and preferences (Çöltekin et al. 2009). This step told us how usable the map was for the participants and allowed us to pinpoint areas where usability could improve. Paired with the previously mentioned think-aloud protocol, we were able to analyze how usable the map was for its intended purpose and determine which types of interactions and map features were most successful. Participants were also asked to choose from a list of 100 emotions, as used by Roth et al. (2014), to gauge their affective responses to the actual distribution of climate change opinions when interacting with the web map. Participants described whether they over or underestimated the actual percentages of support for the different climate change opinions during the experimental phase. They also had the chance to describe why they may have over- or underestimated beliefs. This allowed us to explore the participant's feelings about their own second-order beliefs and gauge whether the participant was likely to update the content of these beliefs.

RESULTS

PRE-MAP RESULTS

First and Second-order Climate Change Beliefs

Participants took the SASSY screener during the pre-map phase of the study to allow us to measure their attitudes toward climate change (Chryst et al. 2018). Of the 30 participants in this study, 63% of participants were Alarmed, and 37% were Concerned. No participants were grouped as Cautious, Disengaged, Doubtful, or Dismissive about climate change. The sample group differed considerably from the national average estimates for the Six Americas groups at the time of the study, in which 26% were Alarmed, 27% were Concerned, 17% were Cautious, 7% were Disengaged, 11% were Doubtful, and 11% were Dismissive. Alarmed participants are convinced global warming is happening, human-caused, and an urgent threat, and they strongly support climate policies but remain unsure of how to solve the problem. Concerned participants share these traits, but they do not consider global warming to be an imminent threat.

Prior to engaging with the web map, participants were asked how they think most people feel about global warming in the US and in NC using a four-category Likert scale, ranging from not at all worried to very worried. Figure 2 shows the results, along with the answers to the same questions in the post-map phase. During the pre-map phase, participants were generally more skeptical of North Carolinians' climate change concern than they were of the US public. 50% of participants thought NC residents were somewhat worried about global warming, while 63% thought that people in the US were somewhat worried. Likewise, the proportion of participants who thought NC residents were not very worried about global warming was higher (47%) than the participants who thought that people in the US were not very worried about it (33%). Only 3% of participants thought that people in the US and NC were very worried about global warming during this phase.

Results from the participants' agreement with Table 2's climate change statements can be seen in Figure 3. The majority of participants strongly agreed with statements tied to ecological activist framings of climate change, including the perception that it is a catastrophic risk to society, support for the adoption of renewable energy, and the need for activism to increase public support for these policies. Participants were on average more neutral about climate change statements that advocated for smart growth and reform. For example, 43% and 46% of participants selected that they neither agreed nor disagreed with the government supporting the adoption of natural gas and nuclear energy, respectively, when compared to other energy sources. However, the majority of participants strongly

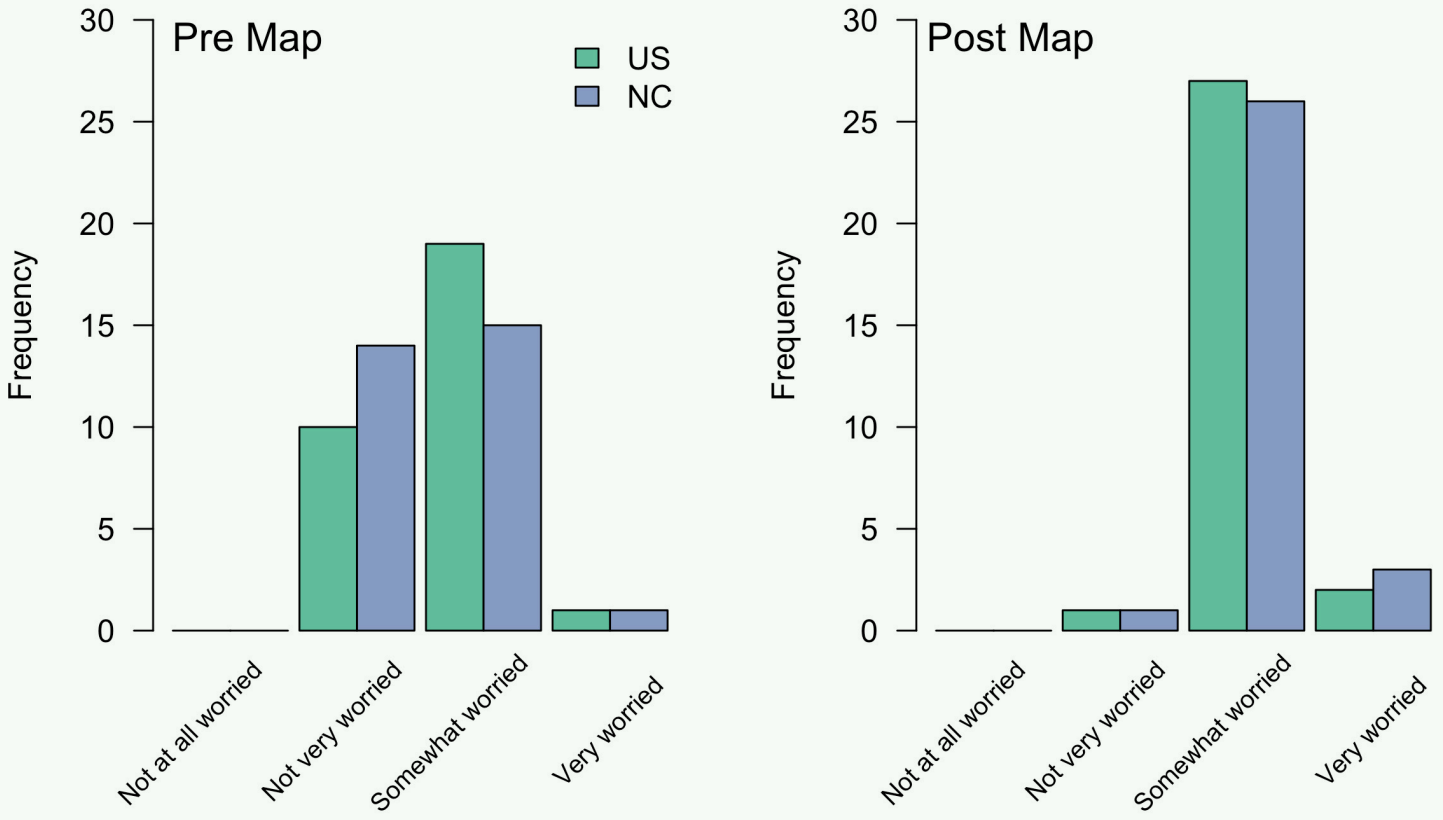

Figure 2. Participants were asked how they think most people feel about global warming in the US and NC during the pre-map phase and post-map phase (after viewing the climate change opinion estimates).

agreed that "sustainable economic growth can continue with the right market-based mechanisms and international agreements." Finally, the sample was more conflicted about statements tied to ecomodernist perspectives and solutions to climate change. When asked whether "climate change has been misdiagnosed as an environmental problem," the majority of participants either disagreed, strongly disagreed, or felt neutral. Yet a majority of participants agreed or strongly agreed that government investment in diverse sets of policies and technologies would lower the cost of action and protect against climate change harms.

IN-PERSON SESSION RESULTS

National and State Level Estimations

During the in-person session, participants were asked to report their estimates of support at the national and state levels for each metric (worried, carbon tax, and offshore drilling; Figure 4). While the study was conducted in 2023, actual survey data from the **Yale Program on Climate Change Communication** were at that time available up through the year 2021. This means that differences in participant estimations and the national and state

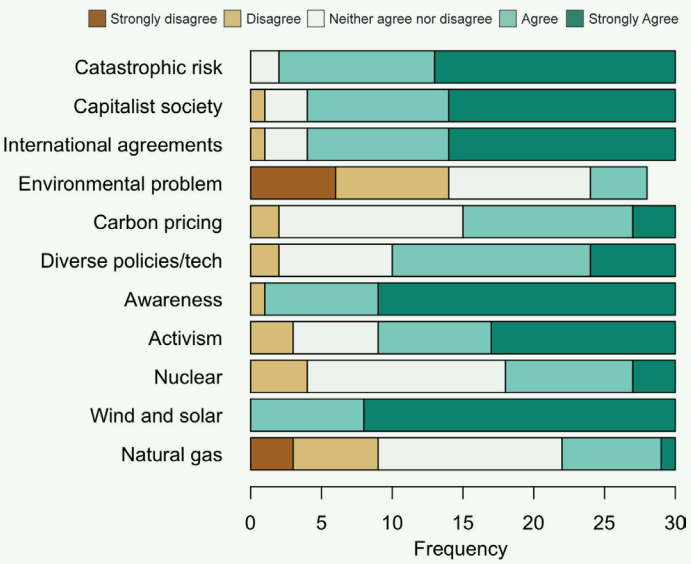

Figure 3. Participants ranked their level of agreement with a range of statements related to climate change, including views of nature, models of social change, and framing of the problem and its solutions. The wording of each statement can be found in Table 2. There were no participants who strongly agreed with the "Environmental problem" statement.

averages may potentially be due to the age of the survey data. When asked what percentage of the US population is worried about climate change, participants on average estimated 62%. The actual national average was 65%, which means that our participants underestimated. At the state level, participants estimated an average of 57%, believing that North Carolinians were less likely than the average American to be worried. The true state average in 2021 was 64%, which again reflects another underestimation by the participants.

Likewise, participants also underestimated support for carbon taxation. Participants on average estimated that 43% supported this policy nationwide, much lower than the true survey figure of 66%. The same is true for the state level, where participant estimates averaged 40% and actual statewide support in 2021 was 66%. Finally, participants also estimated support for offshore drilling in the US and NC. At the national level, survey estimates put support for offshore drilling at 49%, and our survey participants likewise suggested 49% support on average. At the state level, participants believed on average that 47% of NC residents support offshore drilling, whereas the actual percentage is 53%.

Content of Second-order Beliefs

Participants were asked to verbalize how they believed others would explain why they do or do not support each of the climate change opinion variables, and these responses were recorded and later coded. Results of the content analysis can be seen in Figure 5. The overarching codes for all responses include themes of environment, weather, people, beliefs, responsibility, and economics. Of the 30 participant responses, 23 (77%) discussed environmental reasons to explain why they believe others are worried about climate change. Of those who gave environmental responses, 57% spoke about waterways and coastal areas, 39% spoke about agricultural concerns, and 13% spoke about wildlife-related concerns. When participants were asked what other people would say to explain why they are not worried about climate change, all responses fell under the *beliefs* code. 33% said that others would say that climate change is natural, 33% that climate change is not real, and 27% that it "wouldn't affect me."

Two common codes were identified when participants verbalized how others would explain their support for a carbon tax: *responsibility* and *environment*. The majority

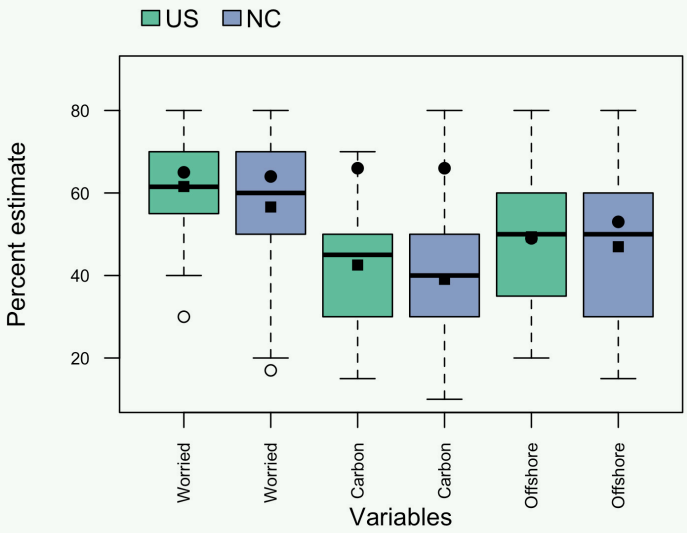

Figure 4. Participants estimated the percentage of adults in the US and NC that support specific climate change opinions. Box and whisker plots show the minimum, first quartile, median, third quartile, and maximum estimates. Square symbols depict the mean estimate and circle symbols depict the actual percentages.

of participants thought others believed that corporations need to take responsibility for their emissions. Other responses indicated emissions reductions (20%) and pollution impacts (7%) as environment-related reasons for supporting a carbon tax. Conversely, when participants were asked what they thought others who do not support a carbon tax would say, the responses shared mainly fell under the *economic* code, with 40% indicating that others would believe a carbon tax to be ineffective, 20% discussing disagreement with government interference, and 20% sharing that others might believe it could negatively affect businesses. 13% of participants said that people who do not support a carbon tax held those beliefs because it is not a corporation's responsibility to pay taxes on carbon emissions, and another 13% said that people do not believe in climate change and therefore do not support a carbon tax.

Lastly, when participants were asked to explain their second-order beliefs related to offshore drilling for oil and natural gas, *economics* and *environment* were used as the principal reasons. For example, economic codes were applied to 28 of the 30 participant responses that explained why others would support offshore drilling. 54% of responses suggested that others would argue that offshore drilling would help make the country more prosperous; similarly, 37% mentioned a need for state-side (i.e., domestically produced) resources. Roughly 16% of respondents believed others thought that offshore drilling is

Figure 5. Common sets of codes were applied to group the participant responses explaining why they thought others do or do not support each of the climate change opinions. Coded responses were also separated according to specific topics falling within each code.

needed to bring more jobs to the country. When asked to verbalize why others do not support offshore drilling, 29 of the responses were categorized with an environmental code. 53% of the responses said that others would be concerned about waterways and coastal areas, 43% said others were concerned about human-made disasters, like oil spills, and 33% were concerned about wildlife. 16% of the responses were classified as economics-related, primarily because they thought others would be interested in ways to reduce reliance on fossil fuels.

Map Reading

The first map reading task had participants select two NC counties of their choice to compare the percentage of adults who were worried about global warming in each. The counties chosen most frequently were Stokes (n=10) and Watauga (n=8). Participants were asked why they chose the counties they did, and when the results were later analyzed, four common codes emerged: home, school, extreme, and interested. For this question, participant responses could belong to multiple categories. The largest category was interested, with 50% of participants choosing counties they wanted to know more about. Additionally, participants chose their home counties (40%) or because they attended school at App State in Watauga County (20%). The extreme code was applied when participants chose counties because they appeared to have the highest or lowest levels of worry about climate change across the state. 23% of participant responses were coded with this tag. Combined, the home and school tags comprise the largest code groups, indicating that participants chose to examine their own map location first.

After reviewing the map, participants were asked to describe how their estimates of each metric in the pre-map phase compared to the actual climate change opinion survey results. Using ATLAS.ti, we coded whether participants' expectations were higher than, similar to, or lower than the values seen on the map. We also separately coded responses with a tag to mark if participants indicated that they were surprised by what they saw. Some of the participant responses did not fit within any of these codes, which accounts for the response rates less than 100%, described below. For the estimated percentage of people who are worried about global warming, 13% were coded as higher, 43% were coded as similar, and 23% were coded as lower. 23% of participants were also surprised by the distributions that they saw on the map. For carbon taxing, 17% of responses were coded as higher, 23% similar, and 37% of responses were coded lower, meaning that participants expected support to be lower than what was seen on the map. 33% of participant responses were coded as surprised, meaning that more participants were surprised by the actual support for carbon taxing than by the percentage of people worried about global warming. For offshore drilling, 33% of responses were coded with higher, 23% were coded similar, and 10% were coded with lower. Participants generally expected there to be more support for offshore drilling than exists. 37% of responses were coded with surprise, indicating that participants were the most surprised by the levels of support for offshore drilling.

Eye tracking was used to understand common patterns of visual attention during map reading tasks, which were then paired with participant verbal responses about their map use and interactions. Figures 6, 7, and 8 show the participant gaze heat maps across all three opinion variable maps. During map use, participants focused heavily on the map elements, including the title, information box, and legend. They also focused heavily on data extremes, where different county populations exhibited relatively low or high percentages of worry about or support for each opinion variable, as shown in the choropleth symbolization. For example, participants fixated on Stokes County for long durations across all three opinion variables. Stokes County is marked by the lowest percentages of climate worry and support for pro-climate policies in NC, as indicated by yellow to red hues in the diverging color palette. Conversely, participants also fixated for longer durations on higher populated and urban counties, where populations exhibit the highest percentages of support for pro-climate policies as indicated by the more saturated blue hues. This includes Mecklenburg County, which contains the city of Charlotte, as well as Durham, Orange, and Wake Counties in North Carolina's Research Triangle area, encompassing the cities of Durham, Chapel Hill, and Raleigh. Lastly, there were also many long-duration fixations on Watauga County, indicating participant interest in climate change opinions near App State. Very few participants paid attention to other map elements, including the opinions variable drop-down menu or the county names layer control while exploring the map.

Across all map reading tasks, participants were asked how they interacted with the map to better understand their map use when solving a problem. These results were then

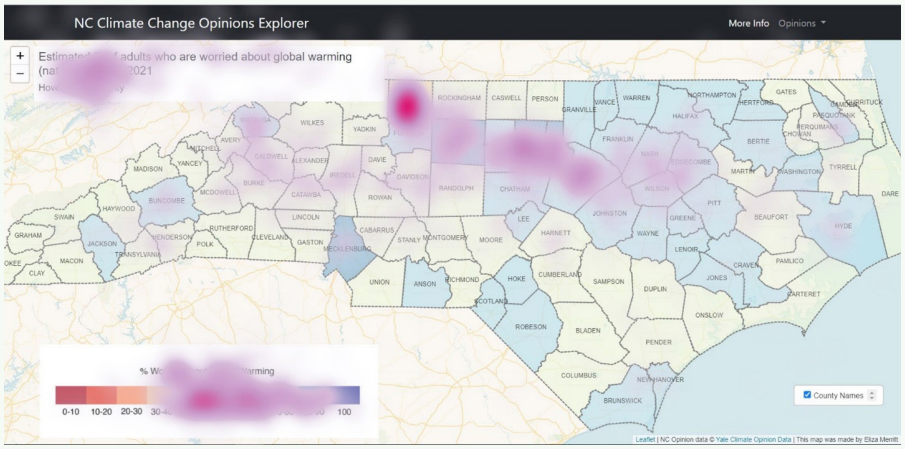

Figure 6. Heat maps depicting the visual attention patterns of participants when viewing the estimated percentages of adults ***who are worried about global warming***. Color presence indicates a fixation, while durations are symbolized sequentially from light purple (shorter) to dark red (longer).

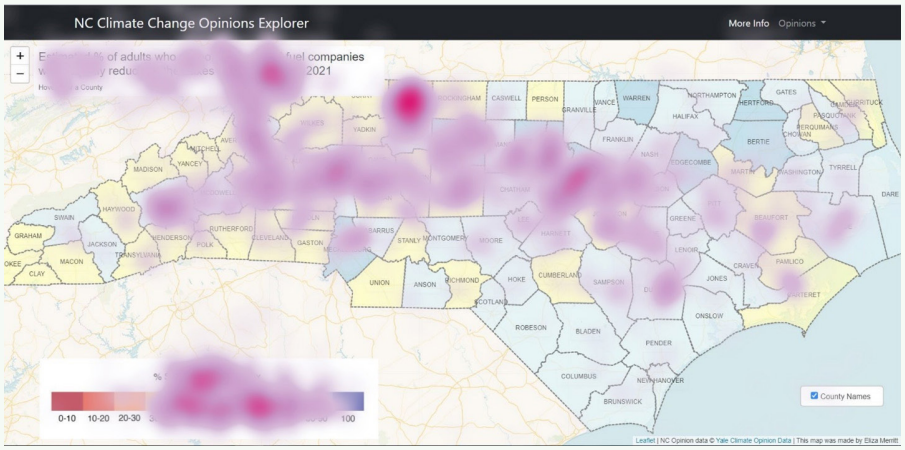

Figure 7. Visual attention patterns when viewing the estimated percentages of adults ***who support taxing fossil fuel companies while equally reducing other taxes***.

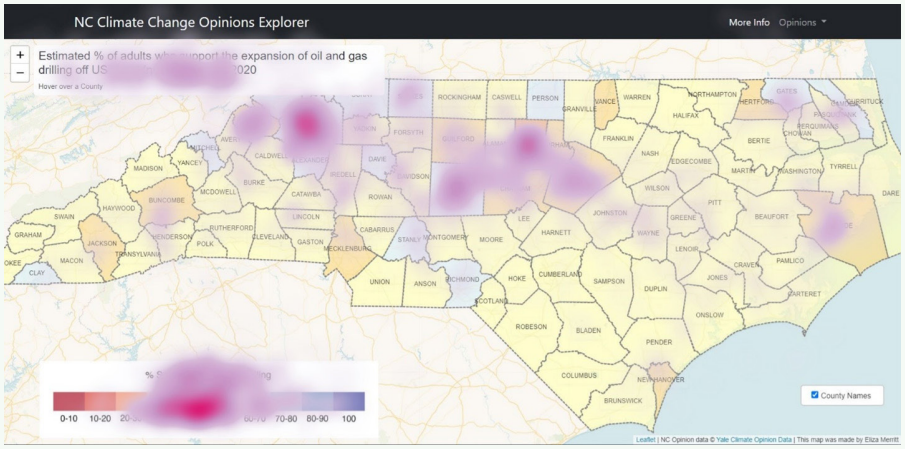

Figure 8. Visual attention patterns when viewing the estimated percentages of adults ***who support the expansion of offshore drilling for oil and natural gas off the US coast***.

coded, and the most commonly applied code was *knew where was*, which indicated that participants already knew the locations of the counties they were searching from prior knowledge. Participants indicated that they hovered over different counties to reveal the data values in the title control while performing map reading tasks. They also used the legend to interpret quantitative differences in the climate change opinions by class. These coded responses were the second most common type of answers. Finally, eleven participants indicated that the tasks were difficult to solve with the map's interactive functions and resorted to a visual search of the counties to complete map reading tasks.

POST-MAP RESULTS

Updating Beliefs, Web Map Usability, and Emotions

At the conclusion of the experiment participants completed a brief survey. We asked participants—again, after viewing the map—a series of follow-up questions related to the actual distribution of climate change opinions. First, participants selected how they thought others in the US and NC felt about global warming, from not at all worried to very worried (Figure 2). For the US, only one participant (3%) felt that people were not very worried about climate change, as compared to 33% in the pre-map phase. Twenty-seven (90%) felt that people were somewhat worried, up from 63%. Finally, two participants (7%) felt that people were very worried, up from one participant (3%) in the pre-map phase. For NC, one participant felt that people were not very worried about global warming (3%, down from 47% prior to viewing the map). Twenty-six felt that people were somewhat worried (87%, up from 50%), and three felt that people were very worried (10%, up from

3%). Thus, there was a substantial increase in the number of participants who thought that most people are somewhat worried about climate change in both the US and NC after viewing the map. These values increased by 8 participants at the national level, and 11 at the state level. Likewise, there was also a decrease in the number of participants who thought that most people are not very worried about climate change.

Second, we asked participants to describe whether or not they were surprised by the actual distributions of climate change opinions in NC, with 23 participants indicating that they were surprised (77%), and seven indicating that they were not (23%). Participants also described whether or not they had expected the climate change opinions to be like their own when viewing the map. Out of the 30 participants, 11 participants had expected others' beliefs to be similar to their own (34%), 15 participants had expected others' beliefs to be less like their own (50%), and four participants' responses indicated neither more nor less (13%). Overall, participants exhibited a decrease in false beliefs after interacting with the map and seeing the actual distribution of climate change opinions when compared to the pre-map phase of the study. Participants were also generally surprised at the results because they expected climate change opinions to be different from their own, indicating pluralistic ignorance of the actual distribution of opinion.

To address map usability, participants were asked to choose features on the map that were most helpful for them to interact with the map (Figure 9). Data visualization was selected as the most helpful feature to understand the distribution of climate change opinions across

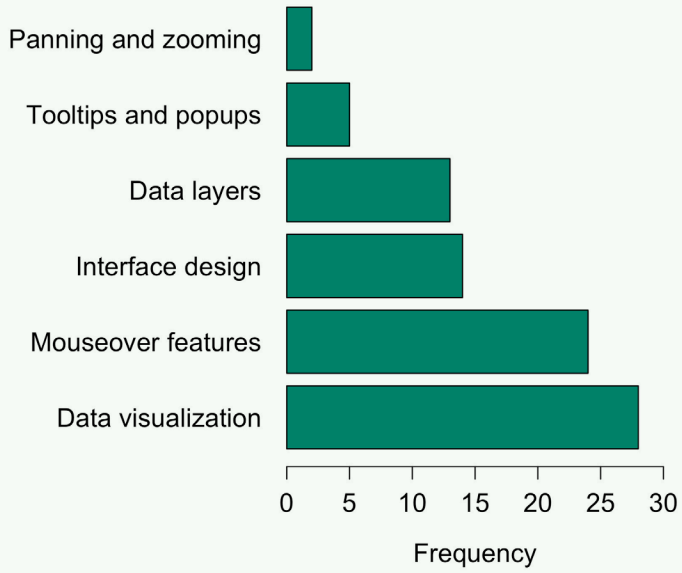

Figure 9. Participants selected the most helpful map features from a list of interface design choices and map interactions after completing the map reading tasks.

the state, with 28 participants choosing this option from the list. Participants also chose mouseover features 24 times, indicating that was the second most helpful map interaction. Fourteen participants chose the interface design as being helpful. Additionally, participants selected emotions that they felt represented their map use during the experiment to further understand affective responses to the mapped climate change opinions (Table 4). From this list, 64 emotions were chosen at least once. Positive valence emotions were selected most frequently, including calm, surprised, curious, okay, and satisfied. Negative valence emotions were chosen less frequently after interacting with the maps. For example, the first overtly negative emotion to show on the list is *rushed*, which ranked 29th with 3 choices.

DISCUSSION

MAGNITUDE AND CONTENT OF SECOND-ORDER BELIEFS ABOUT CLIMATE CHANGE

The pre-map phase of the study established participants' demographics, technological proficiency, political leanings, and climate change beliefs. Overall, the convenience sampling method resulted in the recruitment of a predominantly liberal, majority female, and technologically proficient student sample. This means that our experimental results stem from varying political views from people on the left side of the political spectrum, which is generally associated with greater climate concern and pro-climate policy support (Ehret 2018). In addition, participants were alarmed or concerned about climate change at much higher rates than the national average. We noted that most participants' views aligned primarily with an "ecological activist" framing of climate change, meaning that they think it is a symptom of a capitalist society that has over-prioritized economic growth and dangerously exceeded the carrying capacity of the planet (Nisbet

Accepted	Content	Exhausted	Jealous	Quixotic
Accomplished	Cranky	Flirty	Jubilant	Recumbent
Aggravated	Crappy	Frustrated	Lazy	Refreshed
Alone	Crazy	Full	Lethargic	Rejected
Amused	Crushed	Geeky	Listless	Rejuvenated
Angry	Curious	Giddy	Lonely	Relaxed
Annoyed	Cynical	Giggly	Loved	Relieved
Anxious	Dark	Gloomy	Mad	Resolute
Apathetic	Depressed	Good	Melancholy	Restless
Ashamed	Determined	Grateful	Mellow	Rushed
Awake	Devious	Groggy	Mischievous	Sad
Bewildered	Dirty	Grumpy	Moody	Satisfied
Bittersweet	Disappointed	Guilty	Morose	Shocked
Blah	Discontent	Happy	Motivated	Sick
Blank	Ditzy	High	Naughty	Silly
Blissful	Dorky	Hopeful	Nauseous	Sleepy
Bored	Drained	Hot	Nerdy	Smart
Bouncy	Drunk	Hungry	Numb	Stressed
Calm	Ecstatic	Hyper	Okay	Surprised
Cheerful	Energetic	Impressed	Optimistic	Sympathetic
Chipper	Enraged	Indescribable	Peaceful	Thankful
Cold	Enthralled	Indifferent	Pessimistic	Tired
Complacent	Envious	Infuriated	Pissed off	Touched
Confident	Exanimate	Irate	Pleased	Uncomfortable
Confused	Excited	Irritated	Predatory	Weird

Table 4. Participants selected from a list of emotions to best describe their mood when completing the map reading tasks.

2014). This is important because ecological activists often connect extreme weather events with climate change, even when the attribution of specific events may be uncertain and made with low-to-medium confidence at best. In fact, many participants cited the impacts of extreme weather events as a reason for explaining why others in NC would be worried about climate change, yet still underestimated the percentage of people they thought held this view, thereby demonstrating a false consensus in overestimating the amount of people who are not worried about it.

This study identified common patterns in the content of second-order beliefs. In general, when participants were speaking about pro-climate policies and ideas, several major themes emerged as reasons why they thought others in NC would hold these opinions. The largest theme was environmental in nature, where participants were concerned about coastal areas, agriculture, wildlife, and other environmental impacts of human-caused disasters. Other themes were related to economic concerns and the need for corporate responsibility to address the issue through a carbon tax. These sentiments are directionally consistent with the literature on second-order beliefs among left-leaning individuals, who are more likely to support a policy for climate or environmental reasons (Bergquist 2020; Hamilton 2010; Hamilton et al. 2015).

When speaking about people in NC who are more dismissive of climate change, two major themes emerged. First, many participants thought segments of the public held those views for economically related reasons. This was especially the case when they were asked about those who

oppose a carbon tax and who support offshore drilling for oil and gas. For example, participants frequently cited a carbon tax as a limiter of economic prosperity for business and cited the perceived need for abundant oil and gas resources in local economies as reasons why others would hold these opinions. Second, many participants thought the percentages of people in NC who were more dismissive of climate change held those views due to a set of belief-related concerns around climate skepticism. For example, participants thought that others would question the reality and anthropogenic influence of climate change and therefore question the need for specific policies. Others thought that people who were more dismissive of climate change and climate-related policies were engaging in a set of conspiratorial, ideological, or religious rationales for not being worried about the issue.

This study identified a large gap between the magnitude of participants' false second-order beliefs and the reality of climate change opinions in NC. Participants were likely to underestimate the percentage of adults that were worried about climate change and to underestimate the support for a carbon tax. Participants were also likely to overestimate support for offshore drilling at the national level. Therefore, participants believed that fewer people agreed with their own first-order beliefs, further contributing to false polarization. This finding is consistent with literature suggesting a general population underestimation of support for pro-climate policies (Mildenberger and Tingley 2017). Sparkman et al. (2022) concluded that Americans are living in a "false social reality" due to a shared misperception about how others think or behave around climate change. In this study, most participants were similarly surprised by the actual distribution of climate change opinions across the state, showing how second-order beliefs have reinforced pluralistic ignorance of actual popular support for climate policies (Epley et al. 2004; Epley and Gilovich 2006; Miller and McFarland 1987).

INTERACTIVE WEB MAP USABILITY AND USER PREFERENCES

During the in-person phase of the study, participants were asked why they interacted with the map in the way they did. Participants gave overwhelmingly positive ratings for map usability. It is important to note that all participants reported high levels of technological proficiency and frequency of web map use, which suggests they are more likely to understand, and have an easier time interacting with, the web map than others who have less experience with them (MacEachren et al. 1998). Participants indicated that the most helpful map element for understanding others' beliefs was the data visualization (including the choropleth symbolization). This is consistent with participants' tendencies to refer to the diverging color palette in the legend while exploring the map during the think-aloud protocol.

Participants provided their rationale for exploring different parts of the map when solving the map reading tasks. Across all climate change opinion variables depicted on the map, participants most frequently chose to focus on a given county during a map reading task because it was their home county or because they currently lived in Watauga County to attend App State. Participants were able to use map interactions in the context of the map reading tasks to put climate change opinions into their own personal context before responding to the tasks. Allowing users to manipulate maps based on their own data exploration preferences creates a more personal understanding of the map, as well as the phenomena it is portraying.

We also found evidence in support of spatial optimism bias, where participants perceive their own locations to be less vulnerable to climate extremes than those that are far away (Retchless 2018). During the map reading tasks, many participants shared sentiments that the mountains of western NC, where App State is located, would experience fewer climate change impacts. In reality, the region remains vulnerable to hydroclimatic extremes, ranging from floods to droughts and their subsequent socio-environmental impacts (Labosier and Quiring 2013). Participants were far more concerned about, and more likely to discuss the implications of climate change in, coastal areas. They were also concerned about climate effects on agricultural areas in central and eastern NC. Participants also used the geographic location of interest as a rationale for focusing on specific counties when completing map reading tasks, and frequently chose to compare counties that are geographically located on opposite sides of the state. However, participants also interacted with counties directly adjacent to one another. Often, these participants would be curious as to why two geographically similar places had differing levels of support for the climate change policies or had differing levels of worry about it. These are two common ways that participants interacted with the web map while exploring climate opinions, and may suggest common use patterns among larger populations of map users.

Finally, participants focused on counties with the most extreme levels (i.e., low and high percentages) of worry about climate change or support for climate-related policies when solving the map reading tasks. Many commented during the think-aloud protocol that they used the legend and color palette to assist with identifying these locations. In this case, participants were especially drawn to Stokes County, which had the lowest support for carbon taxes and the lowest levels of worry across the state, as well as the highest levels of support for offshore drilling. The heatmap fixations and durations paired with a high rate of open-ended responses that mention being drawn to extreme counties clearly show this phenomenon. Stokes County has a relatively small population, with an estimated **44,520 people in 2020**. However, the tendency of participants to focus attention there could reinforce false beliefs about statewide support because people have a tendency to better remember highly salient events (Madan 2014). Conversely, participants also focused attention on counties with the greatest support across all three metrics, which generally correspond to Orange (148,696 people), Durham (324,833 people), Mecklenburg (1,115,482 people), and Wake counties (1,129,410 people). NC counties are relatively similar by area when compared with those in many western states, which could pose future problems for interpreting mapped climate change opinion estimates in those locations. We welcome future map studies that would specifically compare differences in the interpretation of climate opinions using other symbolization techniques, like proportional symbols or dot density symbols.

Emotional responses to climate information have received much attention in recent years due to the recognition that visualization and communication make climate change more tangible and relatable for individuals (Fish 2020). Participants in this study overwhelmingly chose emotions with positive valence, such as calm, relief, and surprise, which suggests that users had good experiences interacting with the web map by discovering that their first-order beliefs are not as uncommon as they suspected. Emotions can be indicators of mood and affective responses to storytelling within a map (Roth 2021). Exploring the emotional responses to maps has the potential to increase understanding and provide insights regarding how spatial information can better communicate the human experience (Griffin and McQuoid 2012). When viewing and discussing the political views of others in the perceived social outgroup relative to their own beliefs, individuals tend to have intensely negative emotional responses, like contempt, fear, and disgust (Prinz 2021). Public opinion maps may have the potential to moderate polarization on controversial topics due to their ability to generate more positive affective responses when public support is greater than originally perceived.

In this study, participants updated their second-order beliefs from the pre- to post-map, demonstrating a reduction in false beliefs and misperceptions about what others think and do. There was a substantial increase in the number of participants who thought that US and NC residents were somewhat worried about global warming from pre- to post-map. There was also a decrease in the number who thought these groups were not very worried. Participants were also more skeptical of NC's climate change concern during the pre-map phase than of the US as a whole. This is interesting because an estimated 64% of North Carolinians are worried about global warming, according to the Yale Program on Climate Change Communication, a value which is only 1% less than the national average at the time of the study (Howe et al. 2015). Despite our participants being overall worried about climate change, they thought that few others were prior to viewing the map, demonstrating the pluralistic ignorance effect where one believes others do not believe what they do. Furthermore, scientific knowledge about climate change is inversely correlated with climate change anxiety (Zacher and Rudolph 2023). Our research suggests climate change opinion maps are a useful tool to alleviate the concern about insufficient public or policymaker support for different climate policies among young ecological activists who are alarmed about global warming. Reducing the false perception of weak climate policy support has the potential to depolarize policy discussions, including by refocusing some of the anxiety and grief about it, which has increased in younger populations (Holthhaus 2023; Shaw and Bonnett 2016).

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

There are several limitations that should be discussed in the context of the results. First, this study used an exploratory research design, favoring a natural observational experiment, rather than one with experimental control groups, to examine common patterns that emerged. In addition, methods were primarily qualitative, with eye tracking, surveys, and interviews used to examine the how participants interacted with the map, along with the content of their second-order beliefs. The results should

not be interpreted as causal inferences, nor should we draw any statistical conclusions about the changes in belief from pre- to post-map. In addition, this study used a small, convenience sample of students from App State, who were mostly attending classes adjacent to the subject of the environment. App State consistently receives national recognition for its leadership in sustainability, **listing over 2,000 courses** that incorporate the topic, and the university considers it as a major driver in student enrollment. Participants were alarmed and concerned about climate change, and they were already experienced with map reading and technology. As a result, we caution the reader from drawing more generalizable conclusions about population groups not represented in the study. While the results replicated the larger nationally representative surveys on second-order belief, future research should purposefully sample students who are less proficient with web maps and who are politically conservative and hold doubtful or dismissive views of climate change to verify the reduction in false beliefs through map reading. In addition, we identified several misperceptions that politically liberal and ecologically activist-oriented students hold about others who are more dismissive of climate change. This purposeful sample would show whether there are differences in the accurate perception of others' beliefs across a range of views. Finally, a further limitation of our research is tied to the think-aloud protocol used during the map reading tasks. It is possible that participants forgot, or insufficiently described, on how they interacted with the map, and a concurrent think-aloud protocol may have revealed more about their interactions.

Despite its limitations, this study highlights the ability of interactive web maps to update second-order beliefs, which may, in turn, lead to an increased understanding of climate change and climate change policy. However, we recommend attention be paid in the future towards the specific use cases of climate change opinion maps as they are implemented in the public sphere. Specifically, more research is needed to outline the public's understanding of maps as elite forms of messaging that may reinforce polarization, as has been shown with other forms of media communication (Hart and Nisbet 2012). Retchless et al. (2022) provide a recent discussion of the roles of power and privilege in engaging with climate change maps. If climate change opinion maps are to be effective in communicating the results of the larger, national-level surveys and models, then future work in cartography should account for the diversity of political thought and worldviews that influence the public framing of climate change and trust in science more broadly (Kaurov et al. 2022; Hulme 2009).

CONCLUSION

This study shows how interactive web maps have the potential to correct mischaracterizations of others' beliefs about climate change. We used a set of exploratory methods common to user studies in cartography to provide insights about the content of second-order beliefs and the map reading process with an interactive web map of climate change opinions in North Carolina. The results from this small student sample were similar to those from larger, nationally representative studies in that participants do not accurately estimate the actual percentages of popular support for climate change opinions. However, this study also focused on the content of second-order beliefs among a sample of ecologically activist-oriented and politically left-of-center students to find out why they underestimated popular support for these opinions. Participants primarily used environmental concerns to explain their own beliefs but focused on a set of ideological factors to explain the beliefs of those they thought were more dismissive of climate change policies. The results of our eye tracking and interviews showed that, during map reading tasks, participants used the choropleth symbolization to focus on data extremes and counties that were important to them, including home counties and counties they attend school in, showing evidence of egocentric bias and spatial optimism bias that contributed to false polarization. Participants exhibited overwhelmingly positive emotional responses to the web map and found data visualization and interactions, like mouseover events and tooltips, most helpful in completing map reading tasks. Cartographers should continue to examine the intended use cases and contexts of climate change opinion maps to improve their communication effectiveness. Furthermore, user studies provide a way to more deeply understand how a range of user values and beliefs affects map use. This effort would add to the scope of cartography's attention to climate change. We conclude that interactive maps have the potential to moderate polarization on controversial topics, like climate change, that are otherwise subject to pluralistic ignorance effects that can dampen policy support.

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REFERENCES

Atkins, Rachel M., and Karen S. McNeal. 2018. "Exploring Differences among Student Populations during Climate Graph Reading Tasks: An Eye Tracking Study." *Journal of Astronomy and Earth Sciences Education* 5 (2): 85–114. **https://doi.org/10.19030/jaese.v5i2.10219**.

Ballew, Matthew T., Anthony Leiserowitz, Connie Roser-Renouf, et al. 2019. "Climate Change in the American Mind: Data, Tools, and Trends." *Environment: Science and Policy for Sustainable Development* 61 (3): 4–18. **https://doi.org/10.1080/00139157.2019.1589300**.

Bergquist, Parrish, Matto Mildenberger, and Leah C. Stokes. 2020. "Combining Climate, Economic, and Social Policy Builds Public Support for Climate Action in the US." *Environmental Research Letters* 15 (5): 054019. **https://doi.org/10.1088/1748-9326/ab81c1**.

Cartwright, William, Jeremy Crampton, Georg Gartner, et al. 2001. "Geospatial Information Visualization User Interface Issues." *Cartography and Geographic Information Science* 28 (1): 45–60. **https://doi.org/10.1559/152304001782173961**.

Chryst, Breanne, Jennifer Marlon, Sander van der Linden, Anthony Leiserowitz, Edward Maibach, and Connie Roser-Renouf. 2018. "Global Warming's 'Six Americas Short Survey': Audience Segmentation of Climate Change Views Using a Four Question Instrument." *Environmental Communication* 12 (8): 1109–22. **https://doi.org/10.1080/17524032.2018.1508047**.

Çöltekin, Arzu, Benedikt Heil, Simone Garlandini, and Sara Irina Fabrikant. 2009. "Evaluating the Effectiveness of Interactive Map Interface Designs: A Case Study Integrating Usability Metrics with Eye-Movement Analysis." *Cartography and Geographic Information Science* 36 (1): 5–17. **https://doi.org/10.1559/152304009787340197**.

Davis, Corey, Heather Aldridge, Ryan Boyles, Karen S. McNeal, Lindsay Maudlin, and Rachel Atkins. 2020. "Visually Communicating Future Climate in a Web Environment." *Weather, Climate, and Society* 12 (4): 877–96. **https://doi.org/10.1175/WCAS-D-19-0152.1**.

Duchowski, Andrew T. 2003. *Eye Tracking Methodology: Theory and Practice*. London: Springer-Verlag. **https://doi.org/10.1007/978-1-4471-3750-4**.

Ehret, Phillip J., Leaf Van Boven, and David K. Sherman. 2018. "Partisan Barriers to Bipartisanship: Understanding Climate Policy Polarization." *Social Psychological and Personality Science* 9 (3): 308–18. **https://doi.org/10.1177/1948550618758709**.

Epley, Nicholas, and Thomas Gilovich. 2006. "The Anchoring-and-Adjustment Heuristic: Why the Adjustments Are Insufficient." *Psychological Science* 17 (4): 311–18. **https://doi.org/10.1111/j.1467-9280.2006.01704.x**.

Epley, Nicholas, Boaz Keysar, Leaf Van Boven, and Thomas Gilovich. 2004. "Perspective Taking as Egocentric Anchoring and Adjustment." *Journal of Personality and Social Psychology* 87 (3): 327–39. **https://doi.org/10.1037/0022-3514.87.3.327**.

Farrell, Justin. 2016. "Corporate Funding and Ideological Polarization about Climate Change." *Proceedings of the National Academies of Science* 113 (1): 92–97. **https://doi.org/10.1073/pnas.1509433112**.

Fielding, Kelly S., and Matthew J. Hornsey. 2016. "A Social Identity Analysis of Climate Change and Environmental Attitudes and Behaviors: Insights and Opportunities." *Frontiers in Psychology* 7 (121): 1–12. **https://doi.org/10.3389/fpsyg.2016.00121**.

Fish, Carolyn S. 2020. "Cartographic Content Analysis of Compelling Climate Change Communication." *Cartography and Geographic Information Science* 47 (6): 492–507. https://doi.org/10.1080/15230406.2020.1774421.

Griffin, Amy L., and Julia McQuoid. 2012. "At the Intersection of Maps and Emotion: The Challenge of Spatially Representing Experience." *Kartographische Nachrichten* 62 (6): 291–99.

Griffin, Amy L. 2020. "Trustworthy Maps." *Journal of Spatial Information Science* 20: 5–19. https://doi.org/10.5311/JOSIS.2020.20.654.

Hamilton, Lawrence C., and Kei Saito. 2015. "A Four-Party View of US Environmental Concern." *Environmental Politics* 24 (2): 212–27. https://doi.org/10.1080/09644016.2014.976485.

Hamilton, Lawrence C., Chris R. Colocousis, and Cynthia M. Duncan. 2010. "Place Effects on Environmental Views." *Rural Sociology* 75 (2): 326–47. https://doi.org/10.1111/j.1549-0831.2010.00013.x.

Hamilton, Lawrence C., Joel Hartter, Mary Lemcke-Stampone, David W. Moore, and Thomas G. Safford. 2015. "Tracking Public Beliefs About Anthropogenic Climate Change." *PLoS ONE* 10 (9): e0138208. https://doi.org/10.1371/journal.pone.0138208.

Harold, Jordan, Irene Lorenzoni, Thomas F. Shipley, and Kenny R. Coventry. 2016. "Cognitive and Psychological Science Insights to Improve Climate Change Data Visualization." *Nature Climate Change* 6 (12): 1080–89. https://doi.org/10.1038/nclimate3162.

Hart, P. Sol, and Erik C. Nisbet. 2012. "Boomerang Effects in Science Communication: How Motivated Reasoning and Identity Cues Amplify Opinion Polarization About Climate Mitigation Policies." *Communication Research* 39 (6): 701–23. https://doi.org/10.1177/0093650211416646.

Hoffman, Andrew J. 2011. "Talking Past Each Other? Cultural Framing of Skeptical and Convinced Logics in the Climate Change Debate." *Organization and Environment* 24 (1): 3–33. https://doi.org/10.1177/1086026611404336.

Holmqvist, Kenneth, Marcus Nystrom, Richard Andersson, Richard Dewhurst, Halszka Jarodzka, and Joost van de Weijer. 2011. *Eye Tracking: A Comprehensive Guide to Methods and Measures*. Oxford: Oxford University Press.

Holthhaus, Leonie. 2023. "Feelings of (Eco-) Grief and Sorrow: Climate Activists as Emotion Entrepreneurs." *European Journal of International Relations* 29 (2): 352–73. https://doi.org/10.1177/13540661221136772.

Howe, Peter D., Matto Mildenberger, Jennifer R. Marlon, and Anthony Leiserowitz. 2015. "Geographic Variation in Opinions on Climate Change at State and Local Scales in the USA." *Nature Climate Change* 5 (6): 596–603. https://doi.org/10.1038/nclimate2583.

Hulme, M. 2009. *Why We Disagree about Climate Change: Understanding Controversy, Inaction and Opportunity*. Cambridge: Cambridge University Press. https://doi.org/10.1017/cbo9780511841200.

Jacob, Robert J. K., and Keith S. Karn. 2003. "Eye Tracking in Human – Computer Interaction and Usability Research: Ready to Deliver the Promises." In *The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research.*, edited by Jukka Hyönä, Ralph Radach, and Heiner Deubel, 573–605. Oxford: Elsevier Science BV. https://doi.org/10.1016/b978-044451020-4/50031-1.

Kahan, Dan. 2012. "Why We Are Poles Apart on Climate Change." *Nature* 488 (7411): 255. https://doi.org/10.1038/488255a.

Kahan, Dan M., Hank Jenkins-Smith, and Donald Braman. 2010. "Cultural Cognition of Scientific Consensus." *Journal of Risk Research* 14 (2): 147–74. https://doi.org/10.1080/13669877.2010.511246.

Kaurov, Alexander A., Viktoria Cologna, Charlie Tyson, and Naomi Oreskes. 2022. "Trends in American Scientists' Political Donations and Implications for Trust in Science." *Humanities and Social Sciences Communications* 9: 368. https://doi.org/10.1057/s41599-022-01382-3.

Labosier, Christopher F., and Steven M. Quiring. 2013. "Hydroclimatology of the Southeastern USA." *Climate Research* 57 (2): 157–71. https://doi.org/10.3354/cr01166.

Lee, Tien Ming, Ezra M. Markowitz, Peter D. Howe, Chia-Ying Ko, and Anthony A. Leiserowitz. 2015. "Predictors of Public Climate Change Awareness and Risk Perception around the World." *Nature Climate Change* 5 (11): 1014–20. https://doi.org/10.1038/nclimate2728.

Leiserowitz, Anthony, Edward Maibach, Seth Rosenthal, et al. 2021. "Politics and Global Warming." New Haven, CT: Yale Program on Climate Change Communication.

Lewis, Gregory B., Risa Palm, and Bo Feng. 2019. "Cross-National Variation in Determinants of Climate Change Concern." *Environmental Politics* 28 (5): 793–821. https://doi.org/10.1080/09644016.2018.1512261.

Linden, Sander van der, Anthony Leiserowitz, and Edward Maibach. 2019. "The Gateway Belief Model : A Large-Scale Replication." *Journal of Environmental Psychology* 62: 49–58. https://doi.org/10.1016/j.jenvp.2019.01.009.

MacEachren, Alan M., Francis P. Boscoe, Daniel Haug, and Linda W. Pickle. 1998. "Geographic Visualization: Designing Manipulable Maps for Exploring Temporally Varying Georeferenced Statistics." *Proceedings IEEE Symposium on Information Visualization*, 87–94. https://doi.org/10.1109/infvis.1998.729563.

Madan, Christopher R., Elliot A. Ludvig, and Marcia L. Spetch. 2014. "Remembering the Best and Worst of Times: Memories for Extreme Outcomes Bias Risky Decisions." *Psychonomic Bulletin & Review* 21: 629–36. https://doi.org/10.3758/s13423-013-0542-9.

Marlon, Jennifer R., Xinran Wang, Parrish Bergquist, et al. 2022. "Change in US State-Level Public Opinion about Climate Change: 2008 – 2020." *Environmental Research Letters* 17 (12): 124046. https://doi.org/10.1088/1748-9326/aca702.

Maudlin, Lindsay C., Karen S. McNeal, Heather Dinon-Aldridge, Corey Davis, Ryan Boyles, and Rachel M. Atkins. 2020. "Website Usability Differences between Males and Females: An Eye-Tracking Evaluation of a Climate Decision Support System." *Weather, Climate, and Society* 12 (1): 183–92. https://doi.org/10.1175/WCAS-D-18-0127.1.

Mildenberger, Matto, and Dustin Tingley. 2017. "Beliefs about Climate Beliefs: The Importance of Second-Order Opinions for Climate Politics." *British Journal of Political Science* 49 (4): 1279–1307. https://doi.org/10.1017/S0007123417000321.

Miller, Dale T., and Cathy McFarland. 1987. "Pluralistic Ignorance : When Similarity is Interpreted as Dissimilarity." *Journal of Personality and Social Psychology* 53 (2): 298–305. https://doi.org/10.1037//0022-3514.53.2.298.

Moser, Susanne C. 2016. "Reflections on Climate Change Communication Research and Practice in the Second Decade of the 21st Century: What More is There to Say?" *Wiley Interdisciplinary Reviews: Climate Change* 7 (3): 345–69. https://doi.org/10.1002/wcc.403.

Nisbet, Matthew C. 2014. "Disruptive Ideas: Public Intellectuals and Their Arguments for Action on Climate Change." *Wiley Interdisciplinary Reviews: Climate Change* 5 (6): 809–23. https://doi.org/10.1002/wcc.317.

Popelka, Stanislav, Alena Vondrakova, and Petra Hujnakova. 2019. "Eye-Tracking Evaluation of Weather Web Maps." *International Journal of Geo-Information* 8 (6): 256. https://doi.org/10.3390/ijgi8060256.

Price, Jennifer C., Iain A. Walker, and Fabio Boschetti. 2014. "Measuring Cultural Values and Beliefs about Environment to Identify Their Role in Climate Change Responses." *Journal of Environmental Psychology* 37: 8–20. https://doi.org/10.1016/j.jenvp.2013.10.001.

Prinz, Jesse. 2021. "Emotion and Political Polarization." In *The Politics of Emotional Shockwaves*, edited by Ana Falcato and Sara Graça da Silva, 1–25. Cham, Switzerland: Palgrave Macmillan. https://doi.org/10.1007/978-3-030-56021-8_1.

Retchless, David P. 2018. "Understanding Local Sea Level Rise Risk Perceptions and the Power of Maps to Change Them: The Effects of Distance and Doubt." *Environment and Behavior* 50 (5): 483–511. https://doi.org/10.1177/0013916517709043.

Retchless, David, Carolyn Fish, and Jim Thatcher. 2022. "Climate Change Communication beyond the Digital Divide: Exploring Cartography's Role and Privilege in Climate Action." *Journal of Environmental Media* 3 (1): 101–23. https://doi.org/10.1386/jem_00074_1.

Retchless, David P., and Cynthia A Brewer. 2016. "Guidance for Representing Uncertainty on Global Temperature Change Maps." *International Journal of Climatology* 36 (3): 1143–59. https://doi.org/10.1002/joc.4408.

Roth, Robert E. 2013. "An Empirically-Derived Taxonomy of Interaction Primitives for Interactive Cartography and Geovisualization." *IEEE Transactions on Visualization and Computer Graphics* 19 (12): 2356–65. https://doi.org/10.1109/TVCG.2013.130.

———. 2017. "User Interface and User Experience (UI/UX) Design." *Geographic Information Science & Technology Body of Knowledge* (2nd Quarter 2017 Edition). https://doi.org/10.22224/gistbok/2017.2.5.

———. 2021. "Cartographic Design as Visual Storytelling : Synthesis and Review of Map-Based Narratives, Genres, and Tropes." *The Cartographic Journal* 58 (1): 83–114. https://doi.org/10.1080/00087041.2019.1633103.

Roth, Robert E., Richard G. Donohue, Carl M. Sack, Timothy R. Wallace, and Tanya M. A. Buckingham. 2014. "A Process for Keeping Pace with Evolving Web Mapping Technologies." *Cartographic Perspectives* 78: 25–52. https://doi.org/10.14714/cp78.1273.

Shao, Wanyun, and Angela F. McCarthy. 2020. "Understanding Evangelical Protestant Identity, Religiosity, Extreme Weather, and American Public Perceptions of Global Warming, 2006-2016." *Geographical Review* 110 (4): 485–504. https://doi.org/10.1080/00167428.2019.1702427.

Shaw, Wendy S., and Alastair Bonnett. 2016. "Environmental Crisis , Narcissism and the Work of Grief." *Cultural Geographies* 23 (4): 565–79. https://doi.org/10.1177/1474474016638042.

Smith, E. Keith, and Adam Mayer. 2019. "Anomalous Anglophones? Contours of Free Market Ideology, Political Polarization, and Climate Change Attitudes in English-Speaking Countries , Western European and Post-Communist States." *Climatic Change* 152: 17–34. https://doi.org/10.1007/s10584-018-2332-x.

Sparkman, Gregg, Nathan Geiger, and Elke U. Weber. 2022. "Americans Experience a False Social Reality by Underestimating Popular Climate Policy Support by Nearly Half." *Nature Communications* 13: 4779. https://doi.org/10.1038/s41467-022-32412-y.

Tuitjer, Leonie, Peter Dirksmeier, and Lars Mewes. 2022. "Geographies of Climate Change Opinion." *Geography Compass* 16 (5): e12619. https://doi.org/10.1111/gec3.12619.

Zacher, Hannes, and Cort W. Rudolph. 2023. "Environmental Knowledge Is Inversely Associated with Climate Change Anxiety." *Climatic Change* 176 (4): 32. https://doi.org/10.1007/s10584-023-03518-z.