# THE COGNITIVE PSYCHOLOGY OF CLIMATE CHANGE

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# THE COGNITIVE PSYCHOLOGY OF CLIMATE CHANGE

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Image: Environmental Psychology unit of the University of Gävle.


Climate change is one of society's great challenges. The scientific community agrees that human activity is to a large degree responsible for these changes and efforts to promote more sustainable behaviors and lifestyles often backfire. People travel for longer distances when driving a vehicle that uses a 'sustainable' energy source; they purchase 'organic' food as a means to be environmentally friendly without necessarily reducing other means of consumption; and those who deliberately change their behavior to be more environmentally friendly in one area often start behaving environmentally irresponsibly in another. Environmentally harmful behavior and decision making often have their roots in cognitive biases and cognitive inabilities to properly understand climate change issues, to understand the effects of one's own behavior on the environment, and other means by which thinking and reasoning about climate change issues are biased.

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# Motivated Attention in Climate Change Perception and Action

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Despite the scientific consensus, some people still remain skeptical about climate change. In fact, there is a growing partisan divide over the last decade within the United States in the support for climate policies. Given the same climate evidence, why do some people become concerned while others remain unconvinced? Here we propose a motivated attention framework where socio-political motivations shape visual attention to climate evidence, altering perceptions of the evidence and subsequent actions to mitigate climate change. To seek support for this framework, we conducted three experiments. Participants viewed a graph of annual global temperature change while they were eyetracked and estimated the average change. We found that political orientation may bias attention to climate change evidence, altering the perception of the same evidence (Experiment 1). We further examined how attentional biases influence subsequent actions to mitigate climate change. We found that liberals were more likely to sign a climate petition or more willing to donate to an environmental organization than conservatives, and attention guides climate actions in different ways for liberals and conservatives (Experiment 2). To seek causal evidence, we biased attention to different parts of the temperature curve by coloring stronger climate evidence in red or weak climate evidence in red. We found that liberals were more likely to sign the petition or more willing to donate when stronger evidence was in red, but conservatives were less likely to act when stronger evidence was in red (Experiment 3). This suggests that drawing attention to motivationally consistent information increases actions in liberals, but discouraged conservatives. The findings provide initial preliminary evidence for the motivated attention framework, suggesting an attentional divide between liberals and conservatives in the perception of climate evidence. This divide might further reinforce prior beliefs about climate change, creating further polarization. The current study raises a possible attentional mechanism for ideologically motivated reasoning and its impact on basic perceptual processes. It also provides implications for the communication of climate science to different socio-political groups with the goal of mobilizing actions on climate change.

**Keywords: ideology, motivated reasoning, eyetracking, behavior change, climate communication**

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## INTRODUCTION

Climate change involves a significant change in weather patterns around the world due to increased concentrations of greenhouse gases in the atmosphere mostly driven by human activities over the last 50 years (Intergovernmental Panel on Climate Change, 2014). The atmospheric concentration of carbon dioxide has recently exceeded a mole fraction of 400 parts per million, higher than any century in the past 420,000 years (Petit et al., 1999; National Oceanic and Atmospheric Administration, 2018a,b). Because of the high concentration of $CO_2$, global mean surface temperature increased by 0.87°C in the last decade compared to the average temperature from 1850 to 1900, and it is projected to reach 1.5°C between 2030 and 2052 (Intergovernmental Panel on Climate Change, 2018; National Oceanic and Atmospheric Administration, 2018a,b). The significant changes in $CO_2$ concentration and global temperature pose a significant threat to humanity because of their severe, extensive, adverse impacts on human and natural systems. Studies have shown that climate change increases the frequency and severity of extreme weather events (Intergovernmental Panel on Climate Change, 2015; Wuebbles et al., 2017), impairs global food production (Lobell et al., 2008), shrinks ice volume and snow cover (Robinson et al., 2014), causes sea levels to rise (Kniveton, 2017; Nerem et al., 2018), and leads to forest disturbances (Dale et al., 2001; Seidl et al., 2017) and deterioration of terrestrial and marine ecosystems (Rosenzweig et al., 2008; Hoegh-Guldberg and Bruno, 2010; Levitus et al., 2017). In fact, the combined value of damages across agriculture, coastal storms, energy, human mortality, and labor sectors costs roughly 1.2% of gross domestic product per +1°C on average in the United States (Hsiang et al., 2017).

The scientific evidence for climate change has been unequivocal (Intergovernmental Panel on Climate Change, 2014). In fact, 97% of actively publishing climate scientists agree that human activities are causing global warming (Cook et al., 2013, 2016). However, some people still remain skeptical about climate change despite the scientific consensus (e.g., Hulme, 2009; Poortinga et al., 2011; Weber and Stern, 2011; Hornsey et al., 2016). Within the United States, public views on climate change tend to polarize along party lines (McCright and Dunlap, 2011). According to a recent Gallup Poll, 86% of democrats vs. 42% of republicans agree most scientists believe global warming is occurring; 4% of democrats vs. 69% of republicans think the seriousness of global warming is generally exaggerated; 89% of democrats vs. 35% of republicans believe global warming is caused by human activities; and 91% of democrats vs. 33% of republicans worry about global warming (Brenan and Saad, 2018). This partisan divide has not only endured, but widened over time. A poll from Pew Research Center shows that in 2006, 79% of democrats vs. 59% of republicans said there is solid evidence that the average temperature on Earth has been getting warmer, but in 2017, 92% of democrats vs. 52% of republicans said so (Pew Research Center, 2017). There is also a growing divide in policy priorities: in 1994, 66% of democrats vs. 58% of republicans said stricter environmental laws and regulations are worth the cost, but in 2017, 77% of democrats vs. 36% of republicans said so (Pew Research Center, 2017); in 2008, 47% of democrats vs. 15% of republicans said climate change is a top priority for the president and congress, but in 2018, 68% of democrats vs. 18% of republicans said so (Pew Research Center, 2018).

To explain public skepticism on climate change, traditional accounts have adopted an information deficit model that attributes disbelief to a lack of knowledge or understanding (Lorenzoni et al., 2007; Shi et al., 2016), a lack of affect (Leiserowitz, 2006), or insufficient awareness about the issue (Norton and Leaman, 2004; Lorenzoni and Pidgeon, 2006). However, these accounts have failed to explain the partisan polarization over the years when an increasing volume of information and evidence on climate change has been presented to the public. Another conundrum is that individuals with high science literacy and technical reasoning skills are not the most concerned about climate change, but rather, they are the ones among whom polarization is the greatest (Kahan, 2012; Drummond and Fischhoff, 2017; Kahan et al., 2017). This suggests that the public divide on climate change is not solely driven by a lack of understanding or knowledge, and the mere presentation of climate change evidence is likely insufficient to convince the public.

Recent efforts to explain group polarization have relied on a motivated reasoning approach that traces back to studies on motivated social cognition in the early 1950's. In a pioneering study, Hastorf and Cantril (1954) demonstrated that after watching the same football game between Princeton and Dartmouth teams, Princeton and Dartmouth students drew distinct conclusions about the game, where they largely disagreed on the number of infractions made by each team, the reasons behind these infractions, the roughness of the game, and who started the rough play. This study suggests that the same sensory input is interpreted in vastly different ways depending on the viewer's social affiliations, predispositions, and motivations.

Following the same logic, recent theories focus on identity-based polarization, where perceptions of controversial topics such as climate change are driven by socio-political motivations and beliefs (Drummond and Fischhoff, 2017; Kahan et al., 2017; Bail et al., 2018; Ehret et al., 2018). Specifically, the cultural cognition thesis posits that people form perceptions of risks or controversial topics in a way that coheres with values characteristic of the groups with which they identify (Kahan et al., 2011; Kahan, 2012). One explanation underlying this thesis is that people selectively expose themselves to information from news media that is consistent with their existing motivations and beliefs (Feldman et al., 2012; Newman et al., 2018). Similarly, the identity-protective cognition thesis argues that people high on numeracy skills use their quantitative-reasoning capacity to selectively interpret the data to conform to their cultural and political values (Kahan et al., 2017). Another account suggests that people automatically obey in-group norms and oppose out-group norms, but critically, they exaggerate the extent of opposition from out-group members, creating a false sense of cultural norm on climate change (Van Boven et al., 2018).

Although many studies have suggested social motivations and ideologies determine the interpretation of quantitative evidence, it is currently unknown *how* motivations and ideologies shape perception and judgment. To specifically examine how this process occurs, here we propose a motivated attention framework to offer an attentional mechanism to explain the political polarization on climate change. Specifically, socio-political motivations shape visual attention to climate change evidence, altering the perception of the evidence and subsequent actions to mitigate climate change. The altered perception and actions can further reinforce prior beliefs and motivations, thus creating a positive feedback loop (**Figure 1**). This framework is supported by our previous work that demonstrates that liberals who are concerned about climate change attend more readily to climate-related words over neutral words, but conservatives who are not concerned about climate change do not show an attentional priority of climate-related words over neutral words, suggesting that political orientations are associated with different attentional priorities of climate change (Whitman et al., 2018).

In the motivated attention framework, we define political motivation as political orientation, and we predict that liberals and conservatives attend to the same climate change evidence (i.e., a graph of global temperature) in ways that are consistent with their political norms. Attention is measured by eye gaze dwell time on the graph. We define perception of climate evidence as the estimation of global temperature from the graph, and actions to mitigate climate change as the likelihood to sign climate petitions or donate to an environmental organization. To seek evidence for this framework, we conducted three experiments to examine how people with different political orientations perceive the same global temperature graph and whether the perceptual differences can be explained by different attentional priorities (Experiment 1), how these attentional biases alter actions to mitigate climate change (Experiment 2), and how drawing attention to motivationally consistent evidence influences climate actions (Experiment 3).

## EXPERIMENT 1

This experiment examines how political motivation alters the perception of climate change evidence. We predict that people with different political orientations perceive the same temperature graph differently when the graph is framed as global temperature, but not when the graph is under a neutral frame (i.e., when the evidence is not motivationally relevant). We further examine whether the perceptual differences can be explained by different attentional allocations on the graph. We tracked visual attention using an eyetracker in the lab while participants were viewing the graph. We predict that liberals and conservatives focus on different parts of the graph consistent with their political motivations to guide their temperature estimation.

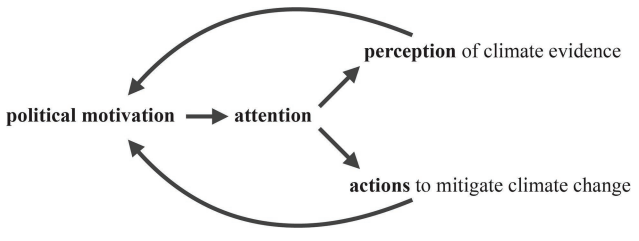


**FIGURE 1 |** A motivated attention framework of climate change perception and action.

### Participants

A total of 213 undergraduate students (142 females; mean age = 20.3 years, SD = 2.7) from University of British Columbia (UBC) participated for course credit. Six participants who provided an estimation above or below 2.5 standard deviations of the group mean were excluded from the study, leaving a final sample of 207. All three experiments reported here were approved by UBC Behavioral Research Ethics Board. All participants in the experiments provided informed consent.

### Stimuli

We used a graph of global annual mean surface air temperature change in Celsius (°C) from 1880 to 2013 (**Figure 2**), generated from estimates based on land data only[1] provided by National Aeronautics and Space Administration (NASA). The y-axis was the temperature change relative to a baseline period from 1951 to 1980, a reference period used by NASA. Specifically, the temperature change was the difference between the global mean surface air temperature in each year and the mean temperature from 1951 to 1980 (baseline period). The graph subtended 27.2° of visual angle in width (916 pixels) and 15.9° of visual angle in height (527 pixels).

### Procedure

Participants were randomly assigned to one of two conditions: temperature condition ($N = 104$) or neutral condition ($N = 103$). In the temperature condition, participants viewed the graph of annual global temperature change. In a descriptive paragraph above the graph, participants were informed that the graph showed the annual global temperature change from 1880 to 2013. There was no label for the x-axis or the y-axis. Participants were eyetracked when they were viewing the graph. Eye gaze was tracked using an SMI RED-250 Mobile Eyetracking System (60 Hz). Each participant was seated 50 cm from a computer monitor with a resolution of 1920 pixels × 1080 pixels. After seeing the graph, participants were asked to estimate the average global temperature change from 1880 to 2013. In the neutral condition, participants viewed the exact same graph but without any framing related to global temperature, and the x-axis and the y-axis were exactly same as in the temperature condition. In the descriptive paragraph above the graph, participants were informed that the graph showed some value change from 1880 to 2013. Same as in the temperature condition, participants were eyetracked when they were viewing the graph.

[1]Data retrieved from: https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_Data_only/graph.csv

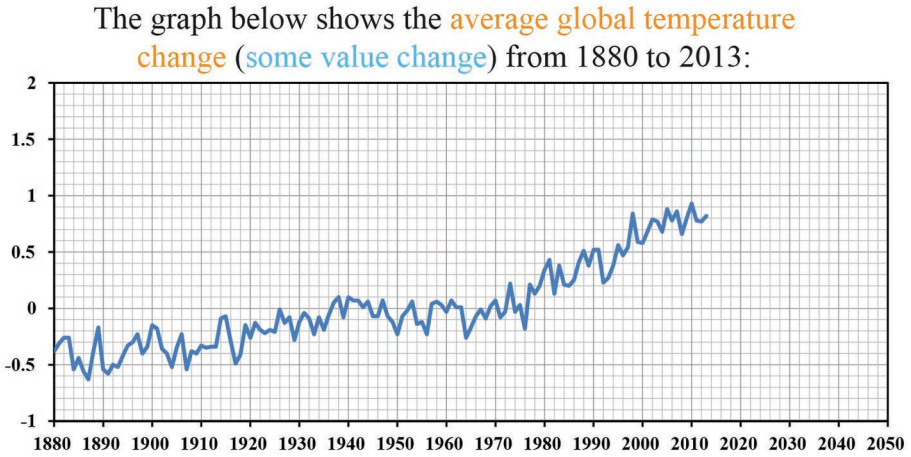


**FIGURE 2 |** A graph of global annual mean surface air temperature change in Celsius (°C) from 1880 to 2013 in the temperature condition, or neutral value change in the neutral condition.

After seeing the graph, participants were asked to estimate the average value change from 1880 to 2013. After the estimation task, participants in both conditions provided their demographic information and rated their political orientation on an 11-point scale from −5 (very liberal, left-wing) to 5 (very conservative, right-wing). In our analysis, we divided participants into a liberal group (whose ratings on the political orientation scale were below 0) and a conservative group (whose ratings on the political orientation scale were above 0). In the temperature condition, the mean rating on the political orientation scale was −1.36 (69 liberals and 21 conservatives). In the neutral condition, the mean rating on the political orientation scale was −1.57 (69 liberals and 21 conservatives).

## Results and Discussion

### Estimation Results

The objective average change in the graph was 0.01, and participants in both conditions over-estimated the average value change (mean estimated change = 0.52 in the temperature condition, mean estimated change = 0.43 in the neutral condition, $p < 0.001$). Participants in the temperature condition estimated the change as numerically larger than those in the neutral condition [$t(205) = 1.49$, $p = 0.14$, $d = 0.20$].

The goal of this experiment was to examine how people with different political orientations perceive the same global temperature graph. In the temperature condition, we found that more liberalism was weakly correlated with higher estimates of the temperature change [$r(102) = -0.19$, $p = 0.055$], suggesting liberals tended to perceive a higher temperature change than conservatives. However in the neutral condition, no correlation was found between political orientation and estimation of temperature change [$r(101) = 0.02$, $p = 0.83$]. These results suggest that political orientation is associated with different perceptions of the same evidence when the graph is framed as global temperature, but not when the graph is under a neutral frame (i.e., when the evidence is not motivationally relevant).

### Eyetracking Results

The heatmaps of the average dwell time for liberals and conservatives in the temperature condition are shown in **Figure 3**. The heatmap of the average dwell time for independents (whose ratings on the political orientation scale were 0) in the temperature condition is shown in **Section A of Supplementary Materials**.

From **Figure 3,** it is evident that both liberals and conservatives looked more at the relatively flat phase of the curve from 1940 to 1980 and the rising phase of the curve from 1990 to 2013. We therefore defined two areas of interest (AOIs) on the curve: the flat phase (1940 to 1980, subtending 5.7° of visual angle in width, 187 pixels, and 1.8° in height, 59 pixels) which we interpret as weaker evidence of climate change, and the rising phase (1990 to 2013, subtending 3.4° of visual angle in width, 112 pixels, and 3.0° in height, 98 pixels) which we interpret as stronger evidence of climate change[2]. To measure visual attention, we calculated dwell time in each AOI. Since participants spent different amounts of time on the graph, we calculated the proportional gaze dwell time for each participant, which was defined as the dwell time spent in each AOI divided by the total dwell time on the graph.

To examine the overall relationship between participants' political motivation and their visual attention on the graph, we correlated political orientation and the difference in proportional dwell time between the rising phase and the flat phase (rising – flat). There was no significant correlation between political orientation and the difference in proportional dwell time between the rising phase and the flat phase in the temperature condition [$r(102) = -0.15$, $p = 0.13$] or the neutral condition [$r(101) = -0.02$, $p = 0.86$]. However, relative to the neutral condition, in the temperature condition, more liberalism tended to be associated with greater proportional dwell time on the rising phase relative to the flat phase. These results point to a possibility that the more liberal the participants,

[2]We define "flat" and "rising" in a relative sense given their different steepness.

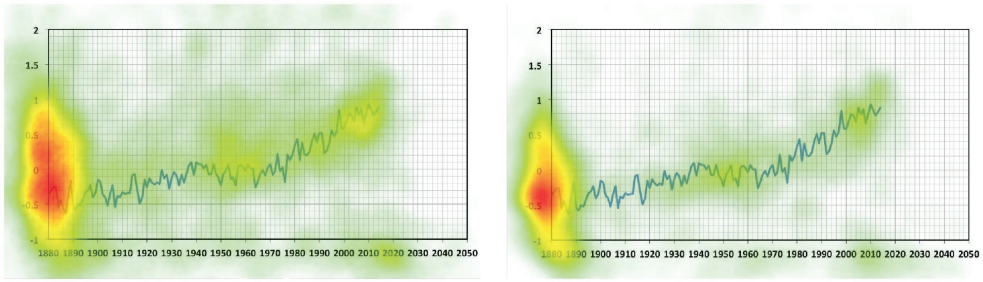


**FIGURE 3 |** A heatmap showing the average duration of dwell time on the temperature curve for liberals (left, $N = 69$) and conservatives (right, $N = 21$) in the temperature condition. Participants whose ratings on the political orientation scale were below 0 were grouped as liberals and whose ratings on the political orientation scale were above 0 were grouped as conservatives. Warmer colors represent higher average duration of dwell time.

the more attention they paid to the rising phase relative to the flat phase of the temperature curve. We further divided the participants into a liberal group and a conservative group. In the temperature condition, we did not find any correlation between attention on the graph and the degree of liberalism [$r(67) = -0.14$, $p = 0.26$] or conservatism [$r(19) = 0.08$, $p = 0.74$]. In the neutral condition, we did not find any correlation between attention on the graph and the degree of liberalism [$r(69) = -0.05$, $p = 0.70$] or conservatism [$r(19) = -0.32$, $p = 0.17$].

We then examined the relationship between visual attention and estimation. In the temperature condition, proportional dwell time on the rising phase relative to the flat phase was positively correlated with estimates of temperature change [$r(102) = 0.33$, $p < 0.001$], but not in neutral condition [$r(101) = 0.05$, $p = 0.60$]. This suggests that more attention to the rising phase relative to the flat phase of the curve (i.e., more attention to stronger evidence of climate change) was associated with higher estimations of temperature change. We further divided the participants into a liberal group and a conservative group. In the temperature condition, we found that liberals who focused more on the rising phase of the curve relative to the flat phase provided higher estimates of temperature change [$r(67) = 0.30$, $p = 0.01$], and for conservatives, there was a marginal correlation [$r(19) = 0.38$, $p = 0.09$]. We note that although the value of $p$ was marginal, the correlation coefficient was larger for conservatives than for liberals. This may be due to the smaller sample size of conservatives. The correlation coefficient may change if the sample size of conservatives increased. In the neutral condition, no correlation was found for liberals [$r(67) = 0.09$, $p = 0.46$] or conservatives [$r(19) = -0.01$, $p = 0.95$]. In sum, these results provide initial evidence suggesting that political orientation could be associated with attentional biases which alter the perception of the same evidence.

# EXPERIMENT 2

Experiment 1 involved a sample of undergraduate students, therefore limiting the generalizability of the findings. Experiment 2 aimed to replicate Experiment 1 with a broader online sample on Amazon Mechanical Turk (MTurk) using a novel attention-tracking technique called BubbleView. More importantly, this experiment aimed to examine how attentional biases were related to actions to mitigate climate change.

## Participants

A new group of 180 participants (58 females; mean age = 38.0 years, SD = 11.9) were recruited on MTurk. All participants gave informed consent and received US$0.25 each as compensation for participation. All participants were from the United States. Three participants who provided an estimation above or below 2.5 standard deviations of the group mean were excluded from the study, leaving a final sample of 177.

## Stimuli and Procedure

The stimulus in this experiment was a graph showing annual global temperature, rather than temperature change as in the previous experiment. This was to ease the estimation of global temperature, as estimating average temperature change may be more difficult than estimating average temperature. Specifically, the graph showed the global annual mean surface air temperature in Celsius (°C) from 1880 to 2017 (**Figure 4**), generated from estimates based on land and ocean data[3] provided by NASA. The graph was changed from land only to land and ocean to show a more representative view of the annual global temperature over years. The graph subtended 23.4° of visual angle in width (783 pixels) and 13.6° in height (450 pixels), assuming that participants were seated 50 cm from a computer monitor with a resolution of 1920 pixels × 1080 pixels.

As in the previous experiment, participants were randomly assigned to the temperature condition ($N = 87$) or the neutral condition ($N = 90$). To measure participants' attention, we used a novel online attention-tracking tool called BubbleView (adapted from Kim et al., 2017). The entire graph, including the x-axis and the y-axis, was covered by a black mask, and only a small circular area around the mouse was transparent where the participant could see the underlying graph (see **Figure 4**). Participants were asked to move their mouse to see the content

[3]Data retrieved from: https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_and_Ocean_Data/graph.csv

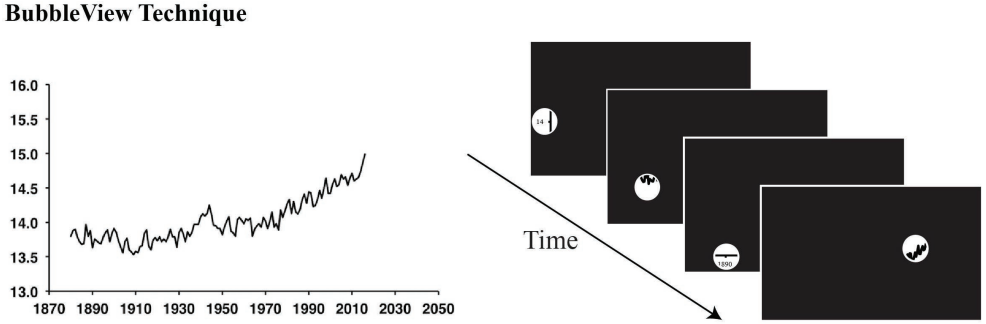


**FIGURE 4 |** Experiment 2 Methods. Using the BubbleView technique, the graph on the left was covered by a black mask, and only a small circular area around the mouse was transparent. Participants had to move their mouse to see the graph.

of the graph. The black mask was the same size as the graph. The transparent circular area subtended 1.2° of visual angle (diameter = 40 pixels). We tracked participants' mouse location as a proxy for visual attention.

After viewing the graph, participants were asked to estimate the average global temperature (°C) in the temperature condition, or the average value in the neutral condition from 1880 to 2017. They were asked to provide an estimate between 13 and 16 (the bounds of the y-axis). After providing the estimates, participants were presented with a petition to stand with the Nature Conservancy to call on United States leaders to stand strong on climate change, and were asked whether they were willing to sign it. Participants also indicated whether they were willing to donate to Natural Resource Defense Council. The order of the petition and the donation question was random. If participants were willing to sign the pledge, they provided their name and email which were then forwarded to change.org. If participants were willing to donate, they were asked to indicate the amount of donation (which was only hypothetical). At the end of the experiment, participants in both conditions provided their demographic information and rated their political orientation on the same 11-point scale. As in the previous experiment, we divided participants into a liberal group and a conservative group. In the temperature condition, the mean rating on the political orientation scale was −0.82 (47 liberals and 29 conservatives). In the neutral condition, the mean rating on the political orientation scale was 0.11 (32 liberals and 39 conservatives).

## Results and Discussion

### BubbleView Results

This experiment aimed to replicate the attentional results from Experiment 1 using the BubbleView technique. To measure attention, we calculated the number of mouse locations in each AOI (defined below). Since there was no time limit for participants to view the graph, we used the proportional number of mouse location, which was calculated as the number of mouse locations in each AOI divided by the total number of mouse locations on the graph.

Similar to Experiment 1, we defined two AOIs on the temperature curve, one on the flat phase from 1880 to 1948 (subtending 8.3° of visual angle in width, 274 pixels, and 3.6° in height, 120 pixels), another on the rising phase from 1949 to 2017 (subtending 7.7° of visual angle in width, 254 pixels, and 5.2° in height, 170 pixels). We adjusted the AOIs from Experiment 1 because this graph was slightly different from the graph in Experiment 1, as it contained both land and ocean data, whereas the one in Experiment 1 contained only land data. This means that there was a small peak of global temperature around 1945 in the current graph, whereas the curve in Experiment 1 was relatively flat before 1980. For this reason, we tried to divide the curve into two halves (with the year 1949 being the mid-point), and the second half of the temperature curve was defined as the rising phase, which was steeper than the first half of the curve defined as the flat phase.

We first examined the relationship between political orientation and attention. This time, we did not find a correlation between political orientation and the proportional number of mouse location in the rising phase relative to the flat phase in the temperature condition [$r(85) = 0.07$, $p = 0.49$] or in the neutral condition [$r(88) = -0.03$, $p = 0.81$]. This did not replicate the numerical trend in Experiment 1. We further divided the participants into a liberal group and a conservative group. In the temperature condition, same as in Experiment 1, we did not find any correlation between attention on the graph and the degree of liberalism [$r(45) = 0.12$, $p = 0.44$] or conservatism [$r(27) = 0.09$, $p = 0.64$]. In the neutral condition, we did not find any correlation between attention on the graph and the degree of liberalism [$r(30) = -0.10$, $p = 0.58$] or conservatism [$r(37) = 0.20$, $p = 0.22$].

We then examined the relationship between attention and temperature estimation. In the temperature condition, we found that greater proportional number of mouse location in the rising phase relative to the flat phase was positively correlated with higher estimate of temperature [$r(85) = 0.34$, $p = 0.001$], but no correlation was found in the neutral condition [$r(88) = -0.10$, $p = 0.37$]. This result replicated the findings in Experiment 2, suggesting that more attention to the rising phase relative to the flat phase of the temperature curve (i.e., more salient evidence of climate change) was associated with higher estimations of global temperature.

The heatmaps of the average density of mouse location on the graph for liberals and conservatives are shown in **Figure 5**. The heatmap of the average dwell time for independents (whose ratings on the political orientation scale were 0) in the temperature condition is shown in **Section B of Supplementary Materials**. In the temperature condition, liberals who focused more on the rising phase relative to the flat phase provided marginally higher estimates of temperature [$r(45) = 0.28$, $p = 0.054$], and the same marginal correlation was found for conservatives [$r(27) = 0.35$, $p = 0.06$]. In the neutral condition, no correlation was found for liberals [$r(30) = 0.10$, $p = 0.59$] or conservatives [$r(37) = -0.25$, $p = 0.13$]. These results suggest that both liberals and conservatives who focused more on the rising phase relative to the flat phase tended to provide a higher estimation of global temperature, which partially replicated Experiment 1 in which we found that liberals who focused more on the rising phase showed significantly higher perceived temperature, but this correlation was only marginal for conservatives.

## Climate Action Results

A more important goal of this experiment was to examine how attentional biases were related to actions to mitigate climate change. We first conducted log linear analyses on petition signing in the three-way contingency table. We found a significant three-way interaction [$G^2(4) = 21.50$, $p < 0.001$]. We then conducted separate chi-square tests for the temperature condition and the neutral condition. We found that more liberals signed the climate-related petition than conservatives did in the temperature condition ($X^2 = 10.19$, $p = 0.001$), but not in the neutral condition ($X^2 = 1.74$, $p = 0.19$) (**Table 1**). This suggests that when the evidence was motivationally relevant, people were more likely to behave in ways that were consistent with their political orientations.

For willingness to donate, we found that there was a significant three-way interaction [$G^2(4) = 12.37$, $p = 0.02$]. However, we did not find a difference in the willingness to donate between liberals and conservatives in the temperature condition ($X^2 = 0.97$, $p = 0.32$) or in the neutral condition ($X^2 = 2.65$, $p = 0.10$) (**Table 1**). The null results in donation could be driven by the fact that the donation question was hypothetical and no actual donations were made.

## Climate Action and Attention Results

In the final analysis, we examined the relationship between attention and the likelihood to sign the petition (we did not consider the donation results as they were insignificant in the previous section). In the temperature condition, greater attention to the flat phase relative to the rising phase was associated with a higher likelihood of signing the petition for liberals [$r(45) = -0.32$, $p = 0.03$]. However, greater attention to the rising phase relative to the flat phase was marginally associated with a higher likelihood of signing the petition for conservatives

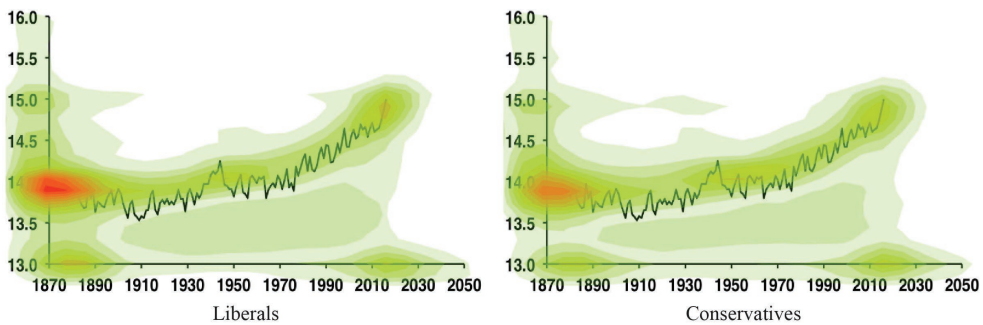


**FIGURE 5 |** A heatmap showing the distribution of the average density of mouse location on the graph for liberals (left, $N = 47$) and for conservatives (right, $N = 29$) in the temperature condition. Participants whose ratings on the political orientation scale were below 0 were grouped as liberals and whose ratings on the political orientation scale were above 0 were grouped as conservatives. Warmer colors represent higher average density of mouse location.

**TABLE 1 |** The number of liberals and conservatives who signed the petition or were willing to donate in the temperature condition and the neutral condition.

| Condition | PO | Yes | No | Percent Yes | Chi-square |
|---|---|---|---|---|---|
| **Petition signing** | | | | | |
| Temperature | Liberals | 25 | 22 | 53.2% | $X^2 = 10.19$, $p = 0.001$ |
| | Conservatives | 4 | 25 | 13.7% | |
| Neutral | Liberals | 12 | 20 | 37.5% | $X^2 = 1.74$, $p = 0.19$ |
| | Conservatives | 8 | 31 | 20.5% | |
| **Donation willingness** | | | | | |
| Temperature | Liberals | 16 | 31 | 34.0% | $X^2 = 0.97$, $p = 0.32$ |
| | Conservatives | 6 | 23 | 20.7% | |
| Neutral | Liberals | 9 | 23 | 28.1% | $X^2 = 2.65$, $p = 0.10$ |
| | Conservatives | 4 | 35 | 10.3% | |

[$r(27) = 0.33$, $p = 0.08$]. In the neutral condition, there was no correlation between attention and willingness to sign for liberals [$r(30) = 0.21$, $p = 0.25$] or conservatives [$r(37) = -0.23$, $p = 0.15$]. This suggests that attention guides climate actions in different ways for liberals and conservatives.

# EXPERIMENT 3

The previous two experiments were correlational by nature. To seek causal evidence for the motivated attention framework, we manipulated attention by coloring different parts of the temperature curve to deliberately bias attention to stronger or weaker evidence of climate change. In other words, we aimed to examine how drawing attention to motivationally consistent evidence influences subsequent actions.

## Participants

A new group of 278 participants (155 females; mean age = 37.5 years, SD = 13.0) was recruited from MTurk. All participants gave informed consent and received US$0.25 for participating. All participants were from the United States.

## Stimuli and Procedure

Given the slight increase in temperature from 1930 to 1945 on the land and ocean graph in Experiment 2 may diminish any attentional bias to the rising phase, the stimulus used in the current experiment was the same global temperature graph used in Experiment 1, generated from estimates based on land data only[4] provided by NASA, except that we converted the unit of global temperature from Celsius to Fahrenheit to facilitate the comprehension of temperature for United States participants, and we also updated the graph from 2013 to 2017. To manipulate attention, we highlighted the rising phase from 1950 to 2017 in red in the "rising red" condition ($N = 105$, **Figure 6A**), or highlighted the flat phase from 1880 to 1949 in red in the "flat red" condition ($N = 84$, **Figure 6B**), or did not highlight the curve in the control condition ($N = 89$, **Figure 6C**). In the rising red condition, the mean rating on the political orientation scale was −1.10 (60 liberals and 26 conservatives). In the flat red condition, the mean rating on the political orientation scale was −1.23 (42 liberals and 25 conservatives). Attention was again tracked using BubbleView as in Experiment 2. After viewing the graph, participants were asked whether they were willing to sign a climate-related petition and whether they were willing to donate to an environmental organization, as in Experiment 2.

## Results and Discussion

### Manipulation Check

As a manipulation check, we examined attention allocation in different phases of the curve in each condition. Participants in the rising red condition paid more attention to the rising phase (AOI fixation = 28.6%) compared to that in the flat red condition (AOI fixation = 25.3%) and control condition (AOI fixation = 24.6%) [$F(2,275) = 4.86$, $p = 0.008$, $\eta_p^2 = 0.03$]. Participants in the flat red condition paid marginally more attention to the flat phase (AOI fixation = 23.4%) compared to that in the rising red condition (AOI fixation = 22.3%) and control condition (AOI fixation = 20.2%) [$F(2,275) = 2.65$, $p = 0.07$, $\eta_p^2 = 0.03$]. This suggests our manipulation of attention was successful, specifically, highlighting the rising phase in red drew more attention to the rising phase, and highlighting the flat phase in red drew more attention to the flat phase. The heatmaps of the average density of mouse location on the graph in each condition are shown in **Figure 6**.

### Climate Action Results

We first conducted log linear analyses on petition signing in the three-way contingency table. We found a significant three-way interaction among condition (rising vs. flat), political orientation (liberals vs. conservatives), and signing (yes vs. no) [$G^2(4) = 13.31$, $p = 0.01$]. This interaction suggests that more liberals than conservatives signed the petition when the rising phase was highlighted, but not when the flat phase was highlighted. To probe this interaction further, we conducted separate chi-square tests for the rising red condition and the flat red condition. Liberals were more likely to sign the petition than conservatives when the rising phase was highlighted ($X^2 = 8.80$, $p = 0.003$). When the flat phase was highlighted, there was no significant difference between liberals and conservatives ($X^2 = 0.66$, $p = 0.42$) (**Table 2**). This suggests that liberals were more likely to sign the petition when the rising phase was highlighted than when the flat phase was highlighted.

For willingness to donate, we again found a significant three-way interaction [$G^2(4) = 20.00$, $p < 0.001$]. Moreover, liberals were more willing to donate than conservatives when the rising phase was highlighted ($X^2 = 13.03$, $p < 0.001$), but there was no significant difference between liberals and conservatives when the flat phase was highlighted ($X^2 = 0.53$, $p = 0.47$). This again suggests that liberals were more willing to donate when the rising phase was highlighted than when the flat phase was highlighted.

The results collectively suggest that drawing attention to more salient evidence of climate change encouraged actions in liberals. Although there was no significant difference between the two groups when the flat phase was highlighted, there was a numerical increase in both petition signing and donation willingness for conservatives when the flat phase was highlighted than when the rising phase was highlighted. In sum, these results provide initial evidence that drawing attention to motivationally consistent evidence can increase actions.

# GENERAL DISCUSSION

The goal of the current study was to examine how political motivations (i.e., political orientation) shape visual attention

[4]Data retrieved from: https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_Data_only/graph.csv

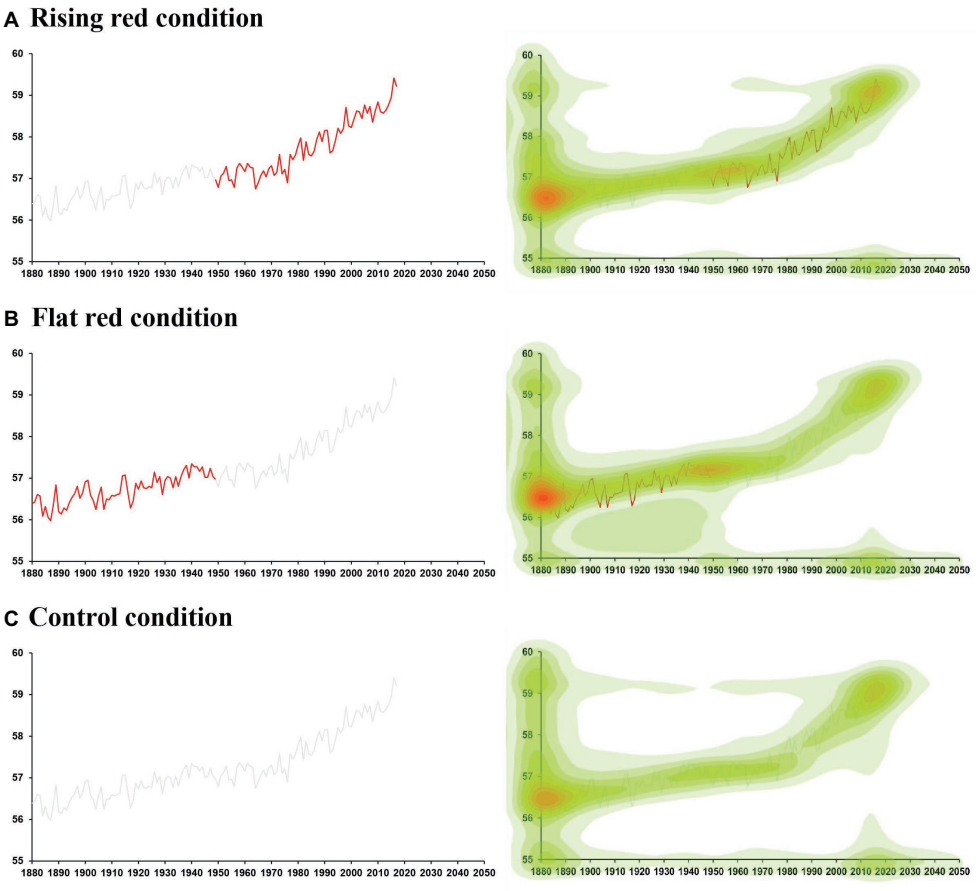


**FIGURE 6 |** Experiment 3. **(A)** In the rising red condition, the rising phase from 1950 to 2017 was highlighted in red. **(B)** In the flat red condition, the flat phase from 1880 to 1949 was highlighted in red. **(C)** In the control condition, both rising and flat phases were in gray. A heatmap representing the distribution of the average density of mouse location on the graph is shown on the right side in each condition. Warmer colors represent higher average density of mouse location.

**TABLE 2 |** The number of liberals and conservatives who signed the petition or were willing to donate in the rising red and the flat red conditions.

| Condition | PO | Yes | No | Percent Yes | Chi-square |
|---|---|---|---|---|---|
| **Petition signing** | | | | | |
| Rising red | Liberals | 34 | 26 | 56.7% | $X^2 = 8.80$, $p = 0.003$ |
| | Conservatives | 5 | 21 | 19.2% | |
| Flat red | Liberals | 19 | 23 | 45.2% | $X^2 = 0.66$, $p = 0.42$ |
| | Conservatives | 8 | 17 | 32.0% | |
| **Donation willingness** | | | | | |
| Rising red | Liberals | 31 | 29 | 51.7% | $X^2 = 13.03$, $p < 0.001$ |
| | Conservatives | 2 | 24 | 7.7% | |
| Flat red | Liberals | 15 | 27 | 35.7% | $X^2 = 0.53$, $p = 0.47$ |
| | Conservatives | 6 | 19 | 24.0% | |

to climate information and how these attentional biases alter the perception of climate evidence and influence subsequent actions to mitigate climate change. We propose a motivated attention framework that offers a cognitive pathway underlying the partisan divide on climate change (**Figure 1**). Specifically, the framework suggests that socio-political motivations shape attention to climate information, altering perception of climate evidence and subsequent actions.

In three experiments, we provided initial preliminary evidence to support the motivated attention framework. In Experiment 1, we found that liberals tended to attend more to the rising phase of the temperature curve than the flat phase of the curve and give a higher estimate of global temperature change than conservatives did. In addition, liberals who attended more to the rising phase of the curve relative to the flat phase gave a higher estimate of temperature change, but this effect

was weaker in conservatives. However, this result was not found in the neutral condition. Thus, attending more to the rising phase of the temperature curve may induce concerns in liberals, leading to a bias in their estimation of the global temperature change, but attending more to the rising phase of the neutral curve does not alter the perception of the evidence because of a lack of prior motivations. These results suggest that political orientation can bias visual attention to climate change evidence, which alters the perception of the evidence.

In Experiment 2, we partially replicated the findings in Experiment 1 with a larger sample in the United States using the BubbleView technique to track attention online. The lack of a correlation between political orientation and attention on the rising phase in Experiment 2 could be driven by the fact that the flat phase was indeed less flat than that in Experiment 1. Since the global temperature graph contained both land and ocean data, there was a slight increase from 1930 to 1945. This increase may have made the flat phase and the rising phase more similar, therefore diminishing any attentional bias to the rising phase.

A more important finding in Experiment 2 was that the attentional difference between the rising phase and the flat phase was negatively correlated with the likelihood of signing the petition for liberals, but positively correlated for conservatives. One explanation is that liberals were equally sensitive to the increase in global temperature from 1930 to 1945 in the flat phase and from 1949 to 2017 in the rising phase, so focusing on both phases equally was associated with a higher likelihood of signing the petition. Another explanation is that liberals who were inherently more likely to sign the petition attended to the increases in temperature in both phases equally. For conservatives, however, the relationship was reversed. There were two possible interpretations of the correlation: those who attended more to the rising phase than the flat phase became more concerned with climate change and therefore were more likely to sign the petition; or, those who are more likely to sign a petition generally attend to the rising temperature as evidence for their action. Since the relationship was only correlational, we cannot identify the directionality. Nonetheless, the results from Experiment 2 suggest that attention guides climate actions in different ways for liberals and conservatives.

Experiment 3 examined the causality between attention and climate action by drawing attention to the rising phase or the flat phase. We found that liberals were more likely to sign the petition or donate to an environmental organization when the rising phase (their motivationally consistent evidence) was highlighted. However, conservatives were more likely to sign or donate when the flat phase (their motivationally consistent evidence) was highlighted. These results suggest that drawing attention to motivationally consistent evidence increases actions for both liberals and conservatives. Critically, the evidence is different for liberals and conservatives depending on their motivations. This also suggests that the same approach that works for liberals may not work for conservatives.

An important limitation of the current study is that it does not provide evidence on how altered perceptions and actions reinforce prior motivations. This is a promising avenue for future studies that can examine this positive feedback loop between actions and motivations. For interventions, future studies can also investigate ways to break the feedback loop to prevent further polarization. For example, since conservatives were more likely to act when they voluntarily attended to stronger evidence of climate change, but not when their attention was deliberately drawn to the evidence, one solution is to implicitly bias conservatives' visual attention to stronger climate change evidence, such as framing the evidence in a way that is consistent with their values and beliefs (Bain et al., 2012). In the current study, we tested people's civic actions in the public sphere by asking them to sign a petition and donate to an environmental organization. Future studies can generalize the findings to behaviors in the private sphere, such as how likely they are to drive or fly less.

The current study suggests that ideologically driven motivations can influence basic perceptual processes. It reveals an attentional pathway underlying motivated reasoning, which helps explain group polarization. For example, students from different schools may attend to different players in the same game, which led to different perceptions of the game (Hastorf and Cantril, 1954). Liberals and conservatives may attend to different numbers in the same table, which led to different perceptions of risk (Kahan et al., 2011). People with greater science literacy or high numeracy skills may be better able to selectively attend to different sources of evidence, which can lead to greater group polarization (Drummond and Fischhoff, 2017; Kahan et al., 2017).

Beyond group polarization, the current study provides an attentional account to several well-established phenomena in social psychology. For example, cognitive dissonance is triggered when the evidence presented is inconsistent with a person's beliefs, which can motivate the person to try to reduce dissonance (Festinger, 1962). One way to reduce dissonance is to avoid focusing attention on situations or information which will likely increase dissonance, and pay greater attention to information which will help to achieve consonance. Another example is confirmation bias where a person seeks or interprets evidence in ways that confirm existing beliefs, expectations, or a hypothesis in mind (Nickerson, 1998). The person may increase his/her attention to evidence that confirms their prior beliefs and suppress attention to evidence that disconfirms their beliefs. A third example is the central and peripheral route to persuasion, where the former involves a deliberate analysis of the content of the message, and the latter uses simple cues in the context (Petty and Cacioppo, 1986). The central route is employed when a person is motivated and has the ability to process the arguments in the message. Otherwise, the peripheral route takes place. When the evidence is consistent with people's motivations, they may pay more attention to the evidence to deliberately analyze the information, which follows the central route. When the evidence is inconsistent with their motivations, they may pay less attention to the evidence and instead to the peripheral cues, which follows the peripheral route. As shown in one of the past studies, when a message is framed consistently with one's value, it is more likely to be processed deliberately, and the strength of the argument influenced one's attitude (von Borgstede et al., 2014).

In addition to theoretical implications, the current findings have potential practical implications for climate communication that uses data visualization to engage the public and policymakers (Harold et al., 2016; Bosetti et al., 2017; Zhao, 2017). First, the current study suggests that providing climate change evidence alone is likely to be insufficient since people may pay attention differently depending on their motivations. Second, the study suggests that we cannot use the same communication strategy for liberals and conservatives. For example, in Experiment 3, we found that drawing attention to more convincing evidence of climate change encouraged more liberals to act, but discouraged conservatives. Third, climate communication needs to align with ideological motivations to capture people's attention. One approach is to frame climate change consistently with people's values, such as framing mitigation efforts as promoting a warmer society and economic or technological development (Bain et al., 2012). Another approach is to provide information on peer group norms to shift attention, since people may have incorrect beliefs of how their peers view a controversial issue (Van Boven et al., 2018).

The current study is significant in several ways. First, it provides an attentional mechanism to understand group polarization on climate change. Specifically, our results provide initial preliminary evidence for the motivated attention framework, suggesting an attentional divide between liberals and conservatives. Second, the current study has implications for theories of ideologically motivated reasoning, demonstrating their influence on basic perceptual processes. Third, we offer a free new tool, BubbleView, to track attention online, which is more cost-effective compared to a conventional eyetracker. Finally, our findings have implications for climate communication and the design of behavioral interventions to mobilize actions on climate change in different socio-political groups.

## ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the University of British Columbia Behavioral Research Ethics Board with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the University of British Columbia Behavioral Research Ethics Board.

## AUTHOR CONTRIBUTIONS

YL and JZ contributed to the conception and design of the study. YL organized the database and analyzed and interpreted the data under the supervision of JZ. Both authors wrote the first draft of the manuscript, contributed to manuscript revision, read and approved the submitted version.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.01541/full#supplementary-material

Section A. Experiment 1: A heatmap for independents

**FIGURE S1 |** A heatmap showing the average duration of dwell time on the temperature curve for independents (*N* = 14) in the temperature condition. Participants whose ratings on the political orientation scale were 0 were grouped as independents. Warmer colors represent higher average duration of dwell time.

Section B. Experiment 2: A heatmap for independents

**FIGURE S2 |** A heatmap showing the distribution of the average density of mouse location on the graph for independents (*N* = 11). Participants whose ratings on the political orientation scale were 0 were grouped as liberals and whose ratings on the political orientation scale were above 0 were grouped as conservatives. Warmer colors represent higher average density of mouse location.

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# Correct Me if I'm Wrong: Groups Outperform Individuals in the Climate Stabilization Task

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Avoiding dangerous climate change requires ambitious emissions reduction. Scientists agree on this, but policy-makers and citizens do not. This discrepancy can be partly attributed to faulty mental models, which cause individuals to misunderstand the carbon dioxide ($CO_2$) system. For example, in the Climate Stabilization Task (hereafter, "CST") (Sterman and Booth-Sweeney, 2007), individuals systematically underestimate the emissions reduction required to stabilize atmospheric $CO_2$ levels, which may lead them to endorse ineffective "wait-and-see" climate policies. Thus far, interventions to correct faulty mental models in the CST have failed to produce robust improvements in decision-making. Here, in the first study to test a group-based intervention, we found that success rates on the CST markedly increased after participants deliberated with peers in a group discussion. The group discussion served to invalidate the faulty reasoning strategies used by some individual group members, thus increasing the proportion of group members who possessed the correct mental model of the $CO_2$ system. Our findings suggest that policy-making and public education would benefit from group-based practices.

**Keywords: climate stabilization task, mental models, group decision-making, carbon dioxide accumulation, stock-flow tasks, emissions reduction**

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## INTRODUCTION

To avoid dangerous climate change, average global temperature must not exceed a critical threshold, defined in the Paris Agreement as 1.5–2°C above pre-industrial levels (UNFCCC, 2015). However, countries' current climate pledges are guaranteed to overshoot this threshold (Mauritsen and Pincus, 2017), indicating that current national emissions policies are grossly inadequate. In a democracy, implementing effective mitigation policy is a two-step challenge: policy-makers must craft appropriate policies and those policies must then receive political and electoral support (Dreyer et al., 2015). Both steps require policy-makers, politicians, and citizens to understand the $CO_2$ system. Unfortunately, most individuals lack this knowledge and consequently underestimate the measures required to mitigate climate change (e.g., Sterman and Booth-Sweeney, 2002; Martin, 2008; Guy et al., 2013).

To reason about emissions policy (in the context of mitigating climate change), an individual must understand how $CO_2$ emissions contribute to climate change. For example, someone who accepts the scientific consensus would: (1) recognize that global temperature is increasing, (2) attribute that increase to human $CO_2$ emissions, and (3) predict that emitting more $CO_2$ will further increase temperature. This knowledge structure is called a "mental model" (Sterman, 1994; Doyle and Ford, 1998). A mental model represents the causal relationships within a system,

and is used to describe, explain, and predict system behavior (Sterman, 1994; Doyle and Ford, 1998). Although crucial for decision-making, mental models are constrained by cognitive limits (Doyle and Ford, 1998; Sterman and Booth-Sweeney, 2002) and can never represent the full complexity of the real world. The human decision-maker is thus likely to make imperfect decisions about complex problems.

The Climate Stabilization Task (hereafter, "CST") represents the complex problem of choosing the appropriate level of climate change mitigation. The CST is a decision-making task in which participants are told that atmospheric $CO_2$ concentration is increased by $CO_2$ emissions (largely from human activities), decreased by $CO_2$ absorption (largely by oceans and plants), and stabilized when the rate of $CO_2$ emissions equals the rate of $CO_2$ absorption. Participants are also told that atmospheric $CO_2$ concentration has increased since the Industrial Revolution, because the rate of $CO_2$ emissions has increased to double the rate of $CO_2$ absorption. Participants are then presented with a hypothetical scenario (**Figure 1A**) in which atmospheric $CO_2$ concentration gradually rises to 400 ppm, then stabilizes by the year 2100. Next, participants must sketch trajectories of $CO_2$ emissions and $CO_2$ absorption that would correspond with this hypothetical scenario (**Figure 1B**).

The "principle of accumulation" states that, at any given time, the level of some accumulating stock (in this case, atmospheric $CO_2$ concentration) is the difference between its inflow (rate of $CO_2$ emissions) and outflow (rate of $CO_2$ absorption) (Martin, 2008). Thus, to stabilize atmospheric $CO_2$ concentration, the rate of $CO_2$ emissions must decrease to equal the rate of $CO_2$ absorption. However, participants often erroneously assert that stabilizing $CO_2$ emissions is sufficient to stabilize atmospheric $CO_2$ concentration (**Figure 1C**). Known as "pattern-matching," this occurs when participants ignore $CO_2$ absorption, believing that the pattern of atmospheric $CO_2$ concentration should "match" the pattern of $CO_2$ emissions. Repeated studies find that only 6–44% of participants answer the CST correctly, with many falling prey to the above mentioned pattern-matching heuristic (Sterman and Booth-Sweeney, 2002, 2007; Moxnes and Saysel, 2009; Boschetti et al., 2012; Guy et al., 2013; Newell et al., 2015). Low success rates on the CST are observed not only for members of the general public (Boschetti et al., 2012), but also for individuals who are a good proxy for policy-makers—namely stakeholders of a project researching climate change impacts (Boschetti et al., 2012) and Masters students studying system dynamics at the Massachusetts Institute of Technology (Sterman and Booth-Sweeney, 2002).

Most interventions to correct decision-makers' mental models of the $CO_2$ system—as indexed by responses on the CST—have been unsuccessful (e.g., Pala and Vennix, 2005; Reichert et al., 2015). Using analogies (e.g., a bathtub in which the water level represents atmospheric $CO_2$ concentration) (Moxnes and Saysel, 2009; Guy et al., 2013; Newell et al., 2015) and promoting "global thinking" over "local thinking" (Fischer and Gonzalez, 2015; Weinhardt et al., 2015) have produced minor improvements in CST performance. A formal university course in system dynamics was more successful (Pala and Vennix, 2005; Sterman, 2010), but this intervention is too resource-intensive to be applied on a large

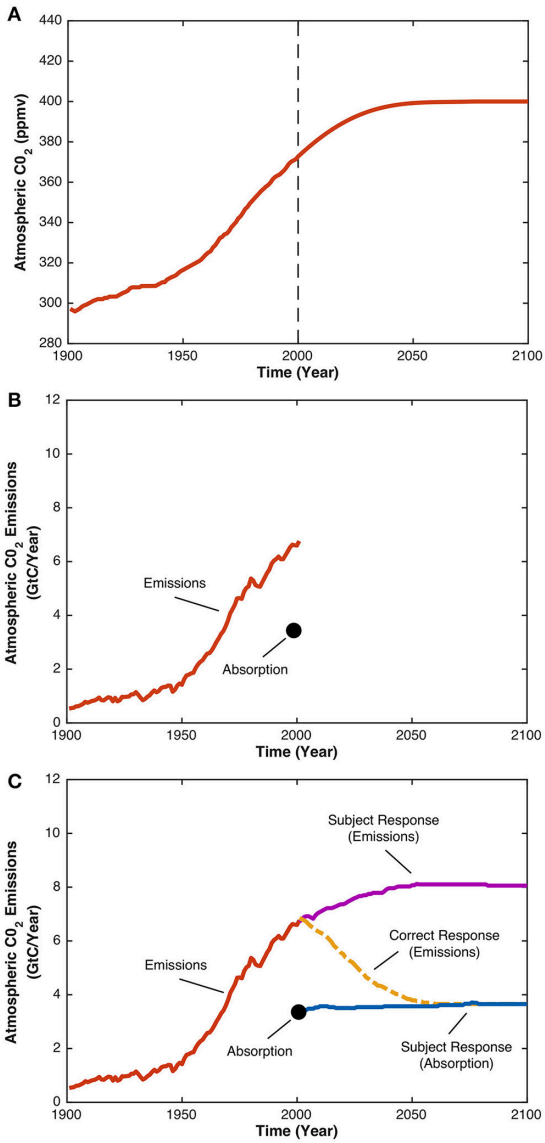



**FIGURE 1 |** Graphical illustration of the CST. Participants are presented with the graph in **(A)** showing the increase of atmospheric $CO_2$ concentration since the year 1900 up until the year 2000. Following 2000, the graph depicts a hypothetical scenario in which atmospheric $CO_2$ concentration increases to 400 ppm before stabilizing by the year 2100. Next, participants are presented with the graph in **(B)** and asked to sketch the trajectories of $CO_2$ emissions and $CO_2$ absorption from years 2000 to 2100 that they believe would be consistent with the hypothetical scenario. The graph in **(C)** shows a typical participant's response to the CST, where the blue line represents the participant's estimate of $CO_2$ absorption, and the purple line represents the participant's estimate of $CO_2$ emissions. As the rate of $CO_2$ emissions exceeds the rate of $CO_2$ absorption, atmospheric $CO_2$ concentration will increase, not stabilize. This is an example of the so-called "pattern-matching" heuristic, whereby the pattern of $CO_2$ emissions is assumed to "match" the pattern of atmospheric $CO_2$ concentration. The correct $CO_2$ emissions trajectory, given the participant's estimate of $CO_2$ absorption, is depicted by the dashed yellow line. The rate of $CO_2$ emissions decreases to equal the rate of $CO_2$ absorption, an equilibrium that would stabilize atmospheric $CO_2$ concentration. This response is consistent with the principle of accumulation, which states that the level of a stock at any given time is the difference between its inflow and its outflow.

scale. Although these results seem discouraging, all interventions so far share the limitation of characterizing decision-makers as individuals. However, real-world decision-making is a social, group-based process informed by the beliefs of others (Tranter, 2011). Previous research shows that groups are better able than individuals to attenuate cognitive biases and decision heuristics (Kugler et al., 2012; Schulze and Newell, 2016), as well as identify, evaluate, and resolve competing hypotheses (Trouche et al., 2015; Larrick, 2016). These benefits notwithstanding, it is important to note that groups do not outperform individuals in all tasks. However, groups do perform consistently better than individuals on intellective, "truth-wins" problems in which the sole correct answer can be determined through logic, and then explained to convince others (i.e., the truth "wins") (Davis, 1973; Laughlin et al., 2006). The CST is one such problem, as understanding the principle of accumulation leads to only one demonstrably correct solution (i.e., the rate of emissions equaling the rate of absorption).

The aim of the current study was to test whether an intervention involving group decision-making can improve performance on the CST. To address this question, we administered a computerized version of the CST to staff and students from the University of Western Australia ($N = 141$). Participants were given background information about the $CO_2$ system, and then presented with the hypothetical scenario in which atmospheric $CO_2$ concentration stabilizes by the year 2100 (**Figure 1A**). The decision-making component was administered at two time points, Time 1 ($T_1$) and Time 2 ($T_2$). At $T_1$, participants were presented with four graphs (**Figure 2**) and asked to select the graph that would produce the hypothetical scenario described. After selecting a graph, participants typed a brief explanation for their decision. At $T_2$, participants were randomly allocated to one of three experimental conditions, before entering an anonymized online chatroom for 10 minutes. In the individuals condition ($N = 21$), participants reflected on their initial answer and explanation by themselves before making a decision about the four graphs again. In the dyads ($N = 40$) and groups ($N = 80$) conditions, either two or four participants, respectively, inspected each other's initial answers and explanations, then engaged in a discussion to reach a consensus decision on which of the four graphs is correct.

There were three key predictions. Firstly, it was predicted that the individual reflection would have no effect on decision-making, such that the success rates of individuals would not increase from $T_1$ to $T_2$. Secondly, it was predicted that the dyad discussion would benefit decision-making, such that the success rates of dyads would increase from $T_1$ to $T_2$. Thirdly, it was predicted that the group discussion would benefit decision-making to a greater extent than the dyad discussion, such that the success rates of groups would increase from $T_1$ to $T_2$, and this increase would be greater than that observed for dyads.

A secondary aim of the current study was to examine whether individual performance on the CST can be explained by a person's (1) demographic characteristics, (2) climate change knowledge and attitudes, and/or (3) personality and cognitive style. These constructs influence performance on comparable tasks that tap similar reasoning skills, but their effects on CST performance are unclear. Participants therefore completed a pre-test questionnaire assessing several individual differences measures. This was an exploratory feature of the current study and accordingly we made no specific predictions about the relationships between the following variables and CST performance.

Most studies find no relationship between demographic variables and performance on tasks similar to the CST (e.g., Moxnes and Saysel, 2004; Sterman, 2008). However, other studies find that younger participants (Browne and Compston, 2015), males (Ossimitz, 2002; Browne and Compston, 2015; Reichert et al., 2015), or students studying STEM degrees (Booth-Sweeney and Sterman, 2000; Browne and Compston, 2015) perform better than older participants, females, or students studying non-STEM degrees. Age, sex, and field of education were therefore included in the questionnaire.

The questionnaire also included a measure of "climate change knowledge," as task-specific knowledge is associated with better performance on some stock-flow tasks (Strohhecker and Größler, 2013), but appears unrelated to performance on the CST (Moxnes and Saysel, 2004). A measure of "climate change attitudes" was also included to rule out the possibility that participants choose a graph based on their own ideology, rather than stock-flow reasoning. For the same reason, a measure of "environmental worldview," or one's beliefs about humanity's relationship with nature (Price et al., 2014), was also included.

Two personality variables are related to the ability to overcome bias by prior belief (Homan et al., 2008; West et al., 2008), and may therefore benefit performance on the CST. "Active open-mindedness" describes an individual's tendency to spend sufficient time on a problem before giving up, and to consider new evidence and the beliefs of others (Haran et al., 2013). "Need for cognition" is the psychological need to structure the world in meaningful and integrated ways, and is associated with expending greater mental effort and enjoying analytical activity (Cacioppo and Petty, 1982).

Lastly, three aspects of cognitive style may be relevant to task performance. "Cognitive reflection" is the ability to resist reporting the first answer that comes to mind (Frederick, 2005), and may therefore protect against pattern-matching. "Global processing" is a way of perceiving the world that favors the organized whole, whereas "local processing" favors component parts and details (Weinhardt et al., 2015). Previous studies have produced conflicting results on the relationship between processing style and stock-flow reasoning (Fischer and Gonzalez, 2015; Weinhardt et al., 2015). "Systems thinking" refers to the tendency to understand phenomena as emerging from complex, dynamic, and nested systems (Thibodeau et al., 2016). It is positively related to the ability to comprehend causal complexity and dynamic relationships (Thibodeau et al., 2016), as well as pro-environmental attitudes (Davis and Stroink, 2016; Lezak and Thibodeau, 2016).

A third and final aim relates to Sterman's (2008) contention that the widespread, global preference for "wait-and-see" or "go-slow" approaches to emissions reduction can be linked to misunderstanding the complex $CO_2$ system. We therefore included a policy preference question in the pre-test

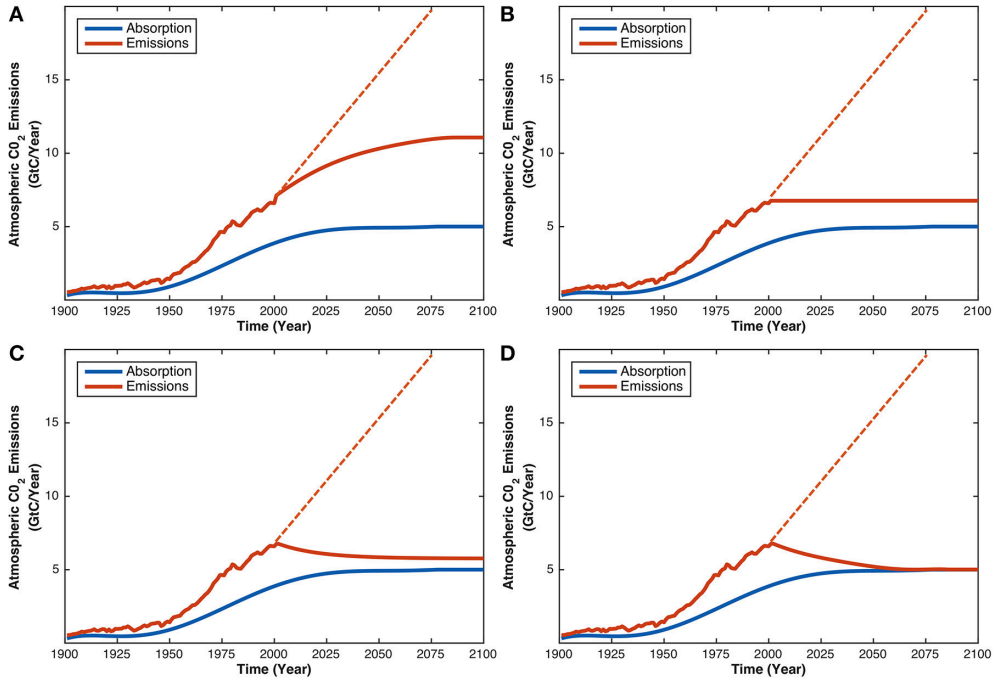



**FIGURE 2 |** The four response alternatives in the multiple-choice version of the CST. All graphs show the same $CO_2$ absorption trajectory with a different $CO_2$ emissions trajectory. Graph **(A)** depicts the typical pattern-matching response in which $CO_2$ emissions rise and then stabilize. Graph **(B)** is a less obvious form of pattern-matching in which $CO_2$ emissions immediately stabilize. Graph **(C)** approximates the correct answer as $CO_2$ emissions decrease, but not to the level required to achieve stabilization. Graph **(D)** is the correct response, because $CO_2$ emissions decrease to equal $CO_2$ absorption, thus stabilizing atmospheric $CO_2$.

questionnaire, which was subsequently repeated at post-test, after completion of the CST. Participants answered the question, "Which of these comes closest to your view on how we should address climate change?" with one of three options: "wait-and-see" (wait until we are sure that climate change is really a problem before taking significant economic action), "go-slow" (we should take low-cost action as climate change effects will be gradual), or "act-now" (climate change is a serious and pressing problem that requires significant action now). If poor understanding of the climate system is indeed responsible for complacent attitudes toward emissions reduction, then we expect participants who answer the CST incorrectly to be more likely to prefer "wait-and-see" or "go-slow" policies at post-test. Conversely, those who answer the CST correctly should be more likely to select the "act-now" option.

# METHOD

Ethical approval to conduct the experiment was granted by the Human Ethics Office at the University of Western Australia (UWA) (RA/4/1/6298).

## Participants

One hundred and forty one members of the campus community at the UWA were recruited to take part in the experiment using the Online Recruitment System for Economic Experiments (ORSEE; Greiner, 2015), an open-source web-based recruitment platform for running decision-making experiments. The ORSEE database at UWA contains a pool of over 1,500 staff and students from a range of academic disciplines. Participants were recruited by issuing electronic invitations to randomly selected individuals in the ORSEE database to attend one of several advertised experimental sessions. Participants' ages ranged from 17 to 74 ($Mdn = 21.00$, $M = 23.80$, $SD = 7.34$) and just over two thirds of participants were female (69.5%). About half studied a degree-specific major under the Faculty of Science (54.5%), but the Business School (15.7%), Engineering, Computing, and Mathematics (14.2%), and Arts (13.4%) faculties were also well represented. Participants were paid $10AUD for attending the experiment.

## Design

The experiment manipulated two independent variables: group size (individuals [$n = 1$] vs. dyads [$n = 2$] vs. groups [$n = 4$]) and time ($T_1$ vs. $T_2$). Group size was a between-participants variable, whereas time was a within-participants variable. Participants were allocated to the different group size conditions in a quasi-random fashion (see below). There was a minimum of 20 cases per group size: $21 \times 1 = 21$ participants in the individuals condition; $20 \times 2 = 40$ participants in the dyads condition; and $20 \times 4 = 80$ participants in the groups condition.

## Apparatus, Materials, and Procedure

The experiment was conducted between May and August 2016 in the Behavioral Economics Laboratory at the UWA (http://bel-uwa.github.io), a computerized laboratory designed

for carrying out collective decision-making experiments. There were 27 experimental sessions in total, with a minimum of two and a maximum of eight participants per session. Group sizes were randomly pre-determined before each session but were subject to change in the event that some participants failed to attend. For example, if eight participants were invited to a session, the goal was often to run two groups of four participants. If however, only six participants attended, then four participants were allocated to the group condition, and two participants were allocated at random either to the dyads condition or the individuals condition.

As participants arrived to each experimental session, they were randomly seated at a workstation containing two computer terminals. This random seating allocation in turn determined the group size condition to which the participants were allocated. The workstations were separated from each other by privacy blinds to prevent participants from observing one another's responses, and participants knew that face-to-face communication was prohibited. Participants read an information sheet and provided written informed consent, after which the experimenter provided an overview of the structure of the session. Using the left computer terminal on their workstation, the participants then completed the individual differences questionnaire (see **Supplementary Materials**, Section Individual Differences Questionnaire), which was executed on an internet browser using Qualtrics survey software. The questionnaire took approximately 20 minutes to complete.

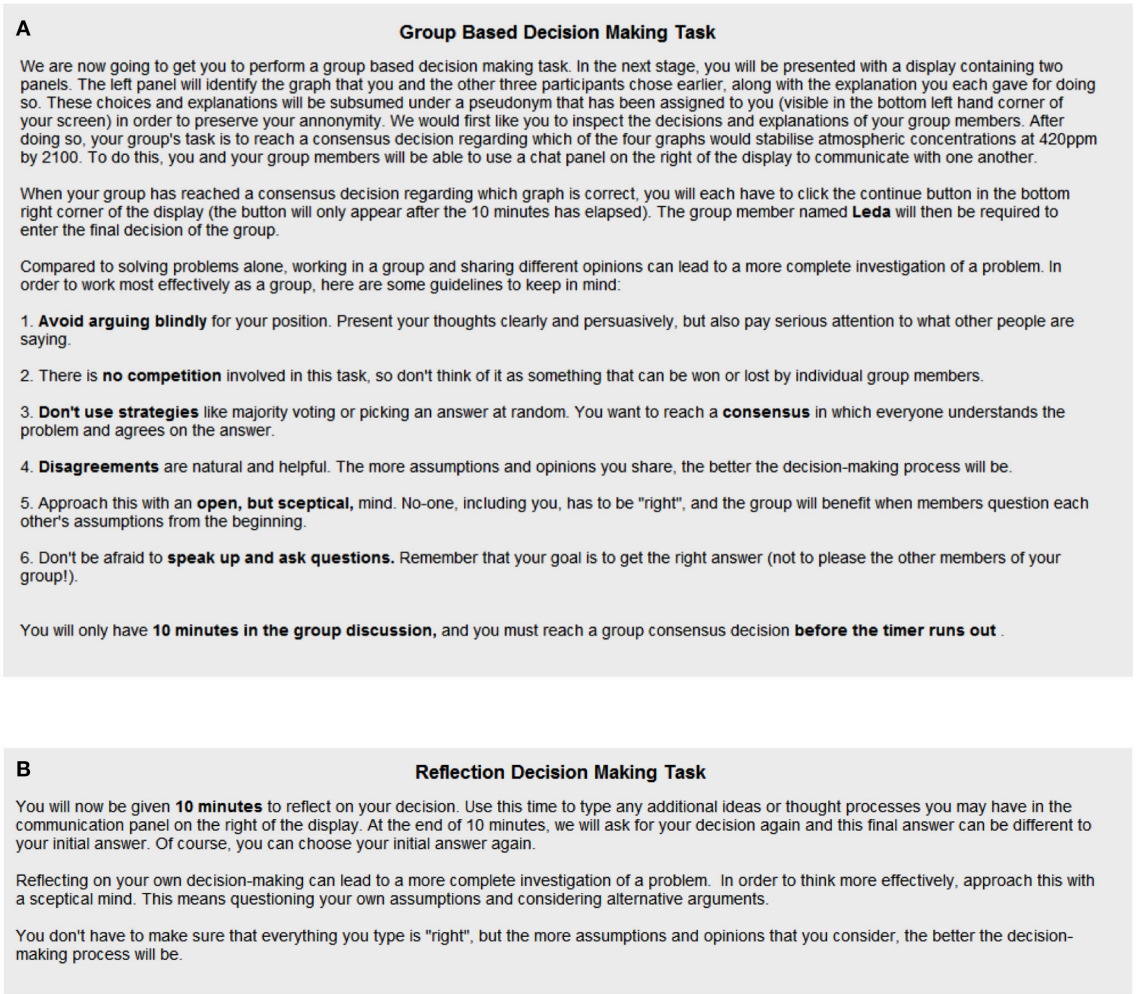
Once all participants had completed the questionnaire, they received verbal instructions from the experimenter to minimize their internet browser, which revealed the electronic instructions for the CST (see **Supplementary Materials**, Section Instructions for CST). The first page foreshadowed what the task would involve. The second page defined $CO_2$, $CO_2$ emissions, atmospheric $CO_2$ concentration, and $CO_2$ absorption. The third page described how $CO_2$ emissions and $CO_2$ absorption, respectively, increase and decrease atmospheric $CO_2$ concentration, and why atmospheric $CO_2$ concentration has increased since the Industrial Revolution. The final page presented the decision-making situation. It described a hypothetical scenario in which atmospheric concentration rises from its current level of 400 ppm to stabilize at 420 ppm by the year 2100. Participants were then confronted with four graphs depicting the same trajectory of $CO_2$ absorption, but different trajectories of $CO_2$ emissions (**Figure 2**), and were required to choose the graph that would give rise to the hypothetical scenario. Graph D (**Figure 2D**) is the correct response, as it is the only graph that depicts the rate of $CO_2$ emissions decreasing to equal the rate of $CO_2$ absorption. We used a multiple-choice format because it is less cognitively-taxing than the version of the CST in which participants sketch trajectories. In Sterman and Booth-Sweeney (2007), a multiple-choice condition with seven textual response alternatives produced equivalent results to conditions requiring participants to sketch graphs.

The decision-making component of the CST was executed as a z-Tree (Fischbacher, 2007) program, which was administered on the right computer terminal of each participant's workstation. The CST required a decision at two different points in time: $T_1$ and $T_2$. At $T_1$, all participants completed the task individually, irrespective of the group size condition to which they had been allocated. The experimental procedure at this time point was therefore identical across all three group size conditions. Participants first read the electronic instructions on the left computer terminal, before indicating on the right computer terminal which of the four graphs they believed would stabilize atmospheric $CO_2$ concentration (**Figure 2**). There was no time limit for this component of the task.

Once participants had registered their $T_1$ graph choice, a text field appeared on screen with a prompt to use the keyboard to type out a brief explanation for why they thought that the graph they had chosen was correct. Participants were allocated 5 minutes to complete this component of the task and a counter in the top right-hand corner of the terminal display indicated the time remaining for participants to supply their written explanations.

At $T_2$, participants were informed of their group size condition allocation. Participants assigned to the dyads or groups conditions were required to discuss the decision problem with their one partner or three group members, respectively, for a fixed period of 10 minutes in order to reach a consensus decision regarding the correct solution. They were first given six guidelines for a productive group discussion (adapted from a study by Schweiger et al., 1986), as shown in **Figure 3A**. They then entered an online chatroom in which they could communicate with one another. The chatroom interface was divided into two panels: the Player Decisions Panel and the Communication Panel (**Figure 4**). The Player Decisions Panel, to the left of the terminal display, presented the $T_1$ graph choices and explanations of each group or dyad member under a pseudonym (Leda, Triton, Portia, or Sinope) to preserve participant anonymity. In the Communication Panel, to the right of the terminal display, dyad and group members could communicate with one another by typing messages into a text entry field. These messages were posted in the Communication Panel under the group or dyad member's designated pseudonym. A timer in the top right corner of the terminal display showed how much time remained. After 10 minutes had elapsed, one group or dyad member was chosen randomly by the computer to register the group's or dyad's consensus decision.

The procedure at $T_2$ was different in the individuals condition. Participants in this condition were instructed to reflect on their $T_1$ decision for 10 minutes, alone. They were instructed to approach this reflection with a skeptical mind, to question their original assumptions, and to consider alternative explanations (**Figure 3B**). The chatroom interface was once again divided into two panels, this time labeled the Decision Panel and the Reflections Panel. In the Decision Panel, to the left of the terminal display, participants could inspect their $T_1$ decision and explanation. In the Reflections Panel, to the right of the terminal display, participants were able to record reflections on their $T_1$ decision. This panel was essentially the same as the Communication Panel for participants in the groups and dyads conditions, except that it was used to record self-reflections, rather than to communicate with group or dyad members. A timer in the top right corner of the terminal display once



**A**

**Group Based Decision Making Task**

We are now going to get you to perform a group based decision making task. In the next stage, you will be presented with a display containing two panels. The left panel will identify the graph that you and the other three participants chose earlier, along with the explanation you each gave for doing so. These choices and explanations will be subsumed under a pseudonym that has been assigned to you (visible in the bottom left hand corner of your screen) in order to preserve your annonymity. We would first like you to inspect the decisions and explanations of your group members. After doing so, your group's task is to reach a consensus decision regarding which of the four graphs would stabilise atmospheric concentrations at 420ppm by 2100. To do this, you and your group members will be able to use a chat panel on the right of the display to communicate with one another.

When your group has reached a consensus decision regarding which graph is correct, you will each have to click the continue button in the bottom right corner of the display (the button will only appear after the 10 minutes has elapsed). The group member named **Leda** will then be required to enter the final decision of the group.

Compared to solving problems alone, working in a group and sharing different opinions can lead to a more complete investigation of a problem. In order to work most effectively as a group, here are some guidelines to keep in mind:

1. **Avoid arguing blindly** for your position. Present your thoughts clearly and persuasively, but also pay serious attention to what other people are saying.

2. There is **no competition** involved in this task, so don't think of it as something that can be won or lost by individual group members.

3. **Don't use strategies** like majority voting or picking an answer at random. You want to reach a **consensus** in which everyone understands the problem and agrees on the answer.

4. **Disagreements** are natural and helpful. The more assumptions and opinions you share, the better the decision-making process will be.

5. Approach this with an **open, but sceptical,** mind. No-one, including you, has to be "right", and the group will benefit when members question each other's assumptions from the beginning.

6. Don't be afraid to **speak up and ask questions.** Remember that your goal is to get the right answer (not to please the other members of your group!).

You will only have **10 minutes in the group discussion,** and you must reach a group consensus decision **before the timer runs out** .

**B**

**Reflection Decision Making Task**

You will now be given **10 minutes** to reflect on your decision. Use this time to type any additional ideas or thought processes you may have in the communication panel on the right of the display. At the end of 10 minutes, we will ask for your decision again and this final answer can be different to your initial answer. Of course, you can choose your initial answer again.

Reflecting on your own decision-making can lead to a more complete investigation of a problem. In order to think more effectively, approach this with a sceptical mind. This means questioning your own assumptions and considering alternative arguments.

You don't have to make sure that everything you type is "right", but the more assumptions and opinions that you consider, the better the decision-making process will be.

**FIGURE 3 |** The instructions given to participants in the groups and dyads conditions **(A)** and individuals condition **(B)** at $T_2$.

again indicated how much time remained. After 10 minutes had elapsed, participants were required to indicate once again which graph they deemed to be correct.

After submitting the $T_2$ decision, all participants completed a post-test questionnaire. Participants in the dyads or groups conditions were asked to choose one of the four CST graphs again, in response to the question; "If the group answer is not what you would have chosen, which answer would you have chosen?". The post-test questionnaire also contained the climate change knowledge and attitudes questions asked in the individual differences questionnaire at the beginning of the experiment.

The CST took approximately 30 minutes to complete, and the entire experimental session lasted approximately 60 minutes.

# RESULTS

## Time 1

The success rates at $T_1$ (blue bars; **Figure 5**) did not differ significantly across the three conditions ($\chi^2_{df=2} = 1.72, p = .424$, two-sided), and the overall success rate was 44%. This is consistent with the highest previously-reported success rate using the CST (Sterman and Booth-Sweeney, 2002). **Table 1** shows the frequency with which participants used various reasoning strategies at $T_1$ to justify their graph choice. For example, Graph D was frequently accompanied by an explanation correctly describing mass balance principles (88.7% of Graph D responses). Although other strategies were referenced by participants who selected Graph D, every other reasoning strategy was more frequently used to justify an incorrect graph.

The full coding scheme consisted of five strategies from Sterman and Booth-Sweeney (2007) and their associated coding criteria, plus four additional categories created *post-hoc* to capture reasoning strategies that did not conform to any previously-defined category. The strategies taken from Sterman and Booth-Sweeney (2007) were: pattern-matching, mass balance, technology, sink saturation, and $CO_2$ fertilization (for details see Table 7 in Sterman and Booth-Sweeney, 2007). Two additional categories defined in their coding scheme

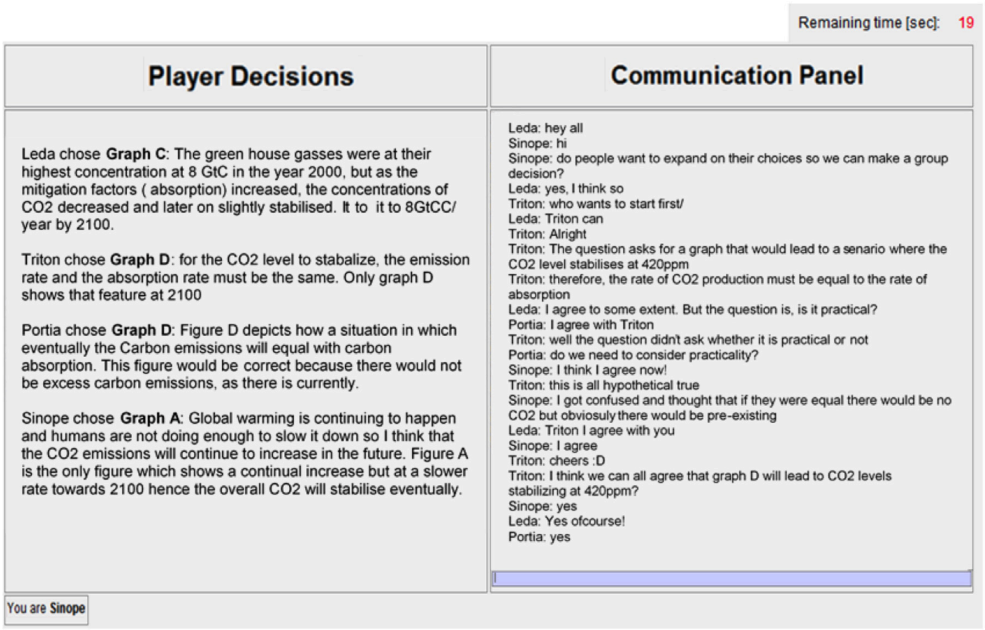



**FIGURE 4 |** Graphical illustration of the chatroom communication interface.

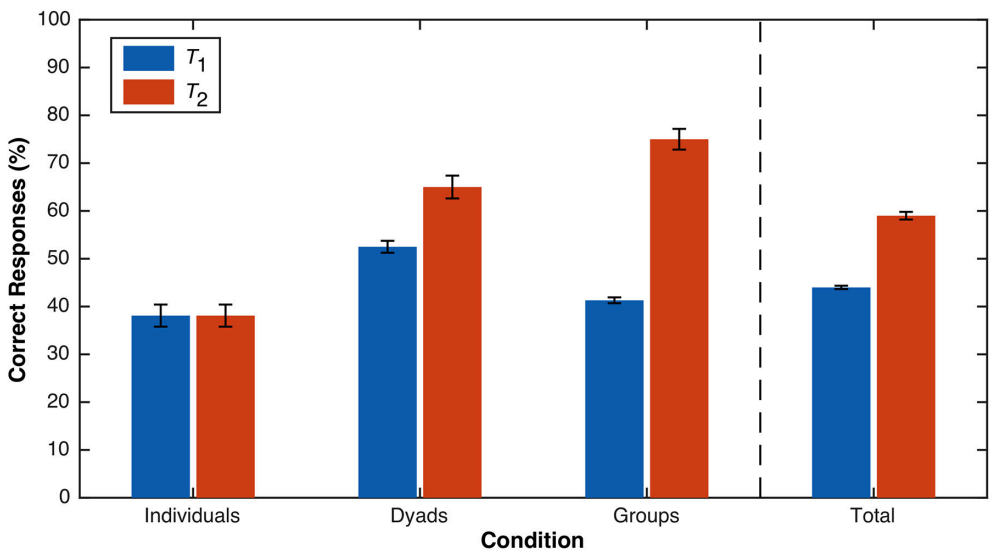



**FIGURE 5 |** Percentage of correct (Graph D) responses to the CST as a function of time ($T_1$ vs. $T_2$) and condition (individuals vs. dyads vs. groups). The bars for $T_1$ (and $T_2$ for the individuals condition) represent the percentage of correct individual responses, whereas the bars for the dyads and groups conditions at $T_2$ represent the proportion of correct dyad and group consensus decisions, respectively. Error bars represent standard errors.

(energy balance and inertia/delays) were not used by any of our participants, and therefore were not included here. Two of the new categories were simply the reverse of the categories identified by Sterman and Booth-Sweeney (2007): mass balance—incorrect (incorrect understandings of mass balance) and technology—reverse (technology will increase emissions, rather than enable emissions reduction). The final two categories, mathematical reasoning, and reasonableness of trajectories, were created by the authors on the basis of an analysis of participants' responses. In this paper, we only report on the five most popular strategies (technology, sink saturation, $CO_2$ fertilization, and technology—reverse were used by <3% of total participants and were therefore excluded from the current analysis).

**TABLE 1 |** The frequency (%) with which different reasoning strategies were adopted, as a function of Graph A, B, C, and D choices at $T_1$.

| Reasoning strategy and coding criteria | Example participant explanation | Graph A ($n = 37$) | Graph B ($n = 12$) | Graph C ($n = 30$) | Graph D ($n = 62$) | % of total |
|---|---|---|---|---|---|---|
| **Mass Balance (Correct)** Description indicating awareness of relationship between emissions and absorption flows and the stock of atmospheric $CO_2$; terms such as mass balance, accumulation, rate of change. | "It's a mass balance and rates of change situation. For the $CO_2$ concentration in the atmosphere to stabilize, you need the rates of emission and absorption to equal." "If emissions are greater than the absorption, the amount of $CO_2$ will increase. If the absorption is greater than the emissions, the amount of $CO_2$ will decrease." | 0.0 | 0.0 | 10.0 | 88.7 | 41.1 |
| **Mass Balance (Incorrect)** Description indicating awareness of relationship between emissions and absorption flows and the stock of atmospheric $CO_2$–but misunderstanding the nature of these relationships. | "In figure D, emissions ended up being the same as absorption, which causes the concentration reducing to 0." "If we keep the same difference between the rate of emission and absorption, the concentration will be the same." | 32.4 | 66.7 | 56.7 | 4.8 | 28.4 |
| **Pattern-Matching** Description mentioning correlations or similarity of behavior or patterns among emissions and atmospheric $CO_2$; indication that emissions should be proportional to changes in atmospheric $CO_2$. | "As I understand it, there is a direct relationship between $CO_2$ emissions and the atmospheric concentration." "If atmospheric concentration increases, that means that $CO_2$ emissions will also increase." "[Graph A] because it rises and then stabilizes." | 59.5 | 33.3 | 10.0 | 1.6 | 21.3 |
| **Mathematical Reasoning** Using algebraic equations, calculating ratios, or quantifying the absolute values of atmospheric concentration, emissions, and/or absorption. | "To achieve the quantity of 420 ppm, should have an increase of 20 ppm. The emission should be only 20% higher than the absorption." "The rate of ppm increase from 1990 to 2025 = 120 ppm/125 years = 0.96 ppm/ear. The ratio of GtC to ppm is around 4GtC = 1ppm." | 21.6 | 50.0 | 16.7 | 8.1 | 17.0 |
| **Reasonableness of Trajectories** Indicates belief that the correct trajectory should reflect business-as-usual or personal predictions about future emissions/absorption rates. | "…it would be too idealistic to imply that the change would be immediate and the decline would be as drastic as depicted in options B, C, and D" "With current pressures on countries by the UNFCCC for setting emission reduction targets, countries will take drastic measures to reduce their carbon emissions." | 21.6 | 33.3 | 20.0 | 6.5 | 15.6 |

*Reasoning strategy was inferred from participants' $T_1$ post-decision explanations. The first column lists the possible reasoning strategies, and the coding criteria for those strategies, whilst the second column gives example participant explanations that conform to each strategy. The third through sixth columns show the percentage of participants who chose Graph A, B, C, or D, respectively, and subsequently referenced each reasoning strategy. As any one explanation could refer to more than one reasoning strategy, the values in columns three through six may sum to >100%. The last column shows the percentage of total responses that referenced each reasoning strategy. Again, this sums to >100% because multiple strategies were possible. For inter-rater reliability information, see* ***Supplementary Materials****, Section Inter-Rater Reliability for Coding of Reasoning Strategies at $T_1$.*

The literature tends to attribute incorrect answers on the CST to the "pattern-matching" heuristic (e.g., Sterman and Booth-Sweeney, 2007; Sterman, 2008; Cronin et al., 2009). Pattern-matching was indeed the most popular reasoning strategy for participants who selected the typical pattern-matching graph of Graph A (**Figure 2A**). However, pattern-matching was not the most popular incorrect reasoning strategy overall. As shown in the last column of **Table 1**, across all responses, incorrect mass balance principles were applied more frequently than pattern-matching. "Mathematical reasoning" and "reasonableness of trajectories" were also common, especially for participants who chose Graph B. The popularity of these strategies suggests that errors on the CST are not exclusively caused by rash, heuristic decisions (i.e., pattern-matching)—even participants who used deliberate and effortful approaches (e.g., unsuccessfully trying to relate $CO_2$ emissions with $CO_2$ absorption, or calculating ratios) failed to reach the correct answer.

## Time 2

There was more heterogeneity in success rates across conditions at $T_2$ (orange bars; **Figure 5**), and the overall success rate of 59% was marginally higher than at $T_1$. The success rate for dyads (65.0%) did not differ significantly from that for individuals (38.1%) ($\chi^2_{df=1} = 2.97$, $p = .121$, two-sided) or groups (75.0%) ($\chi^2_{df=1} = 0.48$, $p = .731$, two-sided). However, the success rate for groups was significantly higher than for individuals ($\chi^2_{df=1} = 5.67$, $p = .028$, two-sided). A more diagnostic set of comparisons involves contrasting the difference in success rates between $T_1$ and $T_2$ for each condition, separately. For individuals, there was no change in success rates over time ($p = 1.00$, McNemar, two-sided). For dyads, the success rate of dyad consensus decisions at $T_2$ (65.0%) was numerically, but not significantly, higher than that of individual dyad member decisions at $T_1$ (52.5%) ($p = .125$, McNemar, two-sided). Recall that after dyads submitted their consensus decision at $T_2$,

individual dyad members were prompted for the answer they would have chosen, regardless of what the consensus decision was. Again, there was no difference in success rates between answers given by individual dyad members at $T_1$ and then at this post-test stage (both 52.5%) ($p = 1.00$, McNemar, two-sided). For groups, the success rate of group consensus decisions at $T_2$ (75.0%) was significantly higher than that of individual group member decisions at $T_1$ (41.3%) ($p < .001$, McNemar, two-sided). Furthermore, the success rate of individual group members' post-test answers (61.3%) was significantly higher than the success rate of individual group members at $T_1$ (41.3%) ($p = .002$, McNemar, two-sided). Thus, the group discussion reliably improved CST success rates, while the individual reflection and dyad discussion did not.

Analysing the content of $T_2$ reflections and discussions (in the same way as analyzing the content of $T_1$ explanations) sheds light on how groups derived their decision-making advantage over individuals. Despite explicit instructions to "approach this with a skeptical mind," "question your own assumptions," and "consider alternative arguments," 80% of participants in the individuals condition did not type anything during the 10-minute reflection period. Of 21 individuals, only one typed an alternative argument, and only three changed their answers at $T_2$. Individuals failed to self-reflect, thus preventing them from recognizing their answer was incorrect, or considering why a different answer may be correct. This is consistent with previous research characterizing individuals as "cognitively lazy" decision-makers who rarely challenge an answer that "feels" right (Trouche et al., 2015; Larrick, 2016).

By contrast, all groups entertained at least two reasoning strategies in their group discussions (except one group in which all group members selected Graph D at $T_1$). Group discussions contained a mean of 2.30 different reasoning strategies, compared to 1.15 for dyad discussions, and 0.24 for individual reflections ($\chi^2_{df=2} = 33.48$, $p < .001$, two-sided). Furthermore, we have tentative evidence that group members helped correct other members' faulty reasoning strategies. For example, in one group, one participant's misunderstanding of mass balance principles ("If emission rate gets close to absorption, concentration will decrease below 400[ppm]") was corrected by two other participants who explained the principle of accumulation ("…but when emissions is greater than absorption, then concentration will increase"). Groups were more likely than individuals ($\chi^2_{df=1} = 23.89$, $p < .001$, two-sided) and dyads ($\chi^2_{df=1} = 8.29$, $p = .010$, two-sided) to refer to the correct reasoning strategy of mass balance (even if no group member had referenced mass balance in their $T_1$ explanation). This supports previous findings showing that exposure to diverse perspectives motivates group members to critically evaluate all arguments (Trouche et al., 2015), thus increasing the likelihood that the correct decision will be discussed and judged to be correct (Schulz-Hardt et al., 2006).

The data seem to speak against—but do not rule out—the alternative explanation that groups only benefited from the increased probability of having one member who knew the correct answer. Eight individuals, 15 dyads, and 15 groups contained at least one member who chose Graph D at $T_1$. If the effect was due merely to the presence of a correct member, we would expect equal performance between dyads and groups, and also for dyads to outperform individuals at $T_2$ (which they did not, $\chi^2_{df=1} = 2.97$, $p = .121$, two-sided). Furthermore, two groups gave the correct consensus decision at $T_2$, despite having no members who gave the correct decision at $T_1$ (an example of "process gain," in which interpersonal interaction between multiple individuals yields an outcome better than that of any single individual, or even the sum of all individuals; Hackman and Morris, 1975).

We were also able to rule out effects of individual differences. Binary logistic regression analyses were conducted to determine whether the various individual difference variables measured at pre-test subsequently predicted performance on the CST at $T_1$. To satisfy the assumption of a dichotomous dependent variable, CST performance was coded as either incorrect (selecting Graphs A, B, or C) or correct (selecting Graph D). Age, actively open-minded thinking, and supporting the policy of "government regulation of $CO_2$ as a pollutant" were the only significant independent predictors ($p < .05$). These variables were subsequently combined into a set of predictors and subjected to a further binary logistic regression analysis. The full model was statistically significant compared to the constant-only model, $\chi^2_{df=3} = 21.47$, $p < .001$, Nagelkerke's $R^2 = 0.19$. Prediction accuracy was 61.9% (50.8% for correct responses, 70.5% for incorrect responses). Thus, the full model with these three predictors was barely above chance at predicting correct answers. This poor predictive performance is noteworthy in revealing that performance on the CST is largely immune to the influence of demographic, attitudinal, personality, and cognitive style variables.

Recall that the individual difference questions about climate change knowledge and attitudes were presented again at the post-test phase. CST performance was not significantly predictive of answers to any of these items. However, in light of the third aim of our study, it is worth discussing the answers to the policy preference question, "Which of these comes closest to your view on how we should address climate change?". At pre-test, 69.1% of participants answered "act-now," 30.9% answered "go-slow," and no participant selected the "wait-and-see" option. Excluding the wait-and-see option, answering the CST correctly did not significantly predict post-test responses ($\chi^2_{df=3} = 7.19$, $p = .066$, two-sided). However, there was an increase in the percentage of individuals who selected "act-now" from pre-test to post-test across all conditions (overall, 80.9% "act-now" at post-test).

## DISCUSSION

Repeated studies employing the CST reveal that individuals systematically underestimate the emissions reduction required to stabilize atmospheric $CO_2$ levels. So far, interventions to increase success rates on the CST have been individual-focused and largely ineffective. We sought to examine whether group reasoning could increase success rates on this task. It was predicted that success rates from $T_1$ to $T_2$ would (1) not increase for individuals,

(2) increase for dyads, and (3) increase for groups to a greater extent than for dyads. The first and third predictions were statistically supported, but there was only qualitative support for the second prediction. The 10-minute group discussions among four participants significantly improved success rates, whereas 10 minutes of individual reflection or dyad discussion did not. By analyzing individual justifications at $T_1$, and reflections and discussions at $T_2$, we found that groups benefited from exposure to multiple perspectives and the opportunity to communicate, which facilitated the falsification of incorrect reasoning strategies. We also found that incorrect reasoning strategies were numerous, and not limited to the oft-reported pattern-matching strategy. Lastly, we rejected two alternative explanations—groups did not improve merely due to a size advantage in the number of members who knew the correct response, nor were individual differences in demographics, climate change knowledge, personality, or cognitive style responsible for any given individual's CST success.

There are some potential limitations of the current study that merit consideration. Firstly, with a minimum of 20 cases in each condition as units for the statistical analysis, our experiment may have had insufficient statistical power to detect a significant improvement in success rates for dyads from $T_1$ to $T_2$. Using a larger sample size may reveal that the numerical, yet non-significant, increase in success rates observed with our dyad members reflects some real benefit of the dyad discussion. Secondly, the group advantage observed in the current study was obtained using a multiple-choice response format, which is different to the conventional CST procedure in which participants must sketch trajectories of emissions and absorption. It therefore remains open whether the results reported here would generalize to an experimental scenario employing this more complicated response format. It is possible, for example, that the uncharacteristically low rates of susceptibility to the pattern matching heuristic observed in the current study are an artifact of our unorthodox response format. Thus, we may expect higher initial rates of pattern-matching when returning to the original CST procedure, but it remains to be seen whether this would eliminate or attenuate the group advantage witnessed here. Thirdly, our intervention at $T_2$ in the dyad and group conditions afforded more than merely the opportunity for individuals to communicate with one another—participants were also afforded the chance to read the $T_1$ explanations of their dyad partner or group members. Although it is our conviction that the opportunity to engage in communication was instrumental to the group decision making advantage, we cannot preclude the possibility that mere exposure to the alternative perspectives of others may confer an advantage in itself, compared to individual reasoning alone. A group condition in which participants are exposed to their group members' $T_1$ decision explanations—without engaging in any subsequent discussion—would reveal whether mere exposure to multiple perspectives can produce a group benefit. Finally, we could not provide strong evidence for Sterman's (2008) argument that policy-makers' and citizens' deficient mental models of the climate system are responsible for complacent attitudes toward emissions reduction. Answers to the CST did not predict subsequent policy preferences. However, all participants in our sample believed that we must take action against climate change ("act-now" or "go-slow"), even before completing the CST. We were therefore unable to test the hypothesis that participants who answer the CST incorrectly also deny the need for emissions reduction ("wait-and-see"). However, the overall increase in "act-now" responses, relative to "go-slow" responses, from pre-test to post-test implies some diffuse benefit of merely completing the CST. Future studies employing a sample with more heterogeneous pre-existing policy beliefs will provide a stronger test for the hypothesized link between accurate mental models of the $CO_2$ system and support for urgent emissions reduction.

Given the abovementioned concerns about the generality of our results, one direction for future work is to determine whether and how our findings generalize to other stock-flow tasks, especially the original CST procedure, in which participants sketch trajectories of emissions and absorption by themselves. Furthermore, although we have shown a benefit on CST performance of reasoning in groups of four members, an additional avenue for future work will be to examine whether this advantage extends to larger groups. On the one hand, we might expect that increasing the number of group members will improve CST performance, because of an increase in information-processing capacity and diversity of perspectives (Cohen and Thompson, 2011; Charness and Sutter, 2012). On the other hand, we might expect that as the group size reaches some critical point, CST performance will begin to decline as the aforementioned benefits of group decision making will be outweighed by the costs of coordinating opinions and resolving disputes within the group (Orlitzky and Hirokawa, 2001; Lejarraga et al., 2014). Identifying the optimal group size for solving the CST will permit more robust recommendations about how group-based practices should be incorporated into the decision-making process.

In closing, we note that the final success rate of group consensus decisions at $T_2$ (75%) is considerably higher than the success rates previously reported with the CST. The success of our group-based intervention suggests that group-based decision-making may help facilitate the two-step implementation of effective emissions policy. First, crafting appropriate mitigation policy requires comprehensive and accurate decision-making, and our results suggest small groups are best-suited for this task. Second, rallying political and electoral support for such policy requires a well-informed population that comprehends the scale of the emissions problem. The general public presently endorses high levels of belief in anthropogenic climate change, but low levels of concern and urgency about climate change mitigation (Akter and Bennett, 2011; Reser et al., 2012). In order to bridge this gap between what the public believes about the climate change problem (that it is real and caused by human activities), and the solutions they are willing to support (immediate and significant emissions reduction), their mental models must be changed. Group-based programs, whether informal conversations about climate change or formal public education initiatives, could establish the correct mental model and help mobilize support for effective mitigation policy.

## ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the National Statement on Ethical Conduct in Human Research, Human Ethics Office at the University of Western Australia. The protocol was approved by the Human Ethics Office at the University of Western Australia. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

## AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design of the study. MH created the software for running the experiment and produced the figures for the paper. BX conducted the experimental sessions, performed the data analysis, and wrote the paper. MH and IW edited the paper and reviewed the results.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2018.02274/full#supplementary-material

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# When A+B < A: Cognitive Bias in Experts' Judgment of Environmental Impact

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When 'environmentally friendly' items are added to a set of conventional items, people report that the total set will have a lower environmental impact even though the actual impact increases. One hypothesis is that this "negative footprint illusion" arises because people, who are susceptible to the illusion, lack necessary knowledge of the item's actual environmental impact, perhaps coupled with a lack of mathematical skills. The study reported here addressed this hypothesis by recruiting participants ('experts') from a master's program in energy systems, who thus have bachelor degrees in energy-related fields including academic training in mathematics. They were asked to estimate the number of trees needed to compensate for the environmental burden of two sets of buildings: one set of 150 buildings with conventional energy ratings and one set including the same 150 buildings but also 50 'green' (energy-efficient) buildings. The experts reported that less trees were needed to compensate for the set with 150 conventional and 50 'green' buildings compared to the set with only the 150 conventional buildings. This negative footprint illusion was as large in magnitude for the experts as it was for a group of novices without academic training in energy-related fields. We conclude that people are not immune to the negative footprint illusion even when they have the knowledge necessary to make accurate judgments.

**Keywords: averaging bias, judgment, environmental impact, climate change, negative footprint illusion**

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## INTRODUCTION

Climate change is one of society's great challenges (American Psychological Association, 2008; Hansen et al., 2013). The scientific community agrees that human activity is to a large degree responsible for these changes (Oreskes, 2005), reinforced by a range of psychological phenomena including justification of environmentally irresponsible behavior with other credentials (Mazar and Zhong, 2010), compensatory green beliefs (Kaklamanou et al., 2015) and rebound effects (Chitnis et al., 2013). People travel for longer distances when driving a vehicle that uses a 'sustainable' energy source; they purchase 'organic' food as a means to be environmentally friendly without necessarily reducing other means of consumption; and those who deliberately change their behavior to more environmentally friendly in one area often start behaving environmentally irresponsible in another. Psychological science may not be able to stop climate change on its own (Gifford, 2011) but it can help identify why and how people's ability to make accurate environmental impact estimates of their actions is biased (Sörqvist, 2016). Drawing from previous research (Holmgren et al., 2018), this paper investigates whether the estimated environmental impact of a set of items is reduced

when "green" objects are added to the set—a negative footprint illusion. Specifically, the current study explores whether people are immune to this illusion when they have the necessary knowledge to make accurate estimates.

A large part of psychological research on erroneous ways of reasoning has concerned probability judgment. This research tradition has identified a large body of heuristics and biases that influence judgments and often lead to inaccuracies (Tversky and Kahneman, 1983; Gilovich et al., 2002; Isaac and Brough, 2014; Gigerenzer and Gaissmaier, 2015). Here, we apply these concepts and methods on the study of people's understanding of environmental impact. Past studies with similar ambitions have shown, for example, that people tend to rely on symbolically significant information (Sütterlin and Siegrist, 2014) or other irrelevant attributes such as object size (Cowen and Gatersleben, 2017) while neglecting other more important information when judging energy use. People also have difficulty understanding the stock-flow relationship of the $CO_2$ accumulation in the atmosphere (Newell et al., 2016); and they believe that environmentally friendly actions and choices can compensate for less sustainable behaviors (Kaklamanou et al., 2015). The latter of these conceptions is called 'compensatory green beliefs' and may be one of the reasons for negative spillover of pro-environmental behavior. Negative spillover occurs when "one pro-environmental behavior decreases the likelihood of additional pro-environmental behavior" (Truelove et al., 2014, p. 128). For example, fuel efficiency is associated with increased driving distance (Matiaske et al., 2012), the presence of a recycling bin increases paper use compared to a control condition (Catlin and Wang, 2012), and car owners of more environmentally friendly cars drive more unethically compared to conventional car owners (Norton, 2012). These negative spillover effects can be linked to moral licensing whereby people justify immoral behavior by establishing moral credentials (Mazar and Zhong, 2010). One possible explanation for this phenomenon – as proposed by Sachdeva et al. (2009) – is that moral behavior is inherently costly for the individual; hence they use moral licensing to get back to a more comfortable state—that is, a regression to the individual average of the 'moral currency.'

Compensatory green beliefs are often associated with behavior; the idea that the benefits of some behaviors can compensate the costs of other behaviors. A similar phenomenon has also been found in people's tendency to think about the costs and benefits of objects. Holmgren et al. (2018) showed that people's estimates of the environmental impact of a set of conventional buildings are higher, compared to a set containing the same number of conventional buildings in addition to a number of "green" (energy efficient) buildings, as if the benefits of the "green" buildings compensate for some of the costs of the conventional buildings. Experimental evidence suggests that an averaging process underpins this "negative footprint illusion," by which people base their estimates on the average rather than the sum of the items in the set. We argue that this averaging process is responsible for people's tendency to think that the addition of environmentally friendly objects compensates for the negative impact of less friendly objects (Holmgren et al., 2018). Further, we assume that the averaging bias has its roots in a balancing heuristic shaped by natural selection to handled social exchange between people (Sörqvist and Langeborg, unpublished). The balancing heuristic is arguably designed to calculate the moral balance in interpersonal relationships and works well when applied to the problem it was designed to solve, but the same principle leads to inaccuracies when applied to estimate the environmental impact of objects and actions.

A negative footprint illusion has also been found in other contexts. Gorissen and Weijters (2016) demonstrated the effect in three experiments on estimates of the environmental impact of food products. In one of their experiments, people rated a hamburger together with an organic apple as having a lower carbon footprint (i.e., environmental impact) compared to the hamburger alone. Collectively, the studies on the negative footprint illusion suggest that the effect influences estimates generally and is not paradigm specific. It should be noted though, that the effect has thus far only been found in between-participants designs in which one group of participants make the environmental impact estimates of the set with regular items and another group of participants make the estimates of the set with regular and "green" items. The illusion has not been shown in within-participant designs where the same participants make estimates of both sets and thus can compare their own estimates of the two. Finding a negative footprint illusion in a within-participant design is both theoretically and methodologically relevant, however, because it would suggest that people are not immune to the illusion when they compare their estimates and, furthermore, such a design can be used to efficiently and reliably analyze individual differences in susceptibility to the illusion.

Another question relating to generalizability is whether expertise modulates the negative footprint illusion. One hypothesis is that the negative footprint illusion arises because people who are susceptible to the illusion lack necessary knowledge of the item's actual environmental impact, perhaps in combination with a lack of mathematical skills. Thus, people who are used to approaching problems with mathematical tools, and have an understanding of the item's actual environmental impact that goes beyond the layperson's, might be less likely to fall prey to the influence of the balancing heuristic, and instead more accurately arrive at the sum of the environmental impact of the items rather than their average. By definition, experts often outperform novices (e.g., Ericsson and Lehmann, 1996). This is typically also the case in the context of judgment and decision-making (Spence and Brucks, 1997; Kuusela et al., 1998) and consequently people often trust experts in making high quality decisions and many let experts make choices for them, for example allowing them to handle their stock-portfolios and funds. However, there are cases where training and practice does not lead to better performance. Research has demonstrated that recognition based portfolios (i.e., the set of most-recognized options) outperform portfolios managed by stock-experts (Ortmann et al., 2008). Correspondingly, there is a large body of research suggesting that experts are little, if at all, better than novices at making accurate judgments. For example, experts as well as novices are susceptible to violations of the conjunction rule (i.e., $A < A+B$; Tversky and Kahneman, 1983), and experts

are good at identifying components necessary for accurate judgments but are poor at combining those components (Newell et al., 2015).

The purpose of the present paper was to investigate whether expertise modulates the magnitude of the negative footprint illusion. To this end, energy systems graduate students—with academic degrees in energy-related fields and academic training in mathematics—were recruited as participants and asked to estimate the environmental impact of buildings with varying energy ratings. Thus, "experts" in the current context refers to people with the necessary knowledge and training in energy systems engineering and its relationship to environmental impact. To further explore the generalizability of the negative footprint illusion, the study was also designed to challenge the hypothesis that the effect disappears when people are able to compare the two sets of to-be-estimated objects (i.e., in a within-participants design). We implemented a new judgmental dimension. Instead of requesting participants to estimate the 'carbon footprint' of the two sets, one set with only conventional items (A) and another set with an addition of "green" items (A+B), the participants of the current study were asked how many trees would be necessary to compensate for the two sets' greenhouse gas emissions due to energy use. We hypothesized that the participants would estimate that more trees are necessary to compensate for a set of conventional buildings (A) in comparison with a set of conventional and "green" buildings (A+B), as they would erroneously think that $A + B < A$.

# MATERIALS AND METHODS

## Participants

A total of 55 participants (42% women), 22 energy system graduates (henceforth called experts) and 33 undergraduate students at the University of Gävle without formal education in environmental issues or energy engineering (henceforth called novices) participated in the experiment (mean age = 27.58, *SD* = 6.18). The study was conducted in accordance with the declaration of Helsinki and the ethical guidelines given by the American Psychological Association. All participants were adults and participated with informed consent. The participants signed an information agreement form. The study did not treat sensitive personal data, did not entail a physical intervention or methods with the purpose of affecting a research person, the data collection did not include apparent risk of injury, and no data could or can be traced to individual persons. Because of this, no external ethical review was requested for the study reported here in accordance with Swedish law.

## Materials

A questionnaire was used to obtain data. On the first page of the questionnaire, participants were told that they were about to make two evaluations and were asked to carefully read the information before making the evaluations. In one condition, the participants viewed an abstract representation of a suburb consisting of 150 'conventional' buildings with appurtenant energy efficiency ratings, and they were told that all units had the same materials and performance characteristics. In the other condition, the participants viewed an identical suburb, with the exception that another 50 'green' (i.e., environmentally certified) buildings with appurtenant energy efficiency ratings were also present (i.e., a total of 200 buildings). For each condition, the participants were given the following information before making the evaluation: *"Energy use is linked to greenhouse gas (GHG) emissions, which in turn are harmful for the environment. For example, assume for every unit of electrical energy used and for every unit of residential heat used, a certain amount of $CO_2$ is produced. A transportation company based in Örebro, has introduced an environmental compensation policy, that is, if one of their cars covers 33,000 km, the company will plant 50 trees. Planted trees absorb $CO_2$ for many years, and can therefore compensate for the negative environmental consequences of increased energy use."* They were then asked to estimate how many trees on a scale from 1 to 100 each suburb needed to compensate for their monthly energy use. The two conditions were counterbalanced between participants.

## Design and Procedure

A within-between mixed participants design was used with two independent variables. One independent variable was 'suburb type,' manipulated within participants in two conditions: 150 conventional buildings (henceforth called the 'conventional condition') vs. 150 conventional buildings with an addition of 50 "green" buildings (henceforth called the 'green addition condition'). The order between the two suburb types was counterbalanced between participants. More specifically, half of the participants were randomly assigned to begin with the green addition condition and the other half were assigned to begin with the conventional condition. The other independent variable was 'group type': 33 participants belonged to the novice group, whereas 22 participants belonged to the experts group.

# RESULTS

As can be seen in **Figure 1**, both the experts and the novices reported that fewer trees were needed for the suburb with 'conventional' and 'green' buildings compared to the condition with only the 'conventional' buildings. This was confirmed by a 2 (suburb type: conventional condition vs. green addition condition) × 2 (group type: novices vs. experts) mixed analysis of variance, which revealed a main effect of suburb type, $F(1,53) = 10.27$, $p = 0.002$, $\eta_p^2 = 0.16$. The analysis did not reveal a significant interaction, $F(1,53) = 0.31$, $p = 0.582$, $\eta_p^2 = 0.01$, nor a main effect of group, $F(1,53) = 2.97$, $p = 0.091$, $\eta_p^2 = 0.05$, showing that experts and novices responded similarly.

Because this conclusion rests on a null-hypothesis, we also report the Bayesian factors (BFs) for the effects. The BF01 for the main effect of suburb type was 0.057, $p(H0|D) = 0.053$, $p(H1|D) = 0.946$, which is regarded as positive evidence of the alternative hypothesis (Masson, 2011). The BF01 for the interaction was 6.32, $p(H0|D) = 0.863$, $p(H1|D) = 0.137$, positive evidence for the null hypothesis, and the BF01 for the main effect of group was 1.01, $p(H0|D) = 0.623$, $p(H1|D) = 0.377$, weak

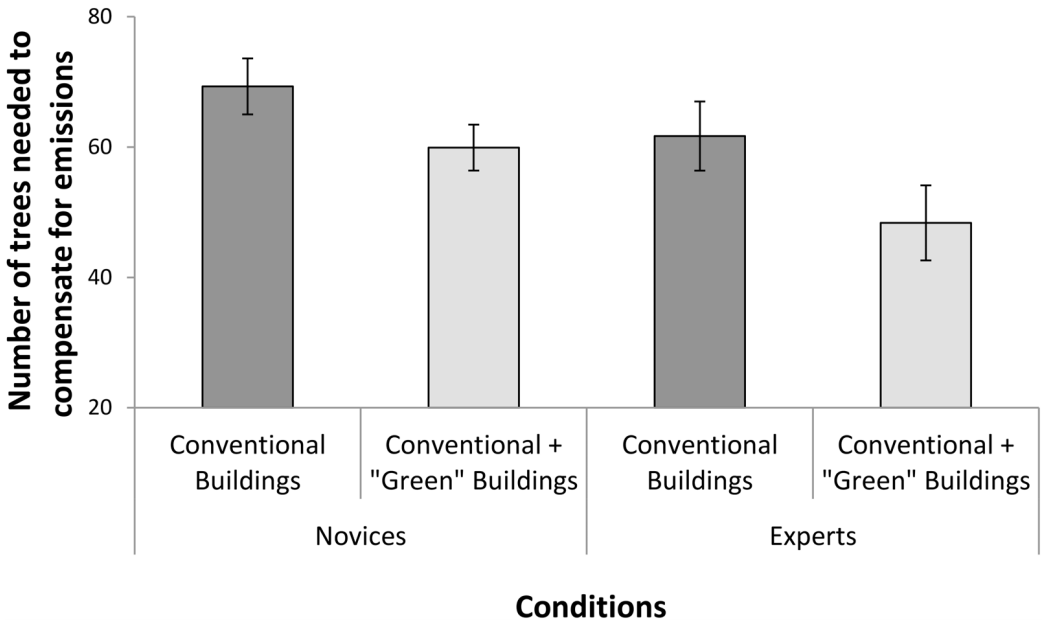


**FIGURE 1 |** Experts' (energy system graduates) and novices' estimates of how many trees are needed to compensate for the energy use of a community with 150 'conventional' buildings and a community with 150 'conventional' and 50 'green' buildings. Estimates appear to be underpinned by an averaging bias by which people believe that the addition of more 'environmentally friendly' objects compensates for the negative impact of less friendly objects. Error bars represent standard error of means.

evidence for the null hypothesis. The Bayesian analyses reinforce the conclusion that experts were susceptible to the negative footprint illusion and to a degree similar to that of novices.

## DISCUSSION

The present study shows that when energy-efficient buildings are added to a set of less energy-efficient buildings, the estimated environmental impact of the total set is *reduced* rather than *increased*. The results revealed a highly reliable manifestation of this illusion with no difference between novices and experts. Because of this, we conclude that people can be susceptible to the negative footprint illusion even when they have sufficient mathematical skills and knowledge of the items' environmental impact. Moreover, the present study also suggests that the illusion can survive when people are able to compare the two to-be-evaluated sets and generalizes to judgment dimensions other than carbon footprint estimates (Gorissen and Weijters, 2016; Holmgren et al., 2018).

While level of expertise made no difference to the negative footprint illusion reported here, it should, however, be mentioned that there are research domains within which experts indeed outperform novices at making accurate decisions (Spence and Brucks, 1997; Kuusela et al., 1998). A group of energy system graduates were chosen as experts in this particular experiment, because the estimates they were asked to make concerned compensation for buildings' energy use. In contrast to novices, energy system graduates had expert knowledge of this issue. Furthermore, this group of 'graduate students' should be viewed as experts in contrast to the group of novices with regards to buildings energy systems and environmental assessments because these subjects are extensively covered in the course work of their graduate program. The 'experts' in the current study are not necessarily representative of energy-system researchers or others with extensive experience of the energy profession, who perhaps more justly could be called "true" experts in the field. However, we conclude that the negative footprint illusion is seemingly resilient to some levels of expertise, including university training in mathematics and at least to a basic understanding of the to-be-estimated objects' actual environmental impact.

A possible explanation of the negative footprint illusion, based on previous research (Holmgren et al., 2018), is that the effect is underpinned by an averaging process. Rather than basing their estimates of the environmental impact of a category of items on the sum of A and B (which would be more accurate), people appear to base their estimates on the average of A and B. The estimator calculates (probably unconsciously) the average of the items in the set, whereby the "green" objects in the set contribute to the average with lower values, whereas the conventional objects contribute with higher values. The environmental impact estimate that results from this process follows a principle that can be expressed as $A + B < A$, whereby A are conventional items and B are environmentally friendly items. This erroneous way of reasoning has been termed "the averaging bias" (Holmgren et al., 2018) and could be responsible for people's false belief that "green" objects actually benefit the environment when in fact they are simply 'less bad' than their conventional counterparts. On this view, an alternative explanation of the negative footprint illusion is that participants more simply assess the sum of conventional

items and "green" items as A – B, where conventional items are viewed as 'bad' for the environment and "green" items as 'good' (or beneficial) to the environment. However, past research shows that people assess "green" items as environmentally harmful, but to a lesser degree than conventional items, why the averaging explanation of the negative footprint illusion appears to be more likely.

Our supposition is that the averaging bias may pervade many contexts and behavioral settings wherein people explicitly and implicitly evaluate a mixture of objects and actions, such as choosing consumer goods and estimating the health of food products (Chernev and Gal, 2010) and the benefits of emission cuts (Lewandowsky, 2016). The averaging bias may also underpin the belief that undertaking environmentally friendly actions can compensate for less friendly ones (Kaklamanou et al., 2015).

## Applied Implications

This study – which suggests that the illusion manifests also when people are able to compare the two to-be-evaluated sets – strengthens the case that this effect can have negative consequences for the environment when people make environment-related decisions. For example, consumers may choose to purchase eco-labeled food products as a way to compensate for buying conventional products, with the intention to decrease the environmental impact of their consumer behavior, when they are – in fact – increasing the burden by adding more products regardless of the eco-label. This stresses the need to find methods that can limit the tendency to base impact estimates on the average of conventional products and "green" products (**?**).

Another real world situation in which the negative footprint illusion can have negative consequences for the environment concerns management decision-making, for example in the context of urban planning. If experts within disciplines that have a direct influence on environmental management – implicitly or explicitly – think "green" buildings have the ability to decrease the carbon footprint of a community (as this study suggests), then it is essential to reconsider how "green" buildings are portrayed in various discourses. The way that "green" buildings appear to be represented in people's minds at present could lead decision makers and policy makers to promote the construction of "green" buildings for the wrong reasons, believing that the "green" buildings will reduce the environmental burden of a community rather than adding further to it.

## AUTHOR CONTRIBUTIONS

MH, AK, and PS generated the idea and study design. MH and AK collected and analyzed the data. MH, AK, JM, and PS wrote the paper.

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# Why People Harm the Environment Although They Try to Treat It Well: An Evolutionary-Cognitive Perspective on Climate Compensation

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Anthropogenic climate changes stress the importance of understanding why people harm the environment despite their attempts to behave in climate friendly ways. This paper argues that one reason behind why people do this is that people apply heuristics, originally shaped to handle social exchange, on the issues of environmental impact. Reciprocity and balance in social relations have been fundamental to social cooperation, and thus to survival, and therefore the human brain has become specialized by natural selection to compute and seek this balance. When the same reasoning is applied to environment-related behaviors, people tend to think in terms of a balance between "environmentally friendly" and "harmful" behaviors, and to morally account for the average of these components rather than the sum. This balancing heuristic leads to compensatory green beliefs and negative footprint illusions—the misconceptions that "green" choices can compensate for unsustainable ones. "Eco-guilt" from imbalance in the moral environmental account may promote pro-environmental acts, but also acts that are seemingly pro-environmental but in reality more harmful than doing nothing at all. Strategies for handling problems caused by this cognitive insufficiency are discussed.

**Keywords: climate change, moral accounting, balancing heuristic, natural selection, compensatory green beliefs, negative footprint illusion, evolutionary-cognitive perspective**

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## INTRODUCTION

The environmental impact of one's own behavior is difficult to grasp, partly because issues related to climate change are perceived as psychologically distant (cf. Spence et al., 2012). When people try to act in environmentally friendly ways, they often in fact do further harm to the environment. They might purchase some extra groceries because the groceries are "eco-labeled"; think that they can justify taking the airplane abroad for vacation because they have been taking the bicycle to work; and think that they can skip recycling their waste because they started having meat-free Mondays. Entire economic systems have been built on the same principle. Companies, private persons, and even nations, trade carbon offsets within the European Union Emission Trading Scheme, whereby they compensate emission rates with financial means. Although interventions in developing countries create some climate gains from the system, the system may also license irresponsible behavior for people prepared to pay for it. Ideas associated with "climate compensation" (e.g., planting trees, trading emission rates or supporting green

projects to compensate for environmentally harmful behavior) can hence be found in the context of both local and global decision making. The purpose of the present paper is to outline a theoretical perspective on the evolutionary basis of the psychology that underpins attempts to compensate for unsustainable behavior.

## THE EVOLUTIONARY BASIS OF HUMAN COGNITION

From an evolutionary psychology perspective, the mind can be seen as a collection of evolved adaptations; people think and behave the way they do because it has given them advantages in the process of natural selection. It is assumed that the human brain structure has been shaped by evolution, which in turn influences human cognition. One such example is hemispheric lateralization, whereby it is easier for most people to perceive speech that enters the right ear (Tervaniemi and Hugdahl, 2003).

The evolutionary perspective also assumes that evolution has shaped specific, recurring thought-patterns or mental heuristics within the human mind. A heuristic is a mental tool or guiding rule, designed to solve a specific goal (Gigerenzer, 2001). An example of such an adaptive heuristic is "availability" (Tversky and Kahneman, 1974); the tendency to think that an occurrence (e.g., a natural disaster) is more likely to happen when the memory of such an occurrence is easily accessible (as after recent reports of an earthquake on the news). Another example is "anchoring"; the tendency for estimates (e.g., of future global temperatures) to fall relatively close to available anchor points (e.g., a proposed future global temperature suggested by someone else; Joireman et al., 2010). Heuristics make information processing and decision-making fast, frugal and computationally inexpensive. They are also largely successful when applied to the type of problem they are supposed to solve. When the human brain confronts a task it is not well adapted to, however, it applies heuristics designed for other purposes. This mismatch often results in erroneous thinking (Gilovich et al., 2002), such as people being more likely to believe in global warming on hot days (Zaval et al., 2014).

## AN EVOLUTIONARY-COGNITIVE PERSPECTIVE ON SUSTAINABLE BEHAVIOR

Evolutionarily speaking, problems associated with climate change and the environmental impact of one's own behavior are novel. Moreover, the relationship between behavior and consequence in the context of climate change and environmental impact is unclear because of the large temporal and geographical distances. Because of this, people are not adapted to the challenges of climate change (Griskevicius et al., 2012), and consequently there are plenty of evolutionary adaptions and cognitive heuristics which influence the way people fail to understand human-environmental interactions accurately (Gifford, 2011; van Vugt et al., 2014; Lewandowsky, 2016; Sörqvist, 2016). Hence, unsustainable behavior often has an evolutionary basis (Griskevicius et al., 2012; van Vugt et al., 2014). For example, people tend to value personal over collective rewards. Environmental problems are often global problems that have to be dealt with through collaboration, but this collaboration is difficult as long as people must give up personal gain in favor of collective rewards. Similarly, people tend to prefer immediate over delayed rewards, which inhibits the transformation to a more sustainable lifestyle among the general public, since the temporal distance between our behavior today and future environmental gains is stretched over generations.

There are also cognitive biases specifically associated with group processes and social behavior (Engler et al., 2018). The sustainability effects of these group biases may outweigh biases on an individual level. For example, people tend to favor their own group over other groups (i.e., the in-group/out-group bias). In view of this global and international nature of climate change issues, the tendency to favor one's own group may prevent acceptance of policies that constrain people who belong to one's in-group in favor of people in the out-group. With this in mind, we now turn to the evolutionary basis for the (often misdirected or futile) attempts to compensate for environmentally negative behavior.

### An Evolutionary-Cognitive Perspective on Attempts to Compensate for Unsustainable Behavior

Problems associated with social interaction and various forms of social exchange have been particularly important to master for successful adaptation. Consequently, rules governing social exchange has shaped human cognition, heuristics, biases, and reasoning abilities (Cosmides, 1989; Tooby and Cosmides, 1996; Hoffman et al., 1998; Kiyonari et al., 2000; Yamagishi et al., 2007; Cosmides et al., 2010). One aspect that might be particularly important, for our purpose here, is the rules governing the balance between giving and receiving favors. People expect reciprocity in interpersonal relationships – when they give something, they generally expect something in return, and when they get something they feel obliged to return the favor. Lack of balance in give-and-receive transactions of a relationship makes people sad and compromises health and wellbeing (Buunk and Schaufeli, 1999). Neglecting the balance in a relationship by receiving more than one gives can lead to shame and guilt, and giving more than one receives can lead to anger. However, the balance can be restored when the one in debt do what is necessary to compensate for past transgressions (Xu et al., 2011).

Because of the importance of social exchange during human evolution, natural selection has shaped human cognition to compute and seek balance in social exchange efficiently. Specifically, natural selection has made this kind of moral accounting important, and formed a balancing heuristic that simplifies cognition concerning interpersonal cooperation by calculating the balance in social transactions. This balancing heuristic still influences the way people think today. For example, people often take action to maintain balance between "good" and "bad" deeds – actions that can be observed in human moral

decision-making (Sachdeva et al., 2009). Morally righteous and unrighteous decisions appear to be mentally accounted for as if they balance each other out. For example, prior good deeds can "license" latter choices of a more self-indulgent character (Khan and Dhar, 2006).

Moral accounting and balance seeking behavior not only apply to social relationships, they seem to apply to environmental issues as well. Some people are more likely to cheat and steal after purchasing "eco-friendly" products (Mazar and Zhong, 2010), probably because they feel licensed to do so since they morally account the "eco-friendly" choice as a "good" deed. Moral licensing has also been observed in the context of cooperation for the good of the environment (Sachdeva et al., 2009). When people are reminded of deeds they have done that they know were harmful to the environment, they might be left with a feeling of "eco-guilt" (Mallett, 2012). People who experience eco-guilt seek pro-environmental actions to compensate for this guilt and restore balance. In their search for such a balance, people are inclined to believe in "quick-fixes," because they want to re-establish the moral balance and escape the guilt as quickly and easily as possible. In the same way that cognitive dissonance may make people change their attitudes to reduce inconsistencies between attitudes and behavior, people may also change their evaluation of past environmentally burdening behaviors and future environmentally friendly behaviors to restore the balance in their relationship with the environment. For instance, people are more likely to sign a petition addressing environmental issues after viewing evidence of human-caused environmental damage (Rees et al., 2015). Hence, the balancing heuristic of the moral accounting seems to have been generalized to human-climate interactions although such interactions are evolutionary novel.

In social exchange, allowing give-and-take transactions to balance each other out works well to maintain well-functioning cooperation. However, the same balancing rule is not appropriate to apply to "environmentally friendly" and "harmful" behavior. When people experience a negative imbalance from having done something harmful to the environment, they may actively seek an opportunity to do something good for the environment to restore the balance. However, the environment is a complex system of processes that does not respond like a person in a reciprocal relationship. Also, and foremost, environmentally harmful behavior can neither be compensated for, restored nor undone. While the tension in a relationship, caused by a harmful action to another person, can be restored by compensation without leaving permanent changes in either person, harmful actions on the environment have permanent consequences. Flying adds to an individual's total environmental burden, no matter how many meat free Mondays that individual has. Still, "compensatory green beliefs" are widespread in the general population (Kaklamanou et al., 2015). The balancing heuristic may make people purchase more "eco-labeled" food in order to do something good for the environment, but the best thing for the environment would of course be to consume less overall. Consuming more of something is never the best way to reduce one's own environmental impact, even if the produce is marketed as "environmentally friendly." In the same spirit, attempts to cancel the guilt from "harmful" deeds, by avoiding taking too hot showers, or driving vehicles that run on "sustainable fuel" might make people feel good about themselves. However, the behavior can cause even more harm to the environment, if showers instead go on for longer and people take the car to work more often (cf. rebound effects; Chitnis et al., 2013).

The balancing heuristic is not only applied when people reason about their own behavior and choices – it also generalizes to items and objects. When so-called "environmentally friendly" items are added to a set of "conventional" items, people believe the environmental impact of the whole set is reduced. For instance, people intuitively think the environmental burden of a hamburger and an "organic" apple in combination is lower than the environmental burden of the hamburger alone (Gorissen and Weijters, 2016). People mentally account for the "environmentally friendly" and the more "harmful" objects as if the objects balance each other out rather than sum up together (Holmgren et al., 2018a,b). This averaging principle leads to quantity insensitivity with regard to the amount of "environmentally friendly" objects in the set. For example, people tend to think that the environmental burden of a car pool remains the same when hybrid cars are added to the pool, as if numbers do not matter as long as the cars are seemingly friendly to the environment (Kim and Schuldt, 2018). One interpretation of this is that the balancing heuristic makes people think that the climate friendlier objects compensate for the more harmful ones, in the same manner as it does for evaluations of people's own deeds.

## Interventions to Overcome the Sustainability Problems That Follow From the Balancing Heuristic

The complexity of the problem is too large for people to understand the effect of their consumer choices, traveling behavior, recycling efforts, and lifestyles on climatic change. Without access to more detailed information, such as life cycle analyses of the products in the grocery stores for instance, people apply the balancing heuristic to guide intuitive judgments and decision-making toward what they think is an overall averaged environmentally friendly behavior. People who experience guilt, from environmentally questionable behavior, will seek what they think are sustainable behaviors as an instrument for restoring moral balance. The balancing heuristic may lead people into believing that the more they do of something "environmentally righteous," the more environmentally friendly they are—since they build up their moral account (cf. Sachdeva et al., 2009). However, although buying a bundle of eco-labeled bananas is better for the environment than buying the same amount of conventionally grown bananas, it is worse than not buying any bananas at all.

One way to help people make more sustainable decisions on the individual level would be to give consumers feedback on the carbon footprint of the wares they are about to purchase, for example by taking advantage of self-scanning systems, where customers scan their products themselves before paying for them. In addition to the accumulated price with each product, the system could also provide the customers with an accumulated carbon footprint estimate of their wares. That way, the costumers

receives immediate feedback saying that "eco-labeled" products do not reduce but add to the accumulated carbon footprint of what they are buying. Giving direct and concrete feedback about the effect of consumer choices can work in an informational way as well as in a way that nudges people to make better choices (Linder et al., 2018). Simple aspects of the design of public places, like a paper towel dispenser that shows a green map of Africa, which slowly fades away for each towel dispended, can affect the choice architecture and thus promote environmentally friendly behavior.

Another approach would be to run information campaigns that make people aware of the misleading concepts of "climate compensation" and "environmentally friendly." The balancing heuristic makes people susceptible to the influence of media communication and policymaking that tell people how to behave (Leiserowitz, 2006; Moser, 2009) and to marketing devices such as "moral labeling" (de Pelsmacker et al., 2005; Yiridoe et al., 2005). Words such as "environmentally friendly," "eco-friendly" and "ecological" run the risk of establishing a public view that objects, behaviors and decisions with these labels are "good" rather than "less bad" for the environment (Holmgren et al., 2018b).

To overcome the balancing heuristic as a cognitive barrier to sustainability, we need to make people deal with the source of the problem instead of seeking ways to compensate for it, in part through education and information campaigns. The cognitive barriers are sometimes hard to break down, however, because people are not prepared to spare what is needed to deal with the source of the problem. Population growth is one of the major driving forces of future climatic change and legislations to prevent population growth would mitigate climatic changes, but such legislations are likely to be met with both ethical, political, and religious arguments (cf. van Vugt et al., 2014).

Being eager to avoid environmental imbalance and eco-guilt may not only make people ready to believe in environmental "quick-fixes." Importantly, it may also affect people's readiness to perceive an imbalance, or guilt, in the first place. Realizing the environmental impact of one's own behavior is challenging, as much emotionally as cognitively. The "ostrich effect" – the tendency to selectively reject available inconvenient information, for example by ignoring the environmental impact of one's own behavior, is a way of avoiding guilt and moral imbalance in the first place. This tendency makes it important to inform the public about the climate changes in the right way – to stress the severity of the problem enough to make people understand the problem, but not so much that it makes people reject the information.

The behavioral patterns that follow from the balancing heuristic influence decisions not only on the individual level but also on macro levels. Nations may justify weaponry exports to dictatorships by also enacting climate-change alleviation interventions in the third world. Companies license their carbon emissions by buying carbon offsets while also building customer loyalty and market their brand as "environmentally responsible." Restaurants serving nothing but red meat may market themselves as "100% climate compensated" which attracts customers who wish to eat hamburgers without experiencing eco-guilt. A sharpened legislation of marketing of products, choices, as well as economic devices for emission regulation as if they are "environmentally friendly" alternatives, is necessary to deal with this problem. The present jurisdiction governing these devices do not fully consider their psychological consequences. Calling a hamburger restaurant "100% climate compensated," for example, may deceive people into believing that eating dinner at that restaurant has no environmental burden. Also, things that are gentle for the closest environment (like organically produced meat) are not necessary gentle on the climate, which calls for more precise climate related labeling of products. A stricter legislation of marketing devices and an obligatory carbon footprint estimate of products could be one way to better guide people's behavior (cf. Steiner et al., 2017), companies and nations away from environmentally harmful behavior they do when they try to do good for the environment.

## CONCLUSION

The proposed framework in this paper suggests that several examples of unsustainable behavior and effects (negative footprint illusions, rebound effects, compensatory green beliefs, quantity insensitivity, etc.) have their roots in mental heuristics shaped by natural selection to handle social exchange. We have tried to show how moral accounting and the balancing heuristic, apparently present in social exchange processes, can explain how people and decision makers think and act in response to environmental and climatic change issues, as well as to marketing devices, pro-environmental political policies and economic systems that involve the idea of "climate compensation." Specifically, a reason why people sometimes harm the environment although they try to do good, is that the balancing heuristic makes them believe "environmentally friendly" behavior can compensate for unsustainable behavior. The strategies proposed can hopefully help toward reducing the negative effects of this inherited cognitive handicap.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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# Regulating Emotional Responses to Climate Change – A Construal Level Perspective

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This experimental study ($N$ = 139) examines the role of emotions in climate change risk communication. Drawing on Construal Level Theory, we tested how abstract vs. concrete descriptions of climate threat affect basic and self-conscious emotions and three emotion regulation strategies: changing oneself, repairing the situation and distancing oneself. In a 2 × 2 between subjects factorial design, climate change consequences were described as concrete/abstract and depicted as spatially proximate/distant. Results showed that, as hypothesized, increased self-conscious emotions mediate overall positive effects of abstract description on self-change and repair attempts. Unexpectedly and independent of any emotional process, a concrete description of a spatially distant consequence is shown to directly increase self-change and repair attempts, while it has no such effects when the consequence is spatially proximate. "Concretizing the remote" might refer to a potentially effective strategy for overcoming spatial distance barriers and motivating mitigating behavior.

**Keywords: Construal Level Theory, spatial distance, climate change, risk communication, emotions, emotion-regulation strategies**

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## INTRODUCTION

There is scientific consensus that anthropogenic climate change is an urgent threat to our planet. Nevertheless, public perceptions remain ambivalent and people continuously fail to take necessary measures to mitigate the negative consequences (O'Neill and Whitmarsh, 2009). In order to reach the goal set out by the UN of limiting mean temperature rise to 2°C (United Nations, 2015), both the global and immediate nature of climate change must be communicated in a way that is personally engaging and motivates behavior change. But how do we communicate a risk that most people simultaneously perceive as both alarmingly present and yet elusively distant? Climate change risk communication is often based on the notion that making climate change appear more proximal in space and time would increase risk perception, involvement, and mitigating actions (Jones et al., 2016). However, recent research has suggested that simply communicating risks of climate change as geographically closer might not in itself increase such actions. Rather, it seems to alter what information guides decision-making (Brügger et al., 2016). Some risks may in fact also be unique to or more severe at spatially distant places and, thus, could not easily be brought to feel closer. New effective ways of communicating climate threat are therefore much called for.

In the present research, we aim to compare different types of risk communication messages, and suggest that emotion mediates readiness to act against climate change threat,

succeeding different descriptions of this threat. Using Construal Level Theory (Liberman and Trope, 2003; Trope and Liberman, 2010) as theoretical framework, an experiment was conducted to test whether and how varying the abstractness of descriptions of climate change consequences, e.g., describing consequences as a heat wave or increase in mean temperature, influence emotional responses and motivation to mitigating action across short and long spatial distances to these consequences. This approach could increase our understanding of what makes risk communication and policy making successful.

## Construal Level Theory and Climate Change

Construal Level Theory (CLT) states that objects, events, and constructs (e.g., consequences of climate change) can be thought of in more or less abstract terms depending on the psychological distance to them. In brief, the further away something is perceived to be from ones immediate experience, the more abstract the construct or event will be perceived as, i.e., we say that the *construal* of the event is abstract. Four types of psychological distances have been proposed: temporal, social, hypothetical, and spatial (Trope and Liberman, 2010), of which the latter is focused on in the present research. Specifically, an event that takes place geographically far away should make us perceive and process it in a more abstract and general way, i.e., the event is construed at a high level. Conversely, an event that is geographically close to us should give rise to a concrete and context-dependent (i.e., low-level) construal (e.g., Bar-Anan et al., 2006; Liberman and Trope, 2008). For example, when people think about an event in an abstract way, they typically also perceive it to be further away geographically than it actually is. Thinking abstractly also makes people susceptible to influences of other abstract, high-level, information, such as values and attitudes (e.g., Eyal et al., 2009; Ledgerwood et al., 2010).

Now consider how ones' construal level would be affected when reading a climate-change risk communication message that relatively concretely describes spatially distant consequences and how these unfolded (e.g., how hurricane Katrina affected New Orleans from a Europeans' perspective). Would it evoke a low-level construal – driven by a dominant effect of a concrete description - or a high-level construal – driven by a dominant effect of spatial distance? Or could there perhaps be counteracting effects of concrete description and spatial distance that evoke an intermediate construal level? It seems that previous research on CLT offers no up-front answers to these questions. Hence, when applying CLT in communicating risks about climate change, we have considered two possible ways in which spatial (psychological) distance to consequences and the description of those consequences (abstract vs. concrete) can affect a persons' construal level.

## Two Construal Level Models

The first is the additive model, in which spatial distance and description abstractness each can have an independent effect and contribute to a high or low construal level (see e.g., Bar-Anan et al., 2006; Henderson et al., 2006; Williams et al., 2014). Accordingly, an abstract description of a spatially distant consequence, – i.e., when psychological distance and description abstractness are fitted – should yield the highest (most abstract) construal level, while a concrete description of a spatially proximate consequence, also representing a fitted description, should yield the lowest (most concrete) construal level. Mismatched descriptions (e.g., concrete description of spatially distant consequence) would on the other hand imply an intermediate construal level in the additive model[1].

The second way spatial distance and description abstractness could affect construal level is by interaction. An interaction model would predict that spatial distance and description abstractness exert conditional or multiplicative effects on construal level. Such a model would be supported if for instance describing a spatially distant consequence as concrete evokes a low-level construal, while at the same time describing a spatially proximate consequence as abstract does not evoke a high-level construal. To our knowledge, no previous study has investigated this type of interaction model (but see Rabinovich et al., 2009 for a similar line of reasoning), which is why we treat the additive model as more plausible while the interaction model is as a theoretical possibility worth exploring.

## Emotional Response to Psychological Distance

Risk communication on climate change has increasingly focused on emotion and related emotion-regulation strategies (Roeser, 2012; Panno et al., 2015) and psychological distance to climate change consequences has also been shown to affect the intensity with which emotions are experienced (Van Boven et al., 2010; McDonald et al., 2015). Emotions are generally felt less intense with increased psychological distance to the emotion-eliciting event. Conversely, when people experience intense emotions, they typically perceive the emotion-eliciting event to be psychologically proximate (e.g., Van Boven et al., 2010; Williams et al., 2014). However, whether emotional intensity is increased by psychological proximity, may depend on what type of emotion is experienced. For example, although basic emotions like fear and anger may involve proximal threats (Giner-Sorolla, 2001), self-conscious emotions like shame or guilt seem to require taking a psychologically (in this case socially) distant perspective, seeing oneself from another person's perspective and judging whether ones' actions are appropriate or not (Agerström et al., 2012). We propose that a high construal level of climate change consequences may evoke stronger self-conscious and weaker basic emotions than a low construal level.

Distinguishing self-conscious from basic emotions is also important as the former are more strongly related to acting on long-term goals (Carver and Scheier, 1990; Baumeister et al., 2010) while the latter are more strongly associated with working toward short-term goals (Frijda et al., 1989; Tracy and Robins, 2004). Self-conscious emotions can thus prove especially

[1]Note that, compared to spatial distance, description abstractness could still be assumed to have a larger additive effect on construal level because it would be a more direct and powerful manipulation of construal level.

important for climate change risk communication, as it enables people to act on the long-term goal of combating negative consequences of climate change. There is also previous evidence suggesting that basic and self-conscious emotions are regulated differently.

## Regulating Basic and Self-Conscious Emotions

Emotional regulation concerns the strategies people use to influence what they are feeling, how intensely they are feeling it and when they are feeling it (Gross and John, 2003). Basic emotions have been linked to regulation strategies like distancing from climate change threat (Lorenzoni et al., 2006; O'Neill and Nicholson-Cole, 2009; Schoenefeld and McCauley, 2015; McDonald et al., 2015), which would be advantageous for the individual but disadvantageous for the environment. Self-conscious emotions on the other hand are not as likely to be regulated by distancing, as the experience of these emotions requires taking a psychologically distant perspective. To increase that distance further would thus only increase the intensity of the negative self-conscious emotion (Katzir and Eyal, 2013). Self-conscious emotions have instead been found to lead to regulation strategies such as motivation to repair a situation or change oneself (Lickel et al., 2014), which would be advantageous for both the individual and the environment. In this study, we will look at the two environmentally beneficial emotion-regulation strategies (changing oneself for the environment and repairing the situation) and one environmentally harmful strategy (distancing from climate change) identified by Lickel et al. (2014).

## The Present Study

The aim of the present study is to examine emotional reactions to and related emotion-regulation strategies following different descriptions of climate change consequences varying in spatial distance and description abstractness. We will test the additive and interaction models and in each treat self-conscious and basic emotions as mediating variables and emotion-regulation strategy as dependent variable. In line with the more established additive model, we expected that a spatially distant and an abstract consequence each would (i) indirectly increase regulation attempts of self-change and repair via strengthening self-conscious emotions (Hypotheses 1) and (ii) indirectly decrease regulation attempts of distancing via decreasing basic emotions (Hypotheses 2).

# MATERIALS AND METHODS

## Participants and Procedure

One hundred and thirty nine individuals (Age $M$ = 29.8, $SD$ = 10.1, 64.7% females), recruited from a participant pool at the University of Gothenburg, Sweden, completed an online survey, without receiving monetary compensation. Participants were randomly assigned in a 2 (spatial distance: Proximal vs. Distal) × 2 (description: Concrete vs. Abstract) between-groups design, using Qualtrics Survey Software. Each participant read one of four scenarios describing consequences of climate change and then watched a short video clip depicting a severe rainstorm in a suburban area. In the spatially close condition, participants read that the storm affected Sweden, while participants in the distal condition read that the storm affected Canada (a geographically distant country, but comparable in terms of climate zone and geo-political situation). Consequence description was framed as concrete by describing tangible consequences of climate change (e.g., heat waves and flooding) that would affect Sweden/Canada or abstract by describing intangible consequences of climate change (e.g., an increase in mean global temperature and a rise of mean sea-level) that would affect Sweden/Canada. Moreover, in the concrete versus abstract scenario descriptions respondents were asked to think about *how* (for concrete) versus *why* (for abstract) climate change consequences will affect Sweden/Canada. The use of *how* (making respondents think about the specific process of climate change impact) and *why* (making respondents think about the cause of climate change impact) questions is a common practice when priming a low and high-level construal, respectively (e.g., Freitas et al., 2004; Liberman and Trope, 2008). After reading the scenario description and watching the video, participants were asked to think about the previously mentioned climate change consequences and then answered questions about how intensely they experienced 15 different emotions (shame, guilt, embarrassment, pride, anger toward oneself, anger toward others, sadness, fear, disappointment, worry, helplessness, interest, joy, relief, hope) presented in random order (*1 - not at all intense* to *9 – very intense*) and the eleven emotion-regulation questions (see Lickel et al., 2014 for complete list of items) measuring self-change, repair or distancing (also presented in random order). The emotion-regulation questions were modified to specifically attain to the question of climate change. For example, self-change was measured by items like "*I feel the need to change myself when I think about climate change*," repair was measured by items like "*I feel that I should apologize for my own impact on climate change*" and distancing by items like "*I want to distance myself from the issue of climate change as much as possible*," all measured on a 1–9 Likert scale (*1 – strongly disagree* to *9 – strongly agree*). Finally, as a manipulation check, participants were asked to rate the statement "*I felt like the storm [in the video-clip] was happening far away from Me.*" on a 1–9 Likert scale (*1 – strongly disagree* to *9 – strongly agree*).

### Manipulation Check

To check whether participants in the spatially distant condition perceived the storm to be further away and participants in the spatially close condition perceived it to be closer, we performed a one-way ANOVA, with spatial distance as independent variable and spatial perception as dependent variable. The difference between Sweden ($M$ = 3.34, $SD$ = 2.24) and Canada ($M$ = 3.52, $SD$ = 2.55) was in the expected direction but lacked statistical significance, $F(1,136) = 0.19$, $p = 0.67$. Note that the manipulation check only pertains to how distant the storm in the video-clip was perceived, not the separate consequence descriptions that

either affected Sweden or Canada. It is thus possible that spatial distance was manipulated at both earlier and later stages only in the text scenario descriptions, which our question did not check for.

## Measures

First, a scale for self-conscious emotions was created (cf. Tracy and Robins, 2004; Agerström et al., 2012), containing emotions of shame, guilt, embarrassment, anger toward oneself and pride. The scores for pride were inverted before entered into the scale, due to it being a positive self-conscious emotion. The scale had acceptable internal reliability (Cronbach's $\alpha = 0.77$; see Nunnally, 1978). Second, a scale for basic emotions was constructed (cf. Arnold, 1960; Frijda, 1986), containing the emotions sadness, anger toward other, fear, disappointment, worry, helplessness, relief, joy and interest. The scores for positive emotions were inverted. The scale showed acceptable internal reliability (Cronbach's $\alpha = 0.78$). Finally, the scales for motivation to self-change, repair and distancing (Lickel et al., 2014) were tested for internal reliability. The scale for repair showed lower reliability, (Cronbach's $\alpha = 0.66$, 3 items), while the scale for self-change (Cronbach's $\alpha = 0.86$, 4 items) distancing both showed acceptable reliability (Cronbach's $\alpha = 0.76$, 4 items).

# RESULTS

## Test of Additive Model

To firstly test the additive model (and our hypotheses), we conducted six simple mediation analyses (PROCESS v.2.16.3, model 4, Hayes, 2013 – see **Figures 1**, **2**), two for each of the three emotion-regulation strategies. In the first set of analyses, description abstractness was entered as independent variable (concrete = 0 vs. abstract = 1), spatial distance as covariate (Sweden = 0 vs. Canada = 1), self-conscious and basic emotions as mediators and emotion-regulation strategy as dependent variable. The second set of analyses was identical to the first, except that spatial distance was entered as the independent variable and description abstractness as the covariate. All confidence intervals (BCCI) reported were bias corrected and bootstrapped from 5000 samples and are at a 95% confidence level.

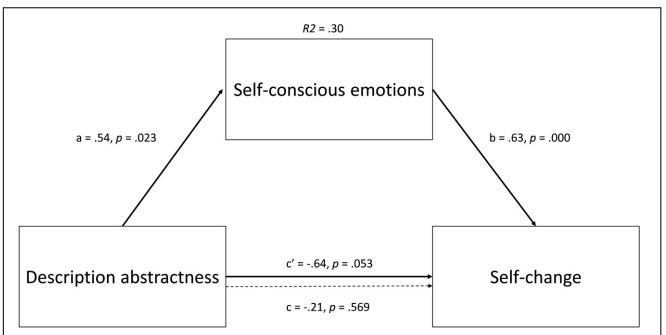


**FIGURE 1 |** Direct and indirect effects in model 4 when spatial distance is entered as covariate. Dotted line denotes the effect of description abstractness on self-change when self-conscious emotion is not included as a mediator.

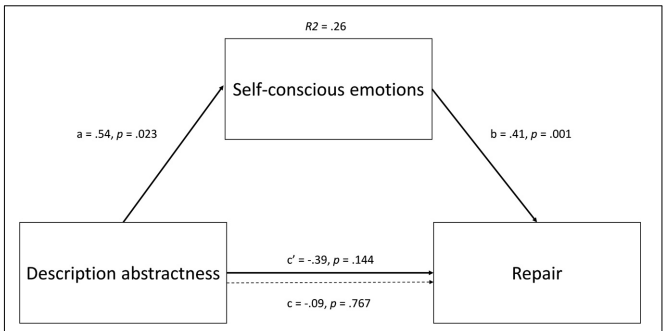


**FIGURE 2 |** Direct and indirect effects in model 4 when spatial distance is entered as covariate. Dotted line denotes the effect of description abstractness on repair when self-conscious emotion is not included as a mediator.

Partially supporting H1, abstractly described consequences, when entered as independent variable, positively influenced both willingness to self-change, $ab = 0.34$, BCCI [0.06, 0.71], and repair, $ab = 0.22$, BCCI [0.05, 0.46], via a positive influence on self-conscious emotions, $\beta = 0.54$, $p = 0.02$, $d = 0.39$. Partial standardization of these indirect effects reveal that abstract consequence description (via its influence on self-conscious emotion) increased willingness to self-change and repair by 0.15 and 0.12 standard deviations, respectively (which may exemplify small effects). Yet, in contrast to H1, spatial distance, when entered as independent variable, did not influence self-conscious emotion ($\beta = 0.04$, $p = 0.87$, $d = 0.03$). The $R^2$ for the total effect model was 0.009 for self-change and 0.001 for repair. Refuting H2, basic emotions were influenced neither by description abstractness ($\beta = 0.26$, $p = 0.27$, $d = 0.19$) nor by spatial distance ($\beta = 0.09$, $p = 0.70$, $d = 0.06$) and were unrelated to distancing attempts ($\beta = 0.03$, $p = 0.78$, $r = 0.02$).

## Test of Interaction Model

To allow testing of the interaction model we conducted six moderated mediation analyses (model 8 – see **Figures 3**, **4**), two for each of the three emotion-regulation strategies. As when testing the additive model, we entered description abstractness as independent variable and spatial distance as moderator in the first set of analyses. Analyses revealed that when consequences occurred in Canada, the concrete description directly increased self-change, $b = -1.2$, $p = 0.01$, $d = 0.44$, BCCI [−2.1, −0.28] and repair $b = -0.86$, $p = 0.02$, $d = 0.39$, BCCI [−1.61, −0.11], compared with the abstract description (see **Figure 4**). However, when consequences occurred in Sweden, the concrete description influenced neither self-change: $b = -0.11$, $p = 0.81$, $d = 0.04$, BCCI [−1.0, 0.77] nor repair: $b = 0.05$, $p = 0.90$, $d = 0.02$, BCCI [−0.68, 0.78].

In the second set of analyses, spatial distance was entered as independent variable and description abstractness as moderator.

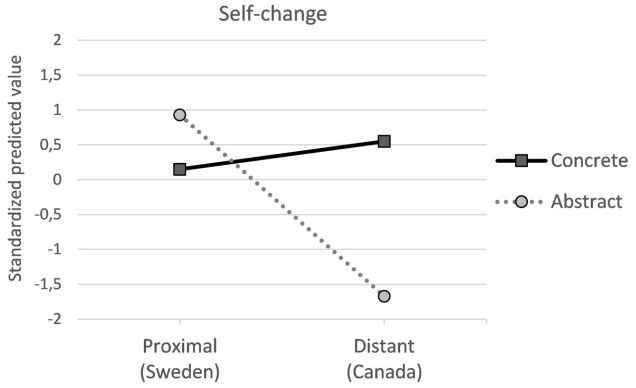


**FIGURE 3 |** Standardized predicted mean values for willingness to self-change.

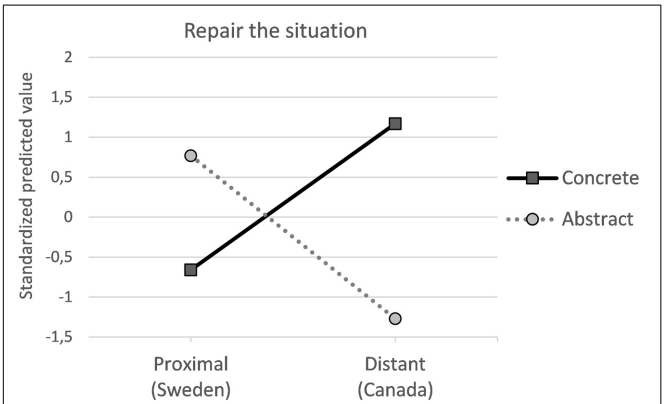


**FIGURE 4 |** Standardized predicted mean values for willingness to repair.

When abstract consequences were described, the reference to Canada decreased self-change, $b = -0.94$, $p = 0.04$, $d = 0.36$, BCCI [−1.8, −0.05] and tended to decrease repair, $b = -0.52$, $p = 0.16$, $d = 0.24$, BCCI [−1.25, 0.21]. When concrete consequences were described the reference to spatial distance had no effect, influencing neither self-change: $b = 0.14$, $p = 0.75$, $d = 0.05$, BCCI [−0.75, 1.04] nor repair: $b = 0.39$, $p = 0.30$, $d = 0.18$, BCCI [−0.35, 1.13]). However, spatial distance and description abstractness did not interact to affect self-conscious ($p = 0.89$, index of moderated mediation, self-change = 0.04, BCCI [−0.49, 0.65], repair = 0.02, BCCI [−0.33, 0.46]) or basic emotions ($p = 0.54$, index of moderated mediation, self-change = 0.1, BCCI [−0.18, 0.6], repair = 0.1, BCCI [−0.18, 0.52]). These results indicate that description abstractness and spatial distance exert multiplicative effects on emotion-regulation strategies only directly.

## DISCUSSION

This research aimed to investigate if and how risk communication messages building on different descriptions of climate change consequences affect our emotional response and emotion-regulation strategies. We found support for our hypothesis that describing climate change consequences in a more abstract way elicits more self-conscious emotions than describing them more concretely. Self-conscious emotions further mediated influences of description abstractness on adaptive responses to climate change such as willingness to self-change and repair. Unexpectedly, we corroborated no such emotional or mediational effects of spatial distance. Yet, spatial distance was for that matter not unimportant but was seen to play a different role. We found that only when consequences were spatially distant did concretizing (vs. abstracting) their description exert an effect, directly positively influencing regulation attempts of willingness to self-change and repair. When consequences were instead described as occurring nearby in space, abstracting (vs. concretizing) did not matter, however, leaving the regulation attempts unaffected. As a possible theoretical implication and practical application (in facilitating mitigating action), this finding would suggest that it is easier to offset spatially distant consequences via concretization – bringing them psychologically closer or lowering a high-level construal – than to offset spatially proximate consequences via abstraction – bringing them into psychological distance or raising a low-level construal.

Furthermore, there was no indication that a concrete representation of climate change consequences would elicit basic emotions or that experiencing intense basic emotions would lead to willingness to distance oneself from climate change. However, the fact that distancing was not predicted by either type of emotional intensity is, perhaps, unsurprising given that the process of distancing from an unpleasant event involves reducing ones' emotional response (Ayduk and Kross, 2010). Distancing from climate change in particular has been shown to be related to experiencing a lower degree of negative emotions (Homburg et al., 2007; Ojala, 2013). If people were distancing themselves the process presumably began already while reading the scenario-descriptions and watching the video-clip, which might have resulted in a lower rated emotional intensity for those participants. It should be noted that the ratings for distancing were relatively low, compared to self-change and repair. The items measuring distancing could also have been too blunt to capture this construct, as admitting to distancing from an important issue like climate change might not be socially desirable. As the measure for distancing might not have accurately captured the construct, we cannot comment as to whether a high intensity of basic emotions predicts distancing or not. This construct might be better measured implicitly rather than, as in this case, explicitly.

That people experience and are guided by high-level constructs like self-conscious emotions when climate change consequences are mentally represented as abstract is a new finding in the field of climate change communication, but is in line with previous research on decision-making (e.g., Eyal et al., 2009; Ledgerwood et al., 2010). This shows that the emotional effects of psychological distance previously

established in other research domains are also relevant for research on environmental risk communication. Interestingly, when consequences are represented as concrete, people do, however, not seem to be guided by basic emotions like fear and sadness. Self-conscious emotions are often experienced simultaneously with basic emotions, but some situations elicit only basic emotions as they are not contingent on a self-evaluative process (Beer and Keltner, 2004). That basic emotions were experienced equally strong in both the concrete and abstract frame might thus not be surprising considering that what is unique about the concrete frame is not the presence of basic emotions but rather the absence of self-conscious emotions. In other words, the concrete frame elicits only basic emotion while the abstract frame elicits both basic and self-conscious emotions. What guides mitigating motivation when people are in a concrete mind-set might thus be something other than emotion. Additional research is certainly needed here.

That spatial distance did not affect emotional intensity is in contrast to previous research where increased psychological distance generally minimizes emotional experience (e.g., Van Boven et al., 2010; Williams et al., 2014). There are three possible explanations for this. Firstly, the fact that we varied spatial distance by comparing two countries that are highly similar with respect to their geo-political situation, to deliberately try to keep social distance – that is, how (dis)similar other people are to us – constant, could have acted to reduce emotional response. It is possible that the emotional effect of spatial distance demonstrated in previous research may have been exaggerated by not controlling for this potential confound. Secondly, consequence description could have been a more direct manipulation of construal level, making spatial distance redundant. Lastly, description abstractness and spatial distance might not have had the same impact on construal level, as description abstractness was manipulated both by describing abstract (vs. concrete) consequences and by asking participants to think about *why* (vs. *how*) consequences were occurring. Spatial distance on the other hand was only manipulated by the wording of Sweden or Canada. This could partly explain why only description abstractness had an impact on emotional response.

There was furthermore no overall direct effect of spatial distance on mitigating motivation, lending support to previous studies (e.g., Schoenefeld and McCauley, 2015; Brügger et al., 2016). However, our findings point to a complex interactive effect of spatial distance in that only when consequences were abstractly described did spatial distance demotivate willingness to self-change and repair. According to Rabinovich et al. (2009), presenting something as simultaneously concrete and distant or abstract and proximate (i.e., non-fitted descriptions) allows people to think both about concrete steps to take in order to mitigate a problem (cf. *how*) whilst also think about the importance of mitigating the problem (cf. *why*). Thus, when we think about climate change consequences as both abstract and distant problems, it could communicate the significance of climate change but fail to motivate self-change and repair because it doesn't get people thinking about *how* to take action. Making a spatially distant problem more concrete may then have a positive effect because it informs people how to respond. Conversely, when we think about climate change consequences as spatially proximate and concrete problems, we might recognize action alternatives but fail to recognize the importance of action. That making a spatially proximate problem more abstract did not encourage action may (or may not) support this interaction account. The possibility of a positive effect of non-fitted descriptions was at most hinted at and future research is certainly needed to further explore this possibility. The scale for repair further showed lower reliability (Cronbach's $\alpha = 0.66$) than the scale for self-change and distancing, which might help explain why the interaction effect of spatial distance and description abstractness was more pronounced for self-change. Future studies might consider using scales that have already been adapted to the climate change context.

In the debate about whether to communicate risks of climate change as spatially distant or proximate, a discussion of consequence description abstractness is missing. Even though construal level is often inferred from psychological distance and vice versa, perceiving climate change consequences as spatially distant must not lead to the same effect as perceiving them as abstract. In fact, our findings suggest that concretizing description of a spatially distant consequence may bring it as psychologically close as a spatially proximate consequence, promoting a similar level of mitigating motivation. This study contributes to this debate by highlighting that there can be a negative effect of perceiving climate change consequences as spatially distant, but only when they are simultaneously described in an abstract way. Spatial distance to risk might thus not in itself reduce willingness to act on climate change, but rather be dependent on other factors (such as consequence information) that might affect level of construal. This provides an indication that there is no "one-way"-strategy to best communicate the risks of climate change. Depending on which aspects one wishes to communicate different framings might be warranted. When environmental risks are occurring at a distance, they should be communicated in a concrete and tangible manner to motivate mitigating action. If, however, risks are close to home, an abstract representation of it could indirectly lead to self-change, via self-conscious emotions.

## CONCLUSION

This study contributes to our understanding of how risk communication can be designed to mitigate negative consequences of climate change. In risk communication we highlight both the importance of construal level and the mediating role of self-conscious emotions. Climate change risk communication might thus make an effort to induce this type of self-relevant emotion rather than relying on basic emotions, like fear, in order to promote sustainable behavior. While abstract representations lead to mitigating motivation by increasing self-conscious emotions, future research should consider more specifically which factors are involved in the

concrete representation of climate change's ability to motivate self-change. Self-conscious emotions are often related to long-term goals, and if this makes also abstract representations of risks better suited for long-term action is a path worth investigating. The results from this study are further in line with that of Brügger et al. (2016) in that relying on making climate change appear proximate is not a clear cut strategy for increasing mitigating behavior motivation. Rather, describing high- and low-level aspects of climate change simultaneously may help us reconcile the discrepancy between an abstract problem and concrete solution.

## ETHICS STATEMENT

This study did not warrant ethical vetting, as it did not record any sensitive information about the research participants or involved sensitive populations. Informed consent was given by the participants before taking part in the online experiment.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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# Climate Change From a Distance: An Analysis of Construal Level and Psychological Distance From Climate Change

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The public perception of climate change as abstract and distant may undermine climate action. According to construal level theory, whether a phenomenon is perceived as psychologically distant or close is associated with whether it is construed as abstract or concrete, respectively. Previous work has established a link between psychological distance and climate action, but the associated role of construal level has yet to be explored in depth. In two representative surveys of Australians ($N$ = 217 and $N$ = 216), and one experiment ($N$ = 319), we tested whether construal level and psychological distance from climate change predicted pro-environmental intentions and policy support, and whether manipulating distance and construal increased pro-environmental behaviors such as donations. Results showed that psychological closeness to climate change predicted more engagement in pro-environmental behaviors, while construal level produced inconsistent results, and manipulations of both variables failed to produce increases in pro-environmental behaviors. In contrast with the central tenet of construal level theory, construal level was unrelated to psychological distance in all three studies. Our findings suggest that the hypothesized relationship between construal level and psychological distance may not hold in the context of climate change, and that it may be difficult to change pro-environmental behavior by manipulating these variables.

**Keywords: climate change, pro-environmental behavior, psychological distance, construal level theory, time perspective, donation behavior, climate change policy**

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## INTRODUCTION

Climate change poses a serious threat to the health, security, and prosperity of all people. Increasing public support for climate policies, and willingness to engage in individual climate action is crucial for directing broader, societal level change (Moser, 2016). The need to engage in sustainable adaptation and mitigation action is growing, and yet among the general public there is widespread apathy and unwillingness to act (Clayton et al., 2014, 2015). While the reasons for a lack of public engagement are wide-ranging and complex (see Castro, 2006; Owens and Driffill, 2008; Gifford, 2011; Fielding et al., 2014 for an overview), a burgeoning body of evidence (reviewed in McDonald et al., 2015) indicates that a key variable is the perception of climate change as a

distant phenomenon. "Psychological distance" is a theoretical construct that refers to the subjective perception of distance between the self and some object or event. Several studies have shown that public concern about climate change decreases as perceived psychological distance of climate change from the self increases (Uzzell, 2000; Leiserowitz, 2005; Lima and Castro, 2005; Reser et al., 2012; Spence et al., 2012; Pahl and Bauer, 2013).

Research on this topic has been guided by the construal level theory of psychological distance (CLT; Trope and Liberman, 2010), according to which objects or events that are perceived as psychologically close tend to be construed in a "concrete" manner (yielding a specific representation of those objects or events), whereas objects or events that are perceived as psychologically distant tend to be construed in an "abstract" manner (yielding a broad representation of those objects or events). If people's perceptions of distance from climate change are governed by a construal level process, then the level at which people construe climate change should be an important determinant of their support for climate action. For example, a concrete construal level may lead climate change to be perceived as psychologically close, which may result in greater acceptance of the problem and willingness to address it; conversely, an abstract construal level may lead climate change to be perceived as psychologically distant, which may result in lower acceptance of the problem and willingness to tackle it.

Understanding the possible link between perceived psychological distance, construal level, and support for climate action is therefore important, since it may provide insights into ways in which climate change communicators can reduce the perceived distance of climate change by manipulating construal level. However, as noted by McDonald et al. (2015) in their review of this field, although much research effort has been expended on understanding the link between the perceived psychological distance of climate change and support for climate action, results have been inconsistent. In three studies, we address this issue by systematically exploring the links between psychological distance, construal level, and support for climate action.

## The Construal Level Theory of Psychological Distance

Psychological distance can be defined as a subjective perception of distance between the self and some object, event, or person. Psychological distance varies as individuals transcend immediate and direct experience, to imagine hypothetical situations, understand socially distant people, care about events in faraway places, and plan for and remember distant times.

The concept of "perceived distance" as a predictor of behavior emerged in the work of Lewin (1951). Lewin's work on field theory introduced the idea that human behavior may be understood according to distances and forces perceived between the self and other entities. The entities that can affect our behavior include the people that we know, events that occur, values we hold, future goals, past memories, and so on.

More recently, CLT theorists introduced four dimensions of psychological distance that may impact on the self: temporal distance, spatial distance, social distance, and hypothetical distance (Trope and Liberman, 2010). Together, these dimensions describe the "perception of when [an event] occurs, where it occurs, to whom it occurs and whether it occurs" (Trope and Liberman, 2010, p. 442).

According to CLT, greater psychological distance is accompanied by a subsequent increase in mental abstraction. The act of moving beyond immediate experience–such as thinking about the future, considering distant locations or people–occurs through this process of mental abstraction (Soderberg et al., 2015). Any moment that is not part of the immediate experience is at once more distant, and considered in more general terms. The notion of "level of construal"–which refers to whether an object or event is represented abstractly or concretely–originates in categorization theories (Rosch, 1999), where items may be categorized into high-level groups, that focus on abstract, superordinate and central features, such as "chairs," or to low-level groups, that focus on concrete, specific and peripheral features, such as "wheelchairs" (Trope and Liberman, 2010).

Psychological distance and construal level share the important feature of varying with preferential attention to information. At any point, an individual's level of abstraction may change, depending on the pertinent goal. High-level construals, and abstraction, may be active over greater temporal distance because the meaning of an abstract construal is unlikely to change, whereas the relevance of a concrete construal may be temporary (Trope and Liberman, 2010). For instance, when asked about health behaviors in the long-term, the salient construal may be "exercise regularly," but if framed in the short-term, the prevailing construal may be "go for a run before work." The central idea is that distant entities are construed abstractly, whereas those near are construed more concretely (Trope and Liberman, 2010). Climate change, for instance, if perceived as distant, may predominantly be conceived of in the abstract. The implication is that an abstract and distant perception of climate change produces vague and uncertain conceptualizations of the issue, which may render it difficult to conceive of specific ways to address climate change (Spence et al., 2012).

Past research has found a strong relationship between psychological distance and construal level in the context of general perceptions and cognitions (Trope and Liberman, 2010; Soderberg et al., 2015): construal level shapes judgments of probability (Todorov et al., 2007), temporal and spatial location (Bar-Anan et al., 2007; Hansen and Trope, 2012), and social information (Ledgerwood et al., 2010). In the next section, we review evidence on the link between construal level and psychological distance in the context of climate change.

## Psychological Distance From Climate Change

Spence et al. (2012) conducted the first study to systematically examine perceptions of psychological distance from climate change along all four dimensions proposed by CLT. In a survey of UK residents, Spence et al. (2012) measured participants' reported psychological distance from climate change: whether it was perceived to be spatially, temporally, socially or hypothetically distant from the self. They tested

whether pro-environmental engagement is best predicted by abstract, distant perceptions of climate change, or concrete, close perceptions of climate change. This rationale was motivated by contrasting research suggesting that both types of perceptions and associated construals may predict pro-environmental engagement. Abstractness fosters a goal-centered mind-set and facilitates decision-making and planning for more distant, abstract events (Liberman and Trope, 2008), and enhances self-control (Trope and Liberman, 2010). Therefore, a psychologically distant and abstract mind-set may to lead to actions that adhere to one's core beliefs (Liberman and Trope, 2008). Conversely, research also suggests that setting specific and concrete goals promotes behavioral engagement (Locke and Latham, 2002; Rabinovich et al., 2009). A concrete construal may promote a psychologically close view (Trope and Liberman, 2010), one that fosters emotional and cognitive engagement with climate change (Van Boven et al., 2010). Hence, making climate change psychologically close and concrete may make the consequences more tangible.

Spence et al. (2012) found that psychological closeness to climate change correlated with greater concern and greater preparedness to reduce energy consumption. However, greater distance along the social distance dimension (viz. the effect of climate change on developing nations) also predicted preparedness to act. This suggests that both psychological closeness and distance can promote pro-environmental action in different contexts.

Crucially, although Spence et al. (2012) theorized about the relationship between psychological distance and construal level, the latter was not empirically measured. This omission makes interpretation of their findings difficult, because although we know that psychological distance is related to perceptions of climate change, we do not know if is also related to construal level. It is possible, for example, that people are motivated to act on climate change when they perceive it in specific, concrete terms, but it does not follow that they perceive it as psychologically close.

Similarly, while several additional studies have found that climate change is perceived as psychologically distant (Spence and Pidgeon, 2010; Scannell and Gifford, 2011; Brügger et al., 2015b), none of these studies has measured psychological distance *and* construal level simultaneously. Although some studies have experimentally induced different levels of construal and shown that this can affect pro-environmental intentions and behaviors (Shwom et al., 2008; Pahl, 2010; White et al., 2011), crucially, they did not measure the resulting construal and perceived psychological distance from climate change.

The result is that there is no way to ascertain from these studies whether pro-environmental actions have been encouraged by a change in perceived distance from climate change, or a change in construal level. Furthermore, without measuring both the change in construal level and psychological distance, it is difficult to know why construal level and psychological distance manipulations sometimes do not produce a change in pro-environmental actions (Shwom et al., 2008; Hart and Nisbet, 2012). These omissions are noteworthy, not only because understanding cognitions of climate change are intrinsically important, but because construal level has been one of the primary devices used to alter psychological distance (Soderberg et al., 2015).

It is possible that climate change is a context in which psychological distance does not always shift in accordance with construal level. If by varying psychological distance we also affect construal level, and vice versa, then making climate change psychologically close should simultaneously increase concrete construals; conversely, increasing abstract construals should simultaneously increase psychological distance. If a change in one necessarily affects the other, then changing abstract construals of climate change may produce contradictory results: for instance, abstract construal can elicit long-term thinking, and greater self-control (Fujita et al., 2006), which may encourage pro-environmental action. On the other hand, abstract construal may also lead to a psychologically distant view which is related to lower concern about climate change. Importantly, if psychological distance and construal level are always matched, this produces a contradiction about how to encourage pro-environmental action. If they operate relatively independently, there is no such contradiction, and we may conceive of construal level and psychological distance as separate pathways to increase pro-environmental action.

A few studies that have examined psychological distance in contexts such as emotional intensity have found that psychological distance and construal level do not directly relate with one another (Van Boven et al., 2010; Williams et al., 2014). There is further evidence to suggest that construal level and psychological distance operate independently in the climate change context, and may constitute separate pathways to climate action. Devine-Wright (2013) argued that the relevance of local climate change effects does not necessarily negate the relevance of distant, global effects; it is possible to conceive of climate change affecting both local (close), and global (abstract) regions simultaneously, and to be concerned about both. Similarly, Rabinovich et al. (2009) argue that it is possible, and even beneficial, to focus on a combination of close and abstract conceptions of climate change. In sum, it is important, both theoretically and practically, to study the unique contributions of psychological distance and construal level to climate change engagement.

## Current Study

The rest of this paper is structured as follows. We report two studies that examined the extent to which climate action is predicted by measures of psychological distance and construal level (Study 1 and 2). To anticipate, the results of these studies revealed an inconsistent pattern: in Study 1, perceived psychological distance from climate change predicted lower support for individual-level pro-environmental behaviors, whereas construal level predicted support for community-level policy support. By contrast, in Study 2 psychological distance no longer predicted support for individual-level pro-environmental behaviors, but there was some evidence that construal level did. Next, we report an experiment (Study 3) that systematically manipulated construal level and perceived temporal distance from climate change in tandem. Contrary to

CLT, construal level did not predict pro-environmental behavior, and counterintuitively, greater, rather than lesser, temporal distance to climate change was associated with greater levels of engagement in pro-environmental behavior.

## STUDY 1

In the context of climate change, the role of psychological distance has not been distinguished from that of construal level. Previous studies have often used construal level as a proxy for psychological distance, assuming an isomorphic relationship which may not hold in the domain of climate change. Accordingly, the primary objective of Study 1 is to examine the relationship between construal level and psychological distance, by measuring both constructs independently, in addition to their relationship with climate change engagement. Such work is necessary to disentangle the role of psychological distance and construal level, as cognitions of climate change, and as predictors of climate change engagement.

To meet this objective, Study 1 measured all four dimensions of psychological distance defined by CLT, in addition to construal level, thereby replicating and extending the work of Spence et al. (2012). We also incorporated two different measures of pro-climate behaviors: (1) a community-level pro-environmental measure, based on support for different carbon emission reduction policies, and (2) an individual-level pro-environmental measure, based on people's willingness to make sacrifices for pro-environmental choices.

Two hypotheses were tested. The first was that individuals reporting greater psychological closeness to climate change should be more engaged in pro-environmental and climate change-friendly activities. That is, individuals who report low scores on measures of psychological distance should report higher existing engagement in pro-environmental behaviors, and exhibit support for more effective and costly climate policies. The second hypothesis, derived from CLT, concerns the relationship between psychological distance and construal level. According to CLT, individuals who report greater psychological distance should also score more highly on abstract construal, however, research in the climate change context suggests that measures of psychological distance and construal level may not be closely associated.

Finally, an ancillary objective was to compare two self-report scales measuring psychological distance from climate change: an extended version of the scale used by Spence et al. (2012), and a scale used by McDonald et al. (2013). There is currently little consensus in the literature regarding how to measure psychological distance from climate change. Our goal was to establish the degree of correspondence between these two scales, and to determine which better predicts engagement with climate change. We also compared two scales measuring construal level, a commonly used measure called the Behavioral Identification Form (BIF), based on work by Vallacher and Wegner (1989), and a more quantitative method proposed by Krüger et al. (2014), based on Pettigrew's Category Width measure (1958).

# Methods

## Participants

An *a priori* power analysis was conducted using G*Power (Faul et al., 2007) to determine the minimum required sample size. Assuming an effect size of 0.29, based on previous work by Spence et al. (2012) and Brügger et al. (2015b), a sample size of 111 would yield a power level of 0.99, at $\alpha = 0.05$. A total of 218 (114 female) Australian adults recruited by Qualtrics–a survey company specializing in representative Internet surveys–participated in the study. The mean age was 47.35 years (range 18–84), and the median gross annual income bracket was $35,000–49,999 per year. Age, gender, and income groups approximated a representative distribution of Australia's population, although high income earners were somewhat over-represented (**Table 1**).

## Materials and Procedure

The study was executed as a questionnaire using Qualtrics survey software–a web-based survey software tool for the creation of online survey instruments, distribution of surveys, data collection, storage and analysis.

### *Psychological distance 1 (PD1)*

The study adapted and extended the questionnaire items used in Spence et al. (2012) to measure psychological distance. The original measure contained 10 items in total: five measured hypothetical distance, one measured temporal distance, and spatial and social distance were each measured by two items. The questions used different response scales and labels. In the present study, we created 18 items measured on a common response scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), with greater endorsement reflecting greater psychological distance. The four dimensions of psychological distance specified by Trope and Liberman (2010) - namely temporal distance, spatial distance, social distance and hypothetical distance - were each measured by four items. Additionally, because one's perceived temporal and hypothetical distance may vary by location and subject, items were created to reflect temporal *and* spatial distance, and temporal *and* social distance (and the same for hypothetical distance). An example of a question is "Climate change will not change my life, or my family's lives anytime soon" (temporal and social distance).

**TABLE 1 |** Sampled distribution for Study 1 compared to Australian population.

| | | Sample (%) | Population (%)* | Annual income | Sample (%) | Population (%) |
|---|---|---|---|---|---|---|
| Sex | Male | 52.5 | 49.3 | <$15,000 | 12.9 | 17.16 |
| | Female | 47.5 | 50.7 | $15,000–$24,999 | 12.9 | 13.49 |
| | | | | $25,000–$34,999 | 11.06 | 15.29 |
| Age | 18–24 | 10 | 12.29 | $35,000–$49,999 | 14.29 | 15.50 |
| | 25–54 | 55 | 53.38 | $50,000–$74,999 | 18.43 | 16.05 |
| | 55–64 | 22 | 14.74 | $75,000–$99,999 | 11.06 | 6.92 |
| | 65+ | 13 | 19.09 | >$100 000 | 19.35 | 9.83 |

**Data has been corrected to exclude the population under 18 years. Population data were obtained from the Australian Taxation Office (2013) and Australian Bureau of Statistics (2014).*

### *Psychological distance 2 (PD2)*

The second measure of psychological distance was taken from McDonald et al. (2013) and used a continuous sliding scale to measure psychological distance along each of the four distance dimensions. An example question is: "When will climate change impacts occur?" Social distance was measured using two separate items, one to measure intimacy (where "close" refers to friends and family), and one to measure similarity (where "close" refers to perceived similarity and dissimilarity from the self). Responses were recorded on a continuous sliding scale ranging from 0 (*right now*) to 100 (*in the very distant future*). Different labels were used for the questions referring to hypothetical, social, and spatial distance. The use of a second measure of psychological distance allows for comparison and assessment of inter-test reliability. The order of presentation of the PD1 and PD2 scales was counterbalanced across participants.

### *Behavioral identification form (BIF)*

To verify the compatibility of psychological distance and construal level in the context of climate change, we used the behavioral identification form (BIF; Vallacher and Wegner, 1989), an established measure of construal level (Soderberg et al., 2015). The BIF is a measure of cognitive processing, and assesses whether participants consider issues in an abstract, vague manner, or in a specific, concrete manner. The task involves a series of two-option forced-choice questions distinguishing whether participants construe actions concretely or abstractly. An example of an item would be whether the participant considers "Growing a garden" to be best described by "planting seeds" (concrete construal), or "getting fresh vegetables" (abstract construal).

### *Response category width (RCW)*

Recently proposed measures of construal level are more direct, focusing on tracing the cognitive processes elicited by construal level. Theoretically, abstract perceptions should be broad and have a wide confidence interval, whereas concrete perceptions should be more specific and have a narrower confidence interval. Krüger et al. (2014) argue that "response category width" (RCW) is one way of measuring construal level of psychological distance–the more concretely an object is perceived, the narrower the range ought to be (Krüger et al., 2014).

An RCW scale was constructed and adapted from Pettigrew's Category Width (Pettigrew, 1958) items, which served as the second measure of construal level. There were two main subcategories of construal level for the RCW scale. Six questions addressed construals specifically related to climate change and the environment, and six questions were taken from the original Pettigrew RCW scale, to measure general tendencies toward abstract or concrete construal. An example item is: "According to a study of 100 households, the average shower taken consumes 62 liters of water. What do you think is the most/least amount of water consumed in a single shower?" Participants were presented with four numerical options each for what they perceived as the upper and lower limit. Responses were coded from 0 to 3, in order of proximity to the average value. Greater scores indicate a wider RCW, and more abstract construal. The order of presentation of the BIF and RCW was counterbalanced across participants.

### *Attitude and belief scales*

Additional items were included to assess the criterion validity and ability of psychological distance and construal level measures to predict environmental behavior above and beyond known measures. The items related to political identification, views about climate change–including concern about climate change and perceived behavioral control (Leviston et al., 2014)–and climate change skepticism (Whitmarsh, 2011). Belief in anthropogenic climate change was measured using a categorical item asking participants to indicate the statement that best describes their thoughts about climate change: "I don't think climate change is happening" (deny); "I have no idea whether climate change is happening or not" (don't know); "I think that climate change is happening, but it's just a natural fluctuation in Earth's temperatures" (natural); and "I think that climate change is happening, and I think that humans are largely causing it" (anthropogenic) (Leviston et al., 2014). In addition, the Myths of Physical Nature scale (Price et al., 2014) was used to measure environmental worldviews. This contains two subscales that measure "ductile" and "elastic" environmental worldviews. The former describes the view that the environment is alterable by human actions, whereas the latter describes the opposite view, that the environment is capable of recovering from human actions. The scale demonstrates good predictive validity for pro-environmental intentions (Price et al., 2014).

Two other measures were included to assess criterion validity. The first measure was time perspective, a distance-related variable that strongly predicts environmental behaviors (Milfont et al., 2012; Arnocky et al., 2013). We used the 14-item Consideration of Future Consequences scale (Joireman et al., 2012), which contains items such as "I only act to satisfy immediate concerns, figuring the future will take care of itself" measured on a response scale ranging from 1 (*very uncharacteristic of me*) to 7 (*very characteristic of me*). The second measure was place attachment, a variable that reflects a bond between person and specific spatial locations. As "global attachments"–a feeling of belonging to the entire world–predict environmental action (Devine-Wright, 2013; Devine-Wright et al., 2015), the place attachment scale (Devine-Wright et al., 2015) was included to test the role of local and global attachments, and their relationship with psychological distance and construal level. This scale measures reported sense of belonging to regions of varying distance from the individual, ranging from one's neighborhood to the entire world, on a response scale ranging from 1 (*no sense of belonging*) to 5 (*very strong sense of belonging*).

### *Dependent measures*

To compare the effect of psychological distance on dependent variables of both high and low abstraction, we incorporated two measures, one pertaining to community-level pro-environmental action and the other to individual pro-environmental behaviors, under the assumption that the former may be construed more

abstractly, and the latter more concretely. The community-level dependent measure was a set of five emission reduction policy choices, based on scenarios modeled by the Australian Treasury (2013). The options increased in cost ($0, $700, $900, $1,000, and $1,200 reduction to annual national income, per person, in 2020) and effectiveness (0%, 5%, 10%, 15%, and 25% reduction in emissions by 2020). Participants were asked to choose the emission reduction policy they would vote for in a hypothetical referendum. The individual-level dependent measure was adapted from Steg and Vlek (2009), Markle (2013), and Leviston et al. (2014) and consisted of items assessing whether participants would make personal sacrifices for pro-environmental choices. Participants were asked to indicate the likelihood that they would sacrifice time, money, social relationships and effort for pro-environmental choices, products and actions. The response format ranged from 1 (*very unlikely*) to 5 (*very likely*).

## Results

One participant was removed for selecting the same option for all questions, so the final sample size for analysis was 217. **Table 2** shows the descriptive statistics for key variables. **Figure 1** shows the responses to measures of psychological distance and construal level, sorted by belief in climate change. Whereas responses on the construal measures do not vary according to climate change belief type, psychological distance appears to decrease with increasing belief in anthropogenic climate change.

**TABLE 2 |** Descriptive statistics for Study 1.

| Type of measure | Variable | Minimum (absolute) | Mean | Maximum (absolute) | *SD* | α |
|---|---|---|---|---|---|---|
| Covariates | Skepticism | 1.00 (1) | 2.37 | 5 (5) | 0.96 | 0.86 |
| | Behavioral control | 1.50 (1) | 2.99 | 4.17 (5) | 0.43 | 0.83 |
| | Ductile worldview | 1.00 (1) | 3.76 | 5.00 (5) | 0.73 | 0.86 |
| | Elastic worldview | 1.00 (1) | 2.27 | 4.28 (5) | 0.76 | 0.85 |
| | Time perspective | 1.00 (1) | 5.00 | 6.80 (7) | 0.75 | 0.87 |
| | Place attachment | 1.00 (0) | 3.52 | 5.00 (6) | 0.97 | 0.87 |
| Psychological distance | PD1 | 1.00 (1) | 2.43 | 4.28 (5) | 0.83 | 0.93 |
| | PD2 | 0.00 (0) | 42.10 | 100 (100) | 18.13 | 0.76 |
| Construal level | BIF | 0.00 (0) | 0.59 | 1.00 (1) | 0.23 | 0.85 |
| | RCW | 0.11 (0) | 1.52 | 3.00 (3) | 0.50 | 0.79 |
| | Environmental (E) | 0.08 (0) | 1.53 | 3.00 (3) | 0.54 | 0.63 |
| | General (G) | 0.00 (0) | 1.51 | 3.00 (3) | 0.66 | 0.65 |
| Dependent measures | Individual pro-environmental behavior | 1.00 (1) | 3.50 | 5 (5) | 0.49 | 0.69 |
| | Policy choice | 1.00 (1) | 3.32 | 5 (5) | 1.46 | NA |
| | **Belief-type** | | | **% of sample** | | |
| Belief in climate change | Deny | | | 6% | | |
| | Don't know | | | 4% | | |
| | Natural causes | | | 32% | | |
| | Anthropogenic | | | 58% | | |

*PD, psychological distance; BIF, Behavioral Identification Form; RCW, Response Category Width.*

### Perceived Psychological Distance From Climate Change

**Figure 2** shows the percentage of responses given on each of the psychological distance scales. **Figure 2A** shows PD1, for which the *x*-axis corresponds to codes on the Likert scale from 1 (strongly disagree) to 5 (strongly agree). The distribution of responses was qualitatively similar across all four distance dimensions, with a peak at distance 2 (the "disagree" response option) and a subsequent monotonic decline with increasing distance. For all four distance dimensions, the percentage of responses at distance 1 (strongly disagree) and distance 3 (neither agree nor disagree) were comparable.

**Figure 2B** shows the pattern of responses on the PD2 scale (responses in this figure have been binned to facilitate graphical illustration of general trends but for subsequent analyses, the aggregated and standardized psychological distance scores were calculated based on the mean of responses). It can be seen from a comparison of **Figures 2A,B** that responses on the PD2 scale showed a somewhat different profile. Most participants reported that climate change is temporally and hypothetically close (0 distance from the self), but more socially and spatially distant. Many responses for these dimensions were near the midpoint, suggesting that participants may perceive climate change to be neither close nor distant along social and spatial dimensions.

### Comparing Psychological Distance Scales

**Table 3** shows significant correlations between all dimensions of the psychological distance scales, though the degree of relationship between items varied greatly. For the PD1 scale, all dimensions were highly correlated. Similarly, all dimensions of the PD2 scale were correlated, though less highly.

#### *Principal components analysis*

A Principal Components Analysis of the PD1 scale had adequate sampling (KMO = 0.95) and Bartlett's test of sphericity showed that the null hypothesis could be rejected, $\chi^2(153) = 3213.32$, $p < 0.001$. An unrotated one-component solution was found, with an eigenvalue of 10.41. All items except one loaded on the first component, which explained 57.89% of the variance (see **Supplementary Information**). As the PD2 scale only had five items, an individual PCA was not conducted.

#### *Correlations with related variables*

Correlations between key variables and psychological distance are shown in **Table 4**. PD1 and PD2 are both positively correlated with climate change skepticism and elastic environmental worldview, and negatively correlated with a ductile environmental worldview, time perspective, and global attachment. That is, greater psychological distance from climate change is associated with greater skepticism, and a view that the environment can recover from any damage caused by humans. Greater psychological closeness to climate change is associated with having an attachment to the world as a whole, having a longer time perspective, and believing that the environment can be altered by human actions. The two measures of psychological distance also correlated positively with one another.

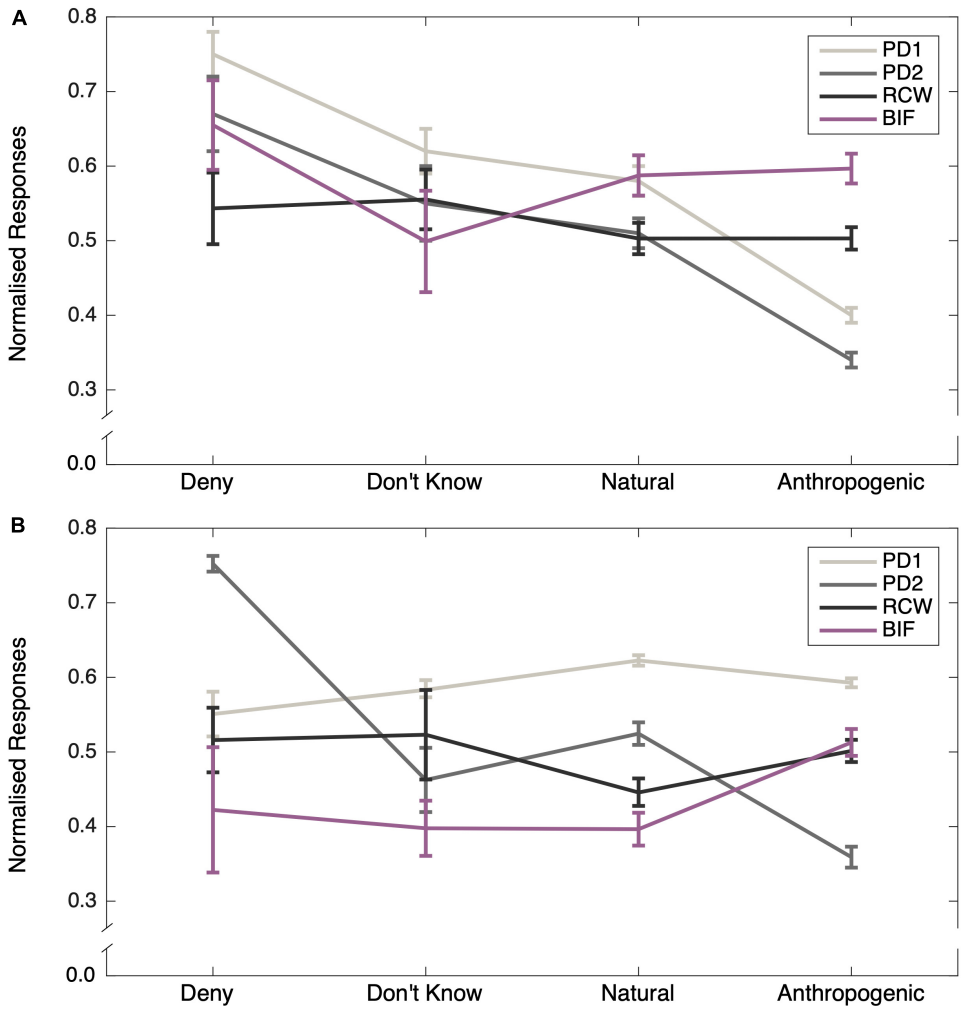


**FIGURE 1 |** Average responses on the construal level and psychological distance measures as a function of categorical belief in climate change. Panel **(A)** shows the results for Study 1, whereas panel **(B)** shows the results for Study 2. Note that scale scores have been standardized to a 0–1 metric. Error bars represent standard errors.

## Comparing Construal Level Measures

The RCW measure of construal level consisted of two sections, one section with questions specific to climate change and the environment, and one section with general estimation questions. A Varimax rotated principal components analysis found a two-component solution (KMO = 0.79, Bartlett $\chi^2(153) = 655.34$, $p < 0.001$), where climate-specific items loaded on one component and general items loaded on a second (see **Supplementary Information**). As there are no environment or climate related questions in the BIF scale, no PCA was conducted to assess its underlying structure.

As seen in **Table 4**, the BIF and RCW were not significantly correlated with each other. Particularly noteworthy is the lack of significant correlation between the two construal level measures and the two psychological distance measures. Of the other variables in the study, the BIF correlated positively with time perspective and global place attachment, indicating that a longer time perspective and sense of belonging to the entire world is to some extent linked to abstract construal. RCW had no significant correlations with any variables, except between the two RCW subscales.

## Predicting Pro-environmental Behavior

Due to high variance inflation factors, we removed a number of variables from the regression (ductile and elastic environmental worldview, see **Supplementary Information**). The second psychological distance measure (PD2) was initially included, but as it also had a high variance inflation factor score, and did not contribute to the model fit, we removed it from subsequent analysis.

A linear regression was conducted to predict individual-level pro-environmental behavior: willingness to sacrifice time, effort, money and social relationships for the environment. Key variables, including the binary "belief in climate change" variable, were entered. The final model is shown in **Table 5**, and accounted for 40% of the variance. The model indicates that age, political

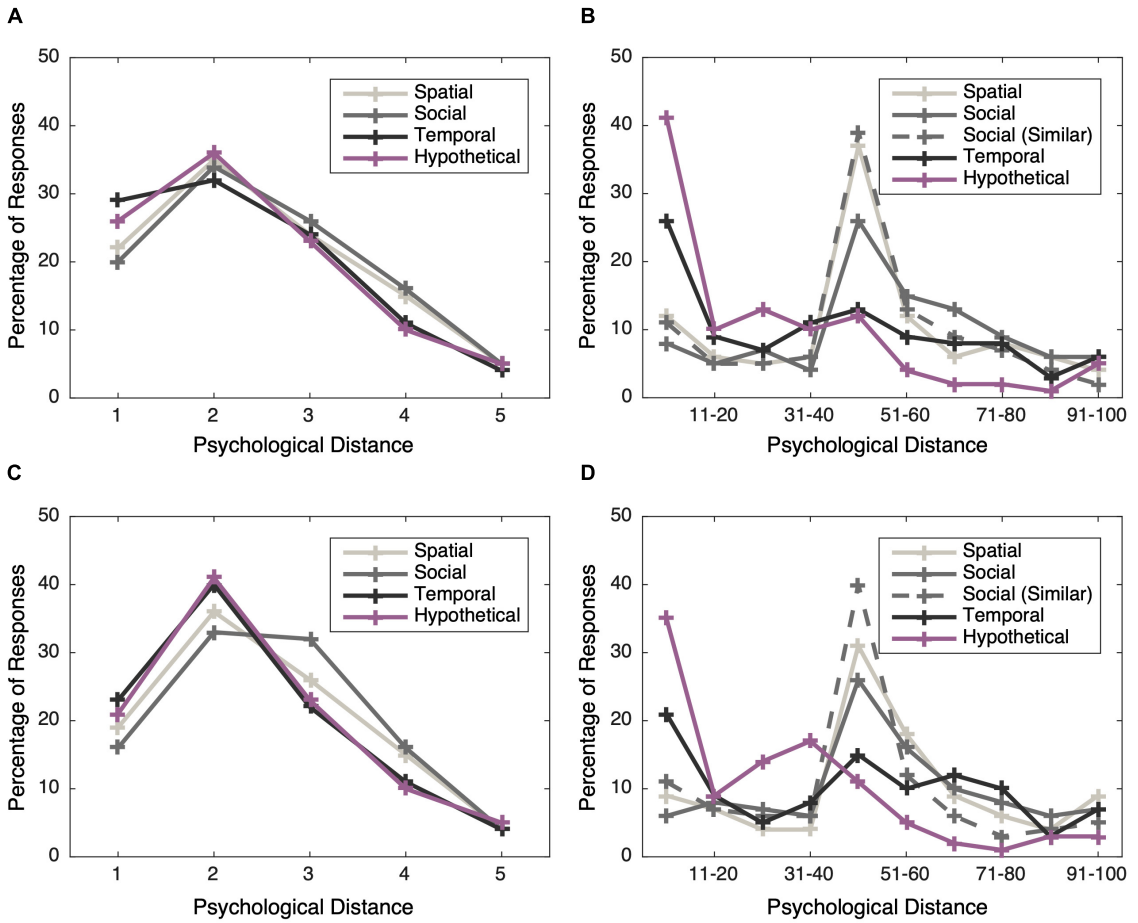


**FIGURE 2 |** Responses on the psychological distance measures. Left: the percentage of responses, according to response category, on the four psychological distance dimensions indexed by PD1. Greater agreement indicates greater psychological distance from climate change. **(A)** PD1 distributions in Study 1, **(C)** PD1 distributions in Study 2. Right: the distribution of responses according to distance from self, on the five psychological distance dimensions indexed by PD2. In the PD2 scale, the "Social" label refers to intimacy (e.g., friends, family), and "Social (similar) refers to similarity to the self. **(B)** PD2 distributions in Study 1, **(D)** PD2 distributions in Study 2.

**TABLE 3 |** Correlations for psychological distance in Study 1.

| Scale | Distance | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| PD1 | (1) Spatial | – | 0.89** | 0.79** | 0.83** | 0.42** | 0.33** | 0.66** | 0.56** | 0.61** |
| | (2) Social | | – | 0.76** | 0.80** | 0.43** | 0.32** | 0.63** | 0.51** | 0.52** |
| | (3) Temporal | | | – | 0.87** | 0.27** | 0.24** | 0.74** | 0.50** | 0.67** |
| | (4) Hypothetical | | | | – | 0.34** | 0.27** | 0.65** | 0.50** | 0.61** |
| PD2 | (5) Social close | | | | | – | 0.46** | 0.29** | 0.50** | 0.18** |
| | (6) Social similar | | | | | | – | 0.22** | 0.41** | 0.18** |
| | (7) Temporal | | | | | | | – | 0.54** | 0.62** |
| | (8) Spatial | | | | | | | | – | 0.35** |
| | (9) Hypothetical | | | | | | | | | – |

***Correlation is significant at the 0.01 level (2-tailed). N = 217.*

orientation, behavioral control, time perspective and PD1 were predictors of individual action. Neither construal level measure significantly predicted individual pro-environmental behavior. To test predictors of policy choice, key variables, including the binary "belief in climate change" variable, were used to construct a linear model. The model explained 49.1% of variance (**Table 5**). Variables influencing the choice of more expensive, effective policies were political orientation, skepticism, behavioral control, RCW-E, time perspective, and place attachment. However, psychological distance as measured by PD1 was a significant

**TABLE 4 |** Correlations for key variables and dependent variables in Study 1.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Skepticism | – | −0.01 | −0.67** | 0.72** | 0.79** | 0.62** | 0.03 | 0.02 | 0.04 | −0.59** | −0.10 | −0.50** | −0.64** |
| (2) Behavioral control | | – | 0.19** | 0.00 | −0.05 | 0.06 | 0.02 | −0.06 | −0.09 | −0.19** | −0.15* | −0.09 | 0.07 |
| (3) Ductile | | | | −0.75** | −0.67** | −0.57** | −0.02 | 0.00 | 0.05 | 0.48** | 0.10 | 0.41** | 0.50** |
| (4) Elastic | | | | – | 0.68** | 0.58** | −0.02 | 0.01 | −0.07 | −0.53** | −0.09 | −0.47** | −0.51** |
| (5) PD1 | | | | | – | 0.76** | 0.02 | 0.01 | 0.00 | −0.57** | −0.10 | −0.50** | −0.53** |
| (6) PD2 | | | | | | – | −0.03 | 0.07 | 0.02 | −0.45** | −0.08 | −0.40** | −0.38** |
| (7) BIF | | | | | | | – | 0.01 | −0.06 | −0.21** | −0.14* | −0.15* | −0.07 |
| (8) RCW-E | | | | | | | | – | 0.58** | 0.02 | −0.01 | 0.06 | 0.10 |
| (9) RCW-G | | | | | | | | | – | 0.11 | 0.04 | 0.11 | 0.09 |
| (10) Time perspective | | | | | | | | | | – | 0.24** | 0.56** | 0.53** |
| (11) Place attachment | | | | | | | | | | | – | 0.18** | 0.25** |
| (12) PEB | | | | | | | | | | | | – | 0.38** |
| (13) Policy | | | | | | | | | | | | | – |

***Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).*

**TABLE 5 |** Models predicting policy support and pro-environmental behavior across Studies 1 and 2.

| | Pro-environmental behavior | | | | Policy choice | | | |
|---|---|---|---|---|---|---|---|---|
| | Study 1 | | Study 2 | | Study 1 | | Study 2 | |
| Variable | *β* | *SE* | *β* | *SE* | *β* | *SE* | *β* | *SE* |
| Gender (M) | −0.05 | 0.12 | −0.26* | 0.12 | 0.19 | 0.11 | 0.11 | 0.14 |
| Age | 0.02** | 0.00 | 0.01** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Politics | −0.06 | 0.05 | −0.04 | 0.04 | −0.02 | 0.04 | −0.06 | 0.05 |
| Income | 0.01 | 0.03 | −0.04 | 0.03 | −0.04 | 0.03 | 0.02 | 0.03 |
| Belief | −0.17 | 0.18 | −0.19 | 0.16 | 0.26 | 0.17 | 0.16 | 0.18 |
| Skepticism | −0.17‡ | 0.11 | −0.14 | 0.09 | −0.41*** | 0.11 | −0.29** | 0.10 |
| Behavioral control | −0.05 | 0.06 | 0.10 | 0.07 | 0.14* | 0.05 | 0.10 | 0.08 |
| PD1 | −0.19* | 0.09 | −0.09 | 0.06 | 0.02† | 0.08 | −0.02† | 0.07 |
| BIF-E | – | – | 0.22** | 0.08 | – | – | 0.05 | 0.09 |
| BIF-G | 0.03 | 0.06 | −0.04 | 0.07 | 0.03 | 0.05 | −0.03 | 0.08 |
| RCW-E | 0.06 | 0.06 | −0.06 | 0.07 | 0.14* | 0.06 | 0.06 | 0.08 |
| RCW-G | 0.01 | 0.06 | 0.02 | 0.07 | −0.03 | 0.06 | −0.10 | 0.08 |
| Time perspective | 0.37** | 0.08 | 0.25** | 0.07 | 0.22** | 0.07 | 0.02 | 0.08 |
| Place attachment | −0.01 | 0.06 | 0.10 | 0.06 | 0.18** | 0.06 | −0.02 | 0.07 |
| Constant | −0.37 | 0.34 | 0.41 | 0.30 | −0.27 | 0.31 | −0.09 | 0.34 |
| Observations | | 217 | | 213 | | 217 | 213 | |
| $R^2$ | | 0.44 | | 0.41 | | 0.51 | 0.22 | |
| Adjusted $R^2$ | | 0.40 | | 0.36 | | 0.48 | 0.17 | |
| Residual *SE* | 0.77 | (*df* = 203) | 0.80 | (*df* = 198) | 0.72 | (*df* = 203) | 0.92 | (*df* = 198) |

*p < 0.1; *p < 0.05; **p < 0.01; ***p < 0.001; †mediated by skepticism; ‡mediated by PD1.*

predictor of policy choice when climate change skepticism was removed from the model. Inversely, for the individual level behavior, PD1 was a significant predictor, but skepticism was not. When either variable was removed from the model, the other became significant.

## Discussion

Study 1 investigated the role of psychological distance and construal level in the context of climate change. Following Spence et al. (2012), a principal question was whether psychological distance from climate change predicted environmental behavior. The results show that psychological closeness predicted greater engagement in pro-environmental behaviors, primarily at the individual level.

Psychological closeness predicted individual pro-environmental behavior, over and above the variance explained by variables such as age and political orientation, belief in climate change, skepticism, and behavioral control. Those who reported greater psychological distance were less willing to make individual sacrifices – their time, money, effort and social status –

for environmental gains. At the community-level, psychological distance only predicted support for more effective emission reduction policies when climate change skepticism was removed from the model.

As psychological distance and construal level have both been theorized to–and have been empirically shown to–affect one another (Soderberg et al., 2015), it was expected that construal level might also predict willingness to undertake environmental actions. However, the results in this study indicate that construal level predicted engagement in the reverse direction, at least in the case of support for emission reduction policies. That is, those with a more abstract construal of the environment were more likely to support more expensive and more effective emission reduction policies, although this result was not statistically reliable.

The construal level literature suggests that there should be a positive association between psychological distance and abstract construal. This finding has been well substantiated in different fields (Soderberg et al., 2015). However, in the present study there was no evidence that psychological distance increased with abstract construal–construal level and psychological distance were uncorrelated across all measures. Psychological distance and construal level also appear to operate independently–the two variables only jointly predicted one dependent variable (policy choice) and in opposite directions from one another. Not only are psychological distance from climate change and construal of climate change uncorrelated, they also behave qualitatively differently as predictors.

Together, the findings show that psychological distance from climate change (closeness to climate change) predicted individual-level behavior, whereas construal level (abstract construal of climate change) predicted community-level action. The finding that psychological predicts environmental behavior is consistent with that of Spence et al. (2012), but the distinction between predictors of individual and community levels of action is a novel one. People who perceive climate change as a distant issue are less likely to express intentions to mitigate climate change, whereas those who think abstractly about climate change are more likely to support climate action on an abstract level.

A key limitation of the present study is that the construal level measures were not related to one another, which renders it difficult to assess whether they are measuring the same psychological construct. One reason for the lack of relationship may be because the RCW scale has items specifically addressing environmental topics, whereas the BIF scale does not. Further, while RCW-E was a significant predictor of policy choice, given that this is a novel scale, it would be prudent to examine whether this finding generalizes to a new dataset. We sought to address these potential issues in a second study.

# STUDY 2

To overcome the limitations of Study 1, we conducted a replication using an augmented version of the BIF. The BIF is a recognized measure of construal level, which has been validated in previous studies (Fujita et al., 2006; Soderberg et al., 2015), whereas the RCW is not (although it possesses characteristics that would lead one to expect that it constitutes a viable measure of construal level; see Krüger et al., 2014).

Further, whereas the psychological distance items dealt specifically with climate change, the BIF items measured construal of "general" actions, but did not measure construal of "climate change" or "pro-environmental" actions specifically. In Study 1, we used two putative measures of construal level, namely the BIF (Vallacher and Wegner, 1989) and the RCW scale (Pettigrew, 1958; Krüger et al., 2014), with only the latter measuring environment-related items. Accordingly, it remains possible that the BIF might predict environmental behavior, and perceived psychological distance from climate change, if it contained items measuring construal of climate change directly. To test this possibility, a replication of Study 1 was conducted using an augmented version of the BIF that contained items assessing general and environmental construals.

## Methods

### Participants, Materials, and Procedure

A total of 216 (105 female) Australian adults recruited once again by Qualtrics.com participated in the study. The mean age was 43.48 years (range 18–79), and the median gross annual income bracket was $35,000–49,999 per year. Age, gender, and income groups approximated a representative distribution of Australia's population, to the same specifications as Study 1.

The materials and procedure of the study followed that of Study 1. The only difference was the inclusion of an augmented version of the BIF. The new BIF scale consisted of 22 items–11 items from the original scale that focused on general issues (general sub-scale; BIF-G), and 11 items that focused on environmental issues (environmental sub-scale; BIF-E; see **Supplementary Information**). Participants were asked to select either a concrete or an abstract description for each action. For instance, the behavior "carpooling" could be described as "sharing transportation with others" (concrete), or "reducing the number of cars on the road" (abstract), or the behavior "taking public transport" could be described as "catching a bus or train" (concrete) or "traveling in an energy efficient way" (abstract).

## Results

**Table 6** shows the descriptive statistics for key variables. While in Study 1, responses on the two psychological distance measures decreased with increasing belief in anthropogenic climate change, in Study 2 this pattern was only replicated for the PD2 measure, whereas responses on the PD1 measure did not vary according to climate change belief category. However, replicating Study 1, responses on both construal level measures were invariant with respect to climate change beliefs (**Figure 1B**). The psychological distance measures also exhibited similar distributions to those observed in Study 1 (**Figure 2B**).

### Comparing Construal Level Measures

Correlations between the environmental form of the BIF and psychological distance, the RCW, and other related variables are shown in **Table 7**. The BIF-E was positively correlated with behavioral control and ductile worldview, and negatively

**TABLE 6 |** Descriptive statistics for Study 2.

| Type of measure | Variable | Minimum (absolute) | Mean | Maximum (absolute) | *SD* | α |
|---|---|---|---|---|---|---|
| Covariates | Skepticism | 1.00 (1) | 2.50 | 5.00 (5) | 0.96 | 0.87 |
| | Behavioral control | 1.50 (1) | 3.15 | 5.00 (5) | 0.72 | 0.76 |
| | Ductile worldview | 1.00 (1) | 3.71 | 5.00 (5) | 0.66 | 0.79 |
| | Elastic worldview | 1.00 (1) | 2.47 | 5.00 (5) | 0.78 | 0.81 |
| | Time perspective | 1.00 (1) | 4.65 | 6.93 (7) | 0.82 | 0.80 |
| | Place attachment | 1.00 (0) | 3.60 | 5.00 (6) | 0.89 | 0.89 |
| Psychological distance | PD1 | 1.00 (1) | 2.48 | 5.00 (5) | 0.73 | 0.94 |
| | PD2 | 0.00 (0) | 43.58 | 100 (100) | 17.91 | 0.73 |
| Construal level | BIF | 0.00 (0) | 0.46 | 1.00 (1) | 0.20 | 0.79 |
| | Environmental | 0.00 (0) | 0.46 | 1.00 (1) | 0.25 | 0.68 |
| | General | 0.00 (0) | 0.46 | 1.00 (1) | 0.22 | 0.63 |
| | RCW | 0.00 (0) | 1.45 | 3.00 (3) | 0.50 | 0.78 |
| | Environmental | 0.00 (0) | 1.49 | 3.00 (3) | 0.55 | 0.66 |
| | General | 0.00 (0) | 1.39 | 3.00 (3) | 0.59 | 0.61 |
| Dependent measure | Individual pro-environmental behavior | 1.71 (1) | 3.37 | 4.65 (5) | 0.52 | 0.75 |
| | Policy choice | 1.00 (1) | 3.07 | 5 (5) | 1.47 | NA |
| | **Belief-type** | | | **% of sample** | | |
| Belief | Deny | | | 3% | | |
| | Don't know | | | 6% | | |
| | Natural causes | | | 35% | | |
| | Anthropogenic | | | 56% | | |

correlated with PD1, PD2, elastic worldview, and skepticism. The BIF-G showed weaker, but still significant correlations with some of these variables, but no relationship with skepticism, and PD2. The BIF-E and BIF-G were moderately correlated with one another, but notably, neither correlated with the RCW scales. As in Study 1, the RCW items showed no significant correlations with any variables besides themselves (PCA shown in **Supplementary Information**).

To probe the BIF and RCW scale in more depth, we examined the underlying component structure of these measures, the results of which are given in **Supplementary Information**. In brief, there were six components extracted. The RCW sub-scale items tended to load on the same components, environmental items loaded on the same components, and general items loaded on the same components. The BIF item loadings fell on three components, apparently distinguished by the nature of the behaviors described, rather than their (lack of) environmental content. For instance, general items such as "greeting someone," and "resisting temptation," loaded on the same component as the environmental item "using canvas bags for shopping," while environmental items such as "recycling," and "installing solar panels," loaded on a separate component, with general behaviors such as "measuring a room for carpeting."

## Predicting Pro-environmental Behavior

**Table 5** shows the results of a linear regression predicting pro-environmental behavior, contrasting Study 1 and 2. The model explained 32.5% of variance. The reliable predictors of pro-environmental behavior in Study 2 were gender, age, political orientation, BIF-E, time perspective and place attachment. Other variables, including psychological distance and skepticism were not significant predictors. There was no replication of the mediation effect found in Study 1 whereby the effect of psychological distance (skepticism) on pro-environmental behavior varied according to whether the skepticism (psychological distance) measure was included or excluded in the regression analysis.

To examine the effect of adding the BIF-E, we conducted the regression in two steps, adding BIF-E at the second step. The contribution of the variable to the model was small but significant ($R^2$ change = 0.021, $F$ = 7.109, $p$ = 0.008). The stepwise model is shown in **Supplementary Information**. However, the introduction of BIF-E did not produce notable differences to the variance attributed to PD1, skepticism, or any of the construal level measures.

For the policy choice variable, the model predicted 19% of variance, and marginally significant predictors were PD1,

**TABLE 7 |** Correlations for key variables and dependent variables in Study 2.

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Skepticism | −0.54** | −0.50** | 0.64** | 0.74** | 0.53** | −0.31** | −0.13 | −0.10 | −0.05 | −0.49** | 0.05 | −0.24** | −0.43** |
| (2) Behavioral control | – | 0.39** | −0.46** | −0.55** | −0.43** | 0.39** | 0.30** | −0.03 | −0.03 | 0.50** | 0.21** | 0.26** | 0.31** |
| (3) Ductile | | – | −0.57** | −0.60** | −0.39** | 0.29** | 0.26** | 0.08 | −0.01 | 0.42** | 0.06 | 0.37** | 0.25** |
| (4) Elastic | | | – | 0.66** | 0.46** | −0.35** | −0.19** | −0.09 | −0.02 | −0.52** | 0.01 | −0.32** | −0.37** |
| (5) PD1 | | | | – | 0.69** | −0.32** | −0.22** | −0.05 | 0.00 | −0.53** | −0.03 | −0.30** | −0.41** |
| (6) PD2 | | | | | – | −0.18** | −0.11 | −0.01 | −0.04 | −0.33** | 0.01 | −0.22** | −0.33** |
| (7) BIF-E | | | | | | – | 0.58** | −0.02 | −0.08 | 0.42** | 0.16* | 0.34** | 0.21** |
| (8) BIF-G | | | | | | | – | 0.09 | 0.07 | 0.26** | 0.19** | 0.14* | 0.08 |
| (9) RCW-E | | | | | | | | – | 0.48** | 0.04 | −0.17* | −0.03 | 0.06 |
| (10) RCW-G | | | | | | | | | – | 0.09 | −0.17* | 0.01 | −0.09 |
| (11) Time perspective | | | | | | | | | | – | 0.11 | 0.42** | 0.27** |
| (12) Place attachment | | | | | | | | | | | – | 0.20** | −0.02 |
| (13) Pro-environmental behavior | | | | | | | | | | | | – | 0.14* |
| (14) Policy | | | | | | | | | | | | | – |

***Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).*

skepticism and RCW-G. This model explains considerably less variance in the data than in the three previous analyses, despite including the same variables.

## Discussion of Studies 1 and 2

The aims of Study 2 were to replicate Study 1, and to incorporate the role of a new BIF scale corresponding to environmental behaviors (BIF-E). The findings from Study 2 do not replicate the results of the first study; psychological distance was not a predictor of individual pro-environmental behavior, and construal level was not a predictor of community-level policy choice. However, there are some results that, when combined, allow us to piece together a picture of how psychological distance and construal level may operate in the context of climate change.

### Does Psychological Distance Predict Pro-environmental Behavior?

The finding from Study 1 that psychological closeness to climate change would be associated with greater willingness to act pro-environmentally, was not replicated in Study 2. Psychological distance did not predict pro-environmental behavior at the individual level in the full model, but PD1 was marginally significant when predicting policy choice. One potential factor may be the difference in psychological distance scores by belief type (**Figure 1**). In Study 1, psychological distance (measured by PD1) was lowest for those reporting belief in anthropogenic climate change, whereas in Study 2, the same group had similar mean scores on PD1 to those in the "deny" and "don't know" groups.

There also appears to be a lot of shared variance with skepticism. Looking at all four analyses, the variance attributed to PD1 shifted when skepticism was added to the model (Study 1, policy; Study 2, policy), and the variance attributed to skepticism shifted when PD1 was added to the model (Study 1, individual, Study 2, policy). Follow-up mediation analyses (see **Supplementary Information**) show significant models for PD1 mediating skepticism and vice versa. The correlational design and the inconsistent pattern of results render it difficult to establish a clear relationship between these variables.

### Does Construal Level Predict Pro-environmental Behavior?

The role of construal level was inconsistent across both studies. The newly added environmental BIF scale was a significant predictor for individual pro-environmental behaviors, but not policy choice. This means that in Study 2, individual pro-environmental behavior was significantly predicted by abstract construal of environmental actions. The addition of BIF-E was an improvement upon the general scale, but considering the finding in Study 1 that abstract construal predicted the abstract behavior, it was expected that the BIF-E would play a role. This was not the case, and further, despite being a significant predictor in Study 1, RCW-E did not play a role in predicting policy choice in Study 2.

One notable aspect of the data is the importance of environment-specific construal level scales: in Study 1, RCW-E predicted policy choice, and in Study 2, BIF-E predicted pro-environmental behavior. The general subscales of both BIF and RCW did not play a role in predicting either. This indicates the potential importance of using topic-specific construal level scales.

### Does Construal Level Relate to Psychological Distance?

While in Study 1, none of the construal level measures correlated with measures of psychological distance, in Study 2, the BIF construal level measure was correlated with psychological distance and this correlation was stronger for the BIF-E than the BIF-G. However, the correlation is in the opposite direction to what is expected based on CLT, wherein concreteness equates to closeness, and abstractness equates to distance. On the contrary, we find that the BIF and psychological distance are negatively correlated, such that greater abstract construal correlates with less psychological distance. This, combined with the results from the regressions, suggests that construal level and psychological distance do not always correspond, and may represent two separate pathways to environmental action.

One particular limitation of the use of the BIF to measure environmental construal lies in the fact that by definition, abstract construal tends to tap into higher order values, and therefore environmental actions (such as using a shower timer) described *abstractly* tend to contain environmental value orientations (e.g., reducing water use), whereas concrete construals involve lower-order descriptions of actions (e.g., having shorter showers), and typically do not. The result is that abstract answers to items on the BIF-E may contain more explicit environmental aims than concrete answers. The potential separation of these factors is one that is worth considering in future work.

### Measurement of Psychological Distance

The two studies compared two measures of psychological distance, to ascertain which measure had the greater explanatory power, and to answer theoretical questions about psychological distance. Both PD1 and PD2 scales correlated in the directions expected, with all theoretically related variables, with the exception of construal level. Psychological distance correlated positively with climate change skepticism and elastic environmental worldview, and negatively with ductile environmental worldview and global place attachment.

There is strong evidence to suggest that both PD scales measure the same underlying construct. Aside from possessing the same relationships with several criterion variables, both measures load primarily on one component. Further, PD1 and PD2 correlate highly with one another, as full scales and as separate dimensions. One difference is that PD1 (Spence et al., 2012) appears slightly superior to PD2 (McDonald et al., 2013) in its capacity to explain pro-environmental behavior, and it has consistently higher correlations with related variables. Length of scale is an important factor in these calculations, so we conducted an analysis using the Spearman-Brown prophecy formula (a test of psychometric reliability that predicts reliability as it varies with scale length), which indicated that if PD2 had the same number of items as PD1, the discrepancy in reliability would disappear. However, the estimated correlations, after correction for attenuation, were still higher for PD1 (see **Supplementary Information**). An additional concern is that the PD2 scale may

not have permitted the full scope of responses. In its current form, the scale does not allow for the answer that climate change will affect all regions and people, regardless of closeness or distance from the self.

Another issue in the measurement of psychological distance is the considerable shared variance between psychological distance and skepticism. One explanation may be that the component of psychological distance that relates to hypothetical distance (whether climate change will happen or not) is analogous to skepticism about climate change. However, as the items across dimensions of psychological distance were all highly correlated, the relationship does not seem driven by the hypothetical distance items. Perhaps in terms of predicting behavior, perceiving climate change to be distant may have the same outcome as being skeptical of its existence.

Additionally, the measurement of psychological distance in PD1 and PD2 may be too literal. In line with CLT, feeling distant from an issue may also lead to abstract, vague thoughts about that issue, whereas feeling close might lead to more specific views. Perhaps for those who are distant from climate change, that distance manifests as more of a vague "feeling," than specific thoughts about when, where, and to whom it will have an effect.

Of the covariates included, time perspective, a distance-related variable, was one of the strongest predictors of policy choice and pro-environmental behavior. The relationship between time perspective and psychological distance was also strong; those who perceive climate change as psychologically close are also more likely to give greater consideration for future consequences, and be less swayed by immediate rewards. These results support and add to the extensive body of work linking time perspective and pro-environmental action (Milfont et al., 2012; Arnocky et al., 2013). The present findings contribute to this literature by suggesting a possible explanation for this relationship–the effect of time perspective on environmental actions may be explained by an underlying similarity between time perspective and psychological distance. Those with longer time perspectives perceive a stronger connection between present actions and future consequences (Joireman et al., 2012), which is an act of reducing distance between the present and the future. Time perspective may be conceived of as the reduction of psychological distance between now and the distant future. This explanation is consistent with research on temporal discounting, which has shown that in general, people discount future environmental costs (Hardisty and Weber, 2009).

### Potential Limitations

There may have been external changes that affected the results between the two studies, and particularly the perception of climate change policies. Study 1 was conducted in 2014, when a climate change policy was being changed. Specifically, an Emissions Trading Scheme was being repealed and replaced with a new policy, and so the issue was at the forefront of many political and policy discussions. By 2016, when Study 2 was conducted, this was no longer the case and climate policy was no longer under the spotlight. We can see from a frequency plot of policy support between the two samples that the earlier sample was more supportive of stronger emissions reduction policies (see **Supplementary Information**).

A separate issue is that Studies 1 and 2 are both correlational, so causality of the observed relationships (e.g., between psychological distance and pro-environmental action) are unclear. It may be that those who are psychologically close make more pro-environmental sacrifices, but it may also be that those less willing to make sacrifices push climate change away psychologically. The latter possibility is consistent with a motivated cognition approach (Hart and Nisbet, 2012; Leviston et al., 2014).

Further, while these correlational results have implications for CLT, particularly for its use in the context of climate change, the lack of relationship in measurement does not suggest a lack of relationship upon manipulation. Individuals are capable of both abstract and concrete construals of climate change, depending on the salient context. As Studies 1 and 2 did not provide a frame, or point of focus for construal level, it is possible that construal level was not salient. This limitation is substantiated by the finding that the effect sizes for the relationship between construal level and psychological distance are larger with greater cognitive engagement (Soderberg et al., 2015).

In Study 3 we experimentally manipulated construal level of, and psychological distance from, climate change to assess whether a relationship exists in a more cognitively engaging context, and whether causal relationships can be established.

## STUDY 3

The main aim of Study 3 was to manipulate both psychological distance and construal level frames of climate change, and test their role in predicting pro-environmental action in an experimental context. As time perspective was a key variable in the previous two studies, and an important dimension in climate change action, the present study manipulated psychological distance using variations in temporal distance.

Experiments conducted outside the context of climate change tend to show consistent and robust effects: manipulating construal level affects temporal distance, and vice versa (Trope and Liberman, 2003; Soderberg et al., 2015), although most studies only looked at timespans of less than a year. In the environmental context, the findings are less clear. In one case, researchers have found exactly what CLT would predict, namely that shifting a temporal horizon to appear closer increases pro-environmental behavior via concrete construals (Bashir et al., 2014). The aforementioned study manipulated the perceived temporal distance of a future date (e.g., "2020") by asking participants to mark the year on a horizontal line. The endpoints of the line began in the current year at the time of testing (2010), and ended either in 2025 (2020 future seems distant) or 2085 (2020 future seems close). Bashir et al. (2014) found that the manipulation successfully led participants to feel temporally closer to 2020, and that this predicted intentions and reported environmental behavior. Further, the relationship between temporal closeness and reported behavior was mediated by concrete construals of pro-environmental actions.

However, the effects reported in Bashir et al. (2014) were small and not representative of the general pattern observed in the wider literature. For instance, Rabinovich et al. (2010) conducted a study in which time perspective was manipulated, and found that people intended to behave more in line with their pro-environmental attitudes when envisioning a temporally distant situation, rather than a temporally close one. Roh et al. (2015) found the opposite; that temporal distance (discussing future consequences of climate change) led to reduced action among Republican participants. In other studies, manipulating the future timing of climate impacts has had no effect in some cases (Sundblad et al., 2011), and in other cases produced results that are variable and difficult to explain (Rickard et al., 2016). The latter study manipulated onset of major climate impacts in a close (New York) versus distant location (Singapore), at three future time points (2020, 2047, and 2066). They found that liberals showed less variability in response to manipulations, but that the highest support for climate policy was from conservatives when climate impacts were spatially close, and temporally distant (New York in 2066).

To further complicate matters, methods to evoke the perception of psychological distance can also take the form of framing tasks that seek to induce a particular construal level, confounding the two variables. One well-tested manipulation of construal level is the "how/why" method (Liberman et al., 2007; Hansen and Trope, 2012; Soderberg et al., 2015). It has been shown that framing a task in terms of "how" one might engage in pro-environmental behaviors leads to more concrete construals than framing a task in terms of "why." Pahl (2010) studied the effect of how/why framing on behavioral intentions for reducing plastic bag usage. Participants estimated engaging in the behavior sooner when they were asked "how" they might reduce plastic bags, rather than when they were asked "why" they might want to reduce plastic bags. This suggests that construal level affects participants' likelihood of engaging in pro-environmental behavior, specifically in the temporal dimension. If the relationship postulated by CLT holds, we expect that this manipulation will affect both construal level and psychological distance, and that a concrete construal ("how") will lead to perceptions of psychological closeness, and an abstract construal ("why") will lead to perceptions of psychological distance.

As discussed earlier, individual difference studies rarely measure both psychological distance and construal level and this problem is also true of the experimental literature on this topic. Additionally, those studies that have experimentally induced different levels of construal to selectively influence pro-environmental behaviors (Shwom et al., 2008; Pahl, 2010) have not measured construal level or psychological distance post-manipulation. Accordingly, in these studies there was no way to verify whether pro-environmental actions have been encouraged by a change in psychological distance, or construal level, or both variables.

The purpose of Study 3 is to plug this experimental gap by co-manipulating psychological distance and construal level. By manipulating the temporal closeness of climate change, and asking participants to evaluate the stimuli either abstractly or concretely, in Study 3 we test the effects of both variables, and measures the corresponding effect on psychological distance and construal level using verified measures. According to CLT, the closest condition should be the one that places climate change at the closest temporal moment, and where concrete construals elicit a sense of psychological closeness. Following this logic, the most distant condition should be the one that situates climate change furthest in the future, and elicits a distant mindset through abstract construals.

Conversely, the findings of Study 1 and 2 suggest that rather than concrete construals, abstract construals tend to predict climate change action. Based on these findings, an alternative prediction would be that the abstract conditions would be more effective than concrete conditions at increasing pro-environmental action.

## Methods

### Participants

A total of 320 undergraduate students (62% female, mean age = 20.83, $s$ = 7.08, range = 17–68) from the School of Psychological Science at the University of Western Australia took part in the study in Perth, in exchange for course credits.

### Design

The study adopted a 2 (construal level: concrete vs. abstract) × 3 (time horizon: past vs. present vs. future) between-participants design. An additional control condition was included in which participants were not exposed to either the construal level or time horizon manipulations. Participants were allocated at random to the seven resulting between-participant conditions. The total number of participants in each of the seven conditions was as follows: control ($N$ = 46), concrete/past ($N$ = 47), concrete/present ($N$ = 43), concrete/future ($N$ = 47), abstract/past ($N$ = 45), abstract/present ($N$ = 48), and abstract/future ($N$ = 44).

### Materials and Procedure

Participants were tested individually. They read an information sheet and provided informed consent, after which they were assigned to closed testing rooms fitted with a PC and monitor. In the experimental conditions, participants were shown a video about rainfall in Western Australia–screenshots of which are shown in **Figure 3**. The video was developed by the CSIRO Climate Adaptation Flagship based on real rainfall data collected between the years 1940 and 2010, and provides a clear visual example of rainfall reduction over time superimposed onto a map of south-west Western Australia, including Perth and surrounds.

The video was altered slightly for different conditions. In the "past" condition, the dates on the video were altered to show the last 70 years. It depicted recorded amounts of rainfall (mm) in the May-June-July period for each year from 1944 to 2014 on a map of Western Australia. This condition placed the onset of severe climate change-linked drought at 2014, and was the condition closest to the year in which the study was conducted (2015). In the "present" condition, the years on the video were modified to show the 70 years around which 2015 was the midpoint (1980 to 2050). This condition placed climate change-linked drought at 2050, and was temporally more distant. In the "future" condition, the years

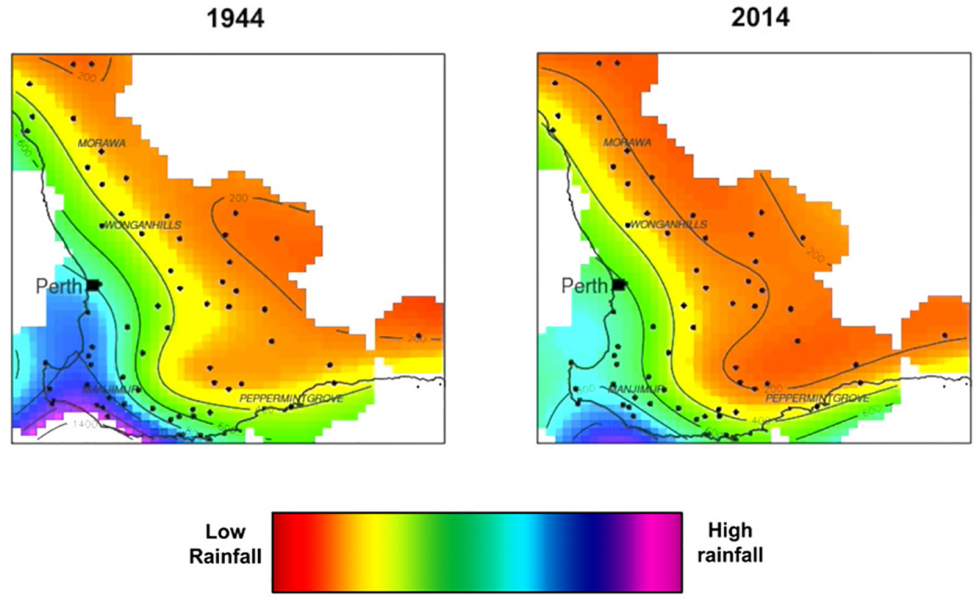


**FIGURE 3 |** Screenshots of the beginning and end of the videos shown to participants in Study 3. The left image shows rainfall levels at the earliest time point, and the right image shows rainfall levels at the latest time point. Years at the top were altered to fit each condition, and advanced as the video progressed. The scale at the bottom was shown to participants before viewing the video.

were modified to show the next 70 years, depicting 2015–2085, and placing the onset of climate change-linked drought at 2085.

In all experimental conditions, the video was followed by a message, modified to fit each condition: "Climate change is happening now. There are more dry days now than there ever have been. Due to a persistent decline in rainfall (past condition: *over the last 70 years*; present condition: o*ver the last 35 years, and that will occur over the next 35 years*; future condition: *that will occur over the next 70 years*), Perth dams (past condition: *have received*; present and future conditions: *will receive*) up to 40 percent less water."

Participants were then asked to respond to attention checks, before completing three questions designed to manipulate construal level using the how/why method (Liberman et al., 2007; Hansen and Trope, 2012; Soderberg et al., 2015). In the concrete construal condition, participants were asked to write responses to questions such as, "How are rainfall patterns changing in Western Australia?" and in the abstract construal condition, participants were asked questions such as "Why are rainfall patterns changing in Western Australia?" Participants in the control condition were not shown the video or accompanying messages, and were not asked to answer construal level questions. All participants were asked to respond to measures of psychological distance (PD1) and construal level (RCW and BIF). The RCW and BIF scales both contained general construal items and environmental construal items.

Next, participants were presented with the first behavioral measure. They were given an endowment of $10, in single $1 coins placed in an envelope on the desk in front of them. In the privacy of their individual testing room, participants had the option of keeping the entire $10, or donating some, or all, of it to Gondwana-Link, a real charity aiming to restore the natural wildlife and landscape in Western Australia. Participants were given a booklet explaining the charity and its purpose, and were invited to explore the website. The box for donations was an opaque locked money box with a coin slot, with coins already placed inside to imply to the participant anonymity of donation. The additional coins were planted by the experimenter, and were not $1 coins, so that the experimenters could distinguish donations.

Participants were then asked to complete a questionnaire measuring demographic variables, and scales used in Study 1 and 2 (time perspective, climate change belief, climate change skepticism, and perceived behavioral control, and a second behavioral measure of pro-environmental behavior: willingness to expend effort and time for the environment).

The final behavioral measure was unobtrusive. As participants were debriefed, they were offered either a Fairtrade chocolate (AlterEco), or a non-Fairtrade chocolate (Lindt) and their chocolate choice was recorded by the experimenter after the participant left the laboratory. A preference for Fairtrade products has been found to be a predictor of global identification (Reese and Kohlmann, 2015) and subsequently pro-environmental intentions and behavior (Devine-Wright, 2013).

## Results

The final sample included 319 participants. One participant was excluded for failing attention and speeding checks. Descriptive information for measured variables, collapsed across conditions, are shown in **Table 8**, and PD, BIF and RCW scores are shown in **Figure 4**.

**TABLE 8 |** Descriptive statistics for Study 3.

| Type of measure | Variable | Minimum (absolute) | Mean | Maximum (absolute) | *SD* | α |
|---|---|---|---|---|---|---|
| Covariates | Skepticism | 1.00 (1) | 2.07 | 4.20 (5) | 0.69 | 0.77 |
| | Behavioral control | 1.50 (1) | 3.43 | 5.00 (5) | 0.63 | 0.72 |
| | PD | 1.00 (1) | 2.21 | 3.86 (5) | 0.59 | 0.72 |
| | Time perspective | 2.87 (1) | 4.79 | 6.67 (7) | 0.78 | 0.86 |
| Construal level | BIF | 0.00 (0) | 0.54 | 1.00 (1) | 0.15 | 0.51 |
| | Environmental | 0.00 (0) | 0.52 | 1.00 (1) | 0.18 | 0.33 |
| | General | 0.00 (0) | 0.57 | 1.00 (1) | 0.20 | 0.53 |
| | RCW | 0.33 (0) | 1.58 | 2.61 | 0.39 | 0.72 |
| | Environmental | 0.17 (0) | 1.57 | 2.67 | 0.39 | 0.56 |
| | General | 0.00 (0) | 1.61 | 3.00 | 0.59 | 0.56 |
| Dependent measures | Pro-environmental behavior | 1.77 (1) | 3.27 | 4.29 (5) | 0.48 | 0.64 |
| | Donation behavior | $0.00 ($0) | $6.03 | $10.00 ($10) | $3.98 | NA |
| | **Belief type** | | | **% of sample** | | |
| Belief | Deny | | | 0.3% | | |
| | Don't know | | | 1.9% | | |
| | Natural causes | | | 16.3% | | |
| | Anthropogenic | | | 81.3% | | |

**All variables were measured after manipulation.*

## Psychological Distance and Construal Level

The short-form of the PD1 scale (PD) had satisfactory internal consistency reliability (α = 0.72) and the reliability coefficients did not vary appreciably across the different conditions. **Figure 4A** shows mean responses on the PD measure. To test whether mean scores differed between conditions, we dropped the control condition and conducted a 2 (construal level: concrete vs. abstract) × 3 (time horizon: past vs. present vs. future) ANOVA on the PD scores. There was no significant main effect of construal level, $F(1,267) = 0.02$, $p = 0.89$, no significant main effect of time horizon, $F(2,267) = 0.22$, $p = 0.80$, and no significant interaction between the two variables, $F(2,267) = 0.60$, $p = 0.55$.

The BIF scale was moderately internally consistent (BIF α = 0.51), but with BIF-E (α = 0.33) showing less consistency than BIF-G (α = 0.53). The low alpha was not a result of any single item. The alpha scores were relatively stable in all experimental conditions, except the control condition (BIF-E α = −0.57, BIF-G α = 0.06; for further information see **Supplementary Information**). **Figure 4B** shows mean responses on the BIF-E and BIF-G as a function of the different conditions. These data were subjected to a 2 (construal level) × 3 (time horizon) × 2 (BIF: BIG-E vs. BIF-G) ANOVA. There was a significant main effect of BIF, $F(1,267) = 14.34$, $p < 0.001$, $\eta^2 = 0.05$, with larger scores on the BIF-G than the BIF-E, but no significant main effect of construal level, $F(1,253) = 0.73$, $p = 0.39$, and no significant main effect of time horizon, $F(2,253) = 0.05$, $p = 0.78$. All of the two-way interactions and the three-way interaction were non-significant (all $F$s < 1, all $p$-values > 0.4).

The internal consistency of the RCW scale was satisfactory (α = 0.72), although this reliability was attenuated when the internal consistency of the two sub-scales was calculated separately (α = 0.57 for RCW-E, α = 0.60 for RCW-G). The average scores on the two versions of the RCW scale, as a function of the different conditions, can be examined in **Figure 4C**. These data were once again entered into a 2 (construal level) × 3 (time horizon) × 2 (RCW: RCW-E vs. RCW-G) ANOVA. There was no significant main effect of construal level, $F(1,267) = 1.34$, $p = 0.25$, no significant main effect of time horizon, $F(2,267) = 0.70$, $p = 0.50$, and no significant main effect of RCW, $F(1,267) = 1.90$, $p = 0.17$. However, there was a significant construal level × RCW two-way interaction, $F(1,267) = 4.96$, $p < 0.05$, $\eta^2 = 0.02$, which arose because there was no effect of construal level on the RCW-E scale, $F(1,267) = 0.09$, $p = 0.76$, but responses on the RCW-G scale were higher in the abstract construal condition than in the concrete construal condition, $F(1,267) = 3.28$, $p = 0.07$. The remaining two-way interactions and the three-way interaction were all non-significant (all $F$s < 1.43, all $p$-values > 0.24).

The last measure we examined as a proxy of psychological distance was time perspective. It is plausible that time perspective would be affected by the temporal manipulations. To this end, we conducted a 2 (construal level) × 3 (time horizon) ANOVA on the time perspective scores. Consistent with the earlier psychological distance analysis, there was no significant main effect of construal level, $F(1,267) = 0.03$, $p = 0.85$, and no significant main effect of time horizon, $F(2,267) = 0.89$, $p = 0.41$, but the interaction between the two variables fell just short of conventional significance levels, $F(2,267) = 2.94$, $p = 0.06$, $\eta^2 = 0.02$.

## Correlations

Correlations between key variables are shown in **Table 9**. As these variables were measured post-manipulation, interpretation should be made with caution. Consistent with the findings of Study 1 and 2, psychological distance was positively correlated with skepticism, and negatively correlated with behavioral control, time perspective, pro-environmental behavior, and donations. There was no correlation between psychological distance and any of the construal measures.

The RCW scale was largely only correlated with itself, although the RCW-G scale was weakly negatively correlated with the BIF-E. A detailed analysis by condition showed that this correlation was only significant in two conditions: concrete/future, $r^2 = -0.30$, $p = 0.05$, and abstract/future, $r^2 = -0.35$, $p = 0.02$. In the concrete/future condition, the environmental subscale of RCW was also negatively correlated with the BIF-E, $r^2 = -0.34$, $p = 0.02$.

The BIF measures partially replicated the findings of Study 2, where BIF-E showed positive correlations with key variables (behavioral control, time perspective, and pro-environmental behavior). In this study, the BIF-G was also positively correlated with the same variables, and more strongly. None of the construal level measures correlated with donation behavior.

## Predicting Pro-environmental Behavior

**Figure 5A** shows willingness to engage in pro-environmental behaviors by condition. As above, a 2 (construal level) × 3 (time horizon) ANOVA was conducted on these data. There was no significant main effect of construal level, $F(1,267) = 0.01$, $p = 0.94$, a marginally significant main effect of time horizon, $F(2,267) = 2.37$, $p = 0.09$, with participants in the past condition having lower pro-environmental behavior scores than those in

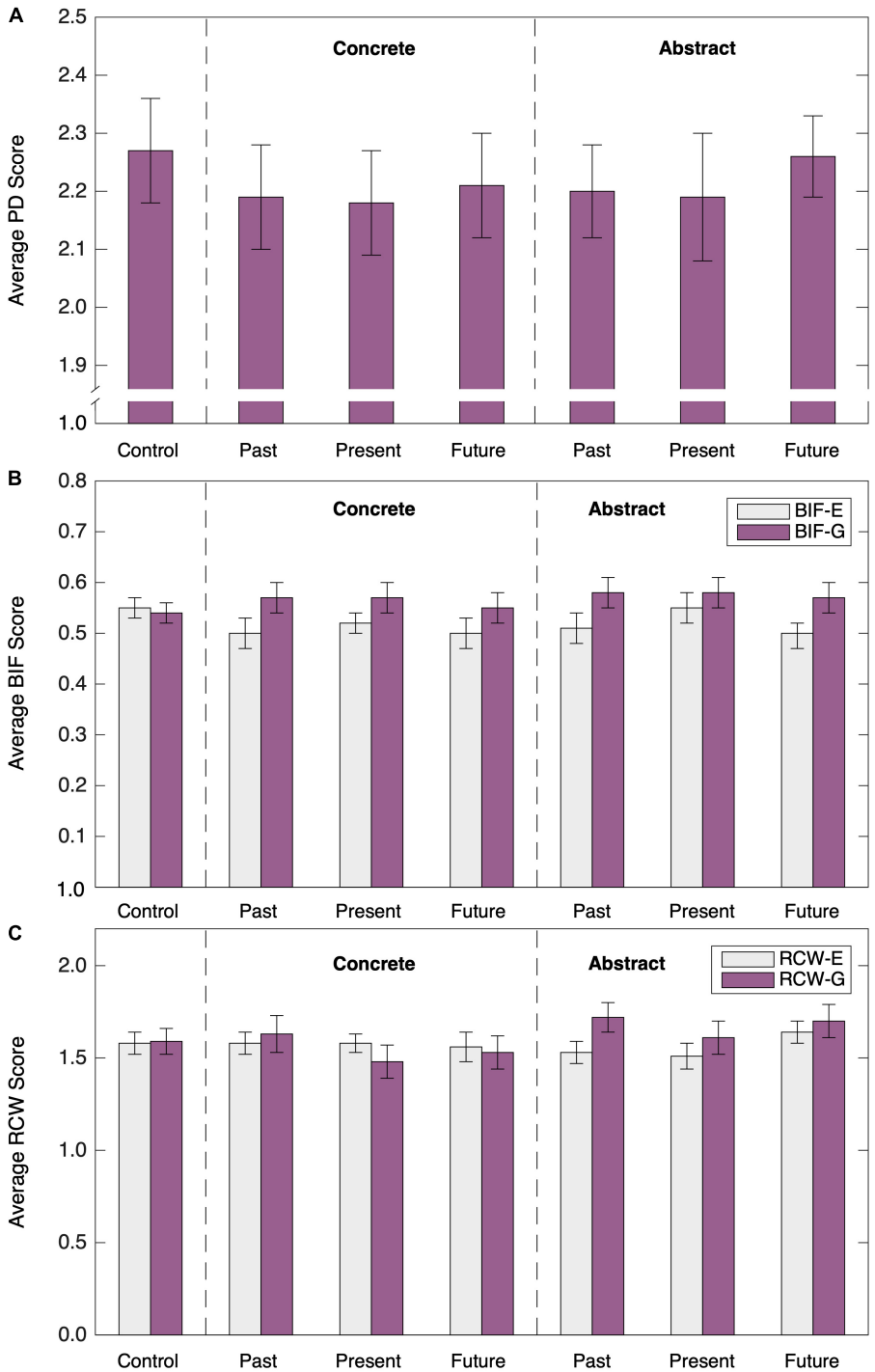


**FIGURE 4 |** Average PD **(A)**, BIF **(B)**, and RCW **(C)** scores by condition in Study 3. Error bars represent standard errors.

the present and future conditions, and no significant interaction between the two variables, $F(2,267) = 0.52$, $p = 0.60$.

## Donation Behavior

The donations to Gondwana-Link across the different conditions are shown in **Figure 5B**. These data were once again analyzed via a 2 (construal level) × 3 (time horizon) ANOVA. There was no significant main effect of construal level, $F(1,250) = 0.14$, $p = 0.71$, no significant main effect of time horizon, $F(2,250) = 1.18$, $p = 0.31$, and no significant interaction between the two variables. Although the main effect of time horizon was not statistically reliable, it merits comment that inspection of **Figure 5B**

**TABLE 9 |** Correlations between variables in Study 3.

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| (1) PD | −0.07 | 0.00 | −0.03 | −0.05 | 0.59** | −0.42** | −0.31** | −0.36** | −0.22** |
| (2) RCW-E | – | 0.44** | −0.07 | −0.07 | −0.04 | 0.01 | −0.10 | −0.10 | 0.06 |
| (3) RCW-G | | – | −0.12* | −0.08 | 0.03 | −0.07 | −0.12* | −0.04 | −0.02 |
| (4) BIF-E | | | – | 0.18** | −0.04 | 0.14* | 0.15** | 0.15** | 0.00 |
| (5) BIF-G | | | | – | −0.05 | 0.11* | 0.30** | 0.26** | 0.06 |
| (6) Skepticism | | | | | – | −0.35** | −0.26** | −0.21** | −0.19** |
| (7) Behavioral control | | | | | | – | 0.35** | 0.41** | 0.21** |
| (8) Time perspective | | | | | | | – | 0.42** | 0.19** |
| (9) Pro-environmental behavior | | | | | | | | – | 0.18** |
| (10) Donation | | | | | | | | | – |

** *Correlation is significant at the 0.01 level (2-tailed).* *Correlation is significant at the 0.05 level (2-tailed).*

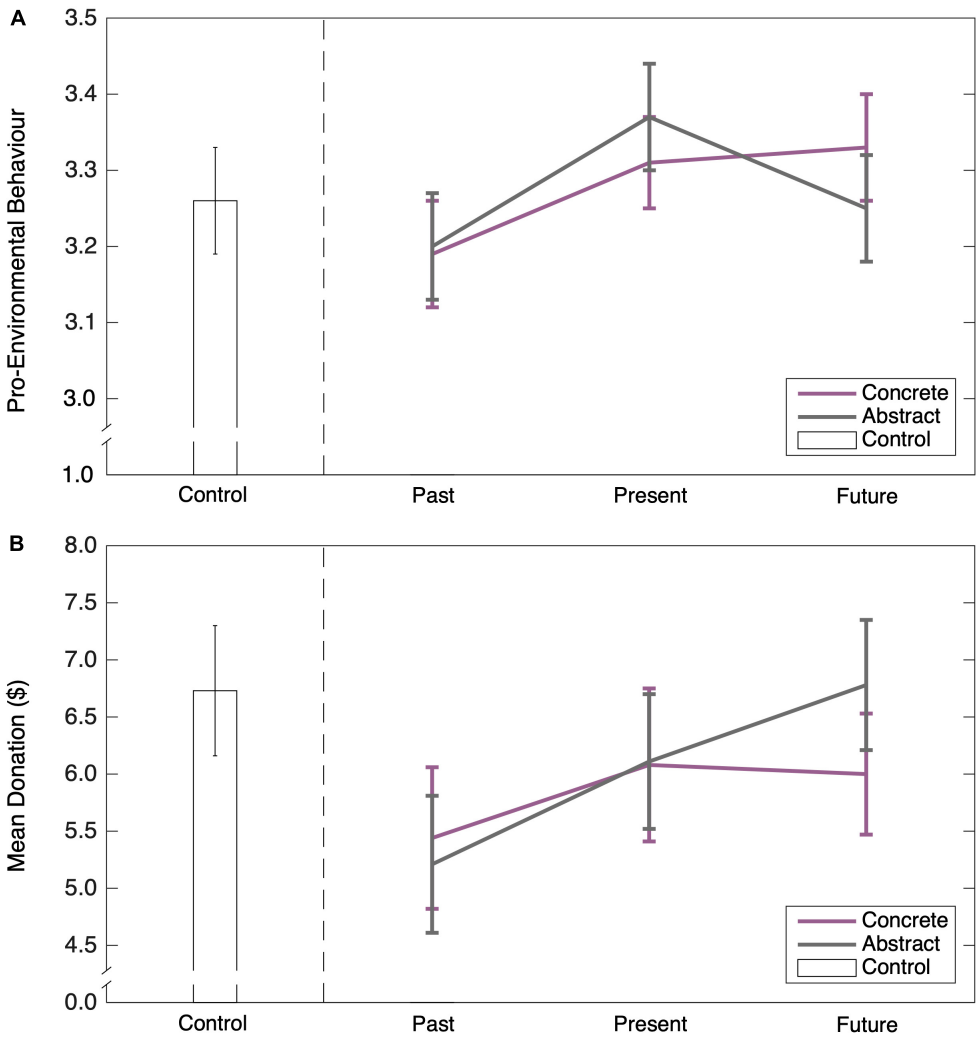


**FIGURE 5 |** Average PEB scores **(A)** and charity donations **(B)** as a function of condition. Error bars represent standard errors.

reveals a similar trend to that of behavioral intentions, whereby participants in the past condition tended to register lower donations than in the present and future conditions.

## Chocolate Choice

**Figure 6** shows the chocolate choice data for the different conditions. These data were subjected to a multinomial logistic

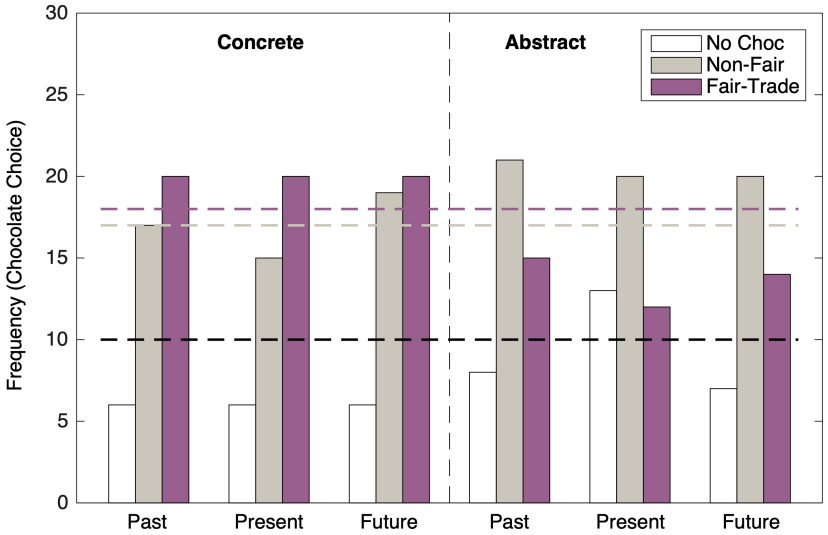


**FIGURE 6 |** Chocolate choice as a function of condition in Study 3. The broken horizontal lines represent the frequency of "No Choc" (black line), "Non-Fair" (gray line), and "Fair-Trade" (purple line) chocolate choices in the control condition.

regression analysis, with chocolate choice (no chocolate vs. non-Fairtrade vs. Fairtrade) as the outcome measure (with "Fairtrade" as the reference category) and construal level, time horizon, and the construal level × time horizon interaction as predictors. A test of the model against a constant only model was not statistically significant, indicating that the predictors as a set did not reliably distinguish between people who chose no chocolate, a non-Fairtrade chocolate, and a Fairtrade chocolate, $\chi^2(10) = 9.26$, $p = 0.51$. Accordingly, none of the variables reliably predicted chocolate choice (see **Supplementary Information** for the full table of results).

## Discussion

The purpose of this study was to test the correlational findings of Study 1 and 2 experimentally by manipulating both psychological distance and construal level. By manipulating the temporal closeness of climate change, and asking participants to evaluate the stimuli either abstractly or concretely, Study 3 tested the effects of both variables on pro-environmental behavior and measured the corresponding impact on psychological distance and construal level. We compared two hypotheses: (1) that the temporally closest condition (the "past" time horizon) would increase pro-environmental actions, and (2) that the abstract construal condition would be more effective than the concrete construal condition at increasing pro-environmental actions.

The temporal manipulations of psychological distance had an unclear effect on behavior. There was a general trend for engagement in pro-environmental behavior and charity donations to be lower in the past time horizon condition than in the present and future conditions. However, according to CLT, the closest condition should have been the past condition, where the temporal manipulation situated the worst effects of climate change at the date closest to the present (2015). Following this logic, the future should have been the most distant condition, situating the worst effects of climate change in the year 2085. However, the past condition did not lead to greater pro-environmental behavior than the future condition on any of the dependent variables. This finding is counter-intuitive, but it does partially replicate the findings of Schuldt et al. (2018), who found positive responses for the spatially near, temporally distant condition in conservatives — although political views were not a factor here. One possibility is that participants in the past condition did not perceive the final outcome (in the present year) to be as harmful as participants in the other two conditions because it represented the current reality. The videos did not clearly specify the amount of rainfall per year, and so participants may have used the current situation as a baseline.

The construal level manipulations (using the how/why method to induce a concrete vs. abstract mindset) also had no clear effect on pro-environmental behavior, which also means there was little support for the findings of Study 1 and 2. We predicted that the abstract condition would more effective than the concrete condition at increasing pro-environmental behavior. Yet the abstract construal manipulation had no more impact than concrete construal, and did not lead to more pro-environmental behavior than the control condition.

There are potential limitations of the study that merit comment. By combining construal and psychological distance manipulations, we were able to explore their compounded effect, but not their standalone impact on pro-environmental behavior. We expected the compounded effects to produce stronger results from manipulations. However, one possibility is that the combination of construal and distance conditions produced unexpected effects that we cannot disentangle without standalone manipulations against which to compare the results. Nevertheless, our findings support research suggesting that the strength of pre-existing views about climate change makes beliefs about this topic difficult to alter with different frames and mindset inductions (Brügger et al., 2015a; Schuldt et al., 2018). The role of psychological distance and time perspective as predictors of

pro-environmental behavior suggest that these views tend to be stable and not easily shifted.

In summary, the manipulation of temporal distance led to similar trends in donation behavior and behavioral intentions, where present and past conditions tended to lead to higher action than future and control conditions. The choice of chocolate showed a trend in favor of CLT, where those in the concrete condition tended to choose fair-trade chocolates more often than those in the abstract condition.

## GENERAL DISCUSSION

The aim of this paper was to systematically investigate the relationship between psychological distance and pro-environmental behavior, including the theorized link between construal level and psychological distance. The present study contributes to the literature by testing the theoretical basis for making climate change closer and more personally relevant, and by exploring the separate effects of construal level and psychological distance in the context of climate change on a range of different environmental behaviors. In three studies (two surveys and one experiment) we have demonstrated that, although there is evidence suggesting that psychological distance and construal level are linked to environmental behavior, this connection is complicated, and manipulating these variables does not necessarily lead to greater pro-environmental behavior.

Psychological closeness was a consistent predictor of pro-environmental behavior, explaining variance in individual-level behavior and policy support (Study 1, 2, 3). By contrast, measures of construal level — environmental or general — were less reliable predictors, suggesting that construal level may have limited use for predicting pro-environmental behaviors.

The research clarifies the role of CLT in the context of climate change action–the CLT proposition that concrete and abstract construals shape perceived psychological distance was not supported. We found evidence that both abstract *and* concrete construals explained variance in policy choice (Study 1, 2) and individual behavior and behavioral intentions (Study 1, 2, 3). This suggests that while psychological distance and construal level affect one another and are linked in other contexts, it is not necessarily the case in the context of climate change. One's perceived psychological distance from climate change appears unrelated to how abstractly one perceives climate change, a finding that complements other studies reporting that representations of climate change are complex and fluid, and at times simultaneously distant and proximal (Brügger and Pidgeon, 2017). The findings identify climate change as an area in which construal level and psychological distance may operate independently rather than interdependently.

Crucially, the inability to affect psychological distance and construal level through experimental manipulations (Study 3) suggests that these constructs are difficult to shift. For instance, there is some evidence to support the idea that construal level may be a stable psychological trait (Darwent, 2012; Sacchi et al., 2016), although this does not explain the lack of correlation between construal level and environmental behavior in Studies 1 and 2.

A growing body of work has shown through multiple methods that it is hard to manipulate psychological distance and construal level to affect pro-environmental action (Brügger et al., 2015b; McDonald et al., 2015; Schuldt et al., 2018). Brügger and Pidgeon (2017) have suggested that variations in individual beliefs, and the focal shifts that these cognitions prompt, can obscure messages designed to frame distance or construal in a particular way. Not only that, but focal shifts that occur as a result of framing manipulations are likely to be temporary and are therefore unlikely to produce lasting change in attitudes or behavior unless the wider context of climate communication changes.

The findings also have implications for the communication of climate change. In particular, the results indicate how to address a lack of public concern toward active engagement with climate change. First, addressing public skepticism about climate change may be more important when seeking support for environmental policies than in the context of individual behaviors and choices. It could be that communication about the imminent and future consequences and impacts of climate change is more effective than showing what has *already* happened (although considering the importance of time perspective, and related temporal discounting literature, the message may need to be more along the lines of "the future is closer than you think"). This is important, as much of climate change communication appears gridlocked on debates about how $CO_2$ levels, sea ice, and so on have changed in the past (Pearce et al., 2017). Such discussions not only focus attention away from the forthcoming consequences, they also play into an unnecessary debate about the reality of climate change and validity of climate science.

In light of the findings of the present study, it will be especially important to focus future research on the underlying features of psychological closeness. This study, and others, have found it difficult to shift these views experimentally (Brügger et al., 2015a; McDonald et al., 2015; Brügger and Pidgeon, 2017; Schuldt et al., 2018), and more recent research has focused instead on pinning down the mechanisms underlying psychological distance (Wang et al., 2018). To know that psychological distance is a predictor of pro-environmental behavior is meaningless unless we understand what it entails, to understand how perceptions of closeness are described, and how they manifest, and ultimately, what it means to be psychologically close to climate change.

## ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Human Research Ethics Office of the University of Western Australia with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Human Research Ethics Office of the University of Western Australia.

## AUTHOR CONTRIBUTIONS

SW wrote the initial drafts of the manuscript, and collected data for all studies. SW and MH conducted analyses and MH created

the figures. SW, MH, ZL, IW, and CL all contributed to designing the studies, interpreting the findings, and editing the manuscript.

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# Experiencing a Severe Weather Event Increases Concern About Climate Change

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Climate change is primarily driven by human-caused greenhouse gas (GHG) emissions, and may therefore be mitigated by changes to human behavior (Clayton et al., 2015; IPCC, 2018). Despite efforts to raise awareness and concern about climate change, GHG emissions continue to rise (IPCC, 2018). Climate change seems to be at odds with the immediate, present threats to which humans are adapted to cope (Gifford et al., 2009; Schultz, 2014; van Vugt et al., 2014). In contrast to immediate dangers, climate change is typically abstract, large scale, slow and often unrelated to the welfare of our daily lives (e.g., Ornstein and Ehrlich, 1989; Gifford, 2011). But there are moments when the consequences of climate change are readily apparent, such as extreme weather events. In the current paper, we examine the impact of personal experience with an extreme weather event, and the impact of this experience on beliefs about climate change, and intentions to take actions that can help prepare for and mitigate the consequences of climate change.

**Keywords: pro-environmental, environmental concerns, attitudes, extreme weather and climate events, hurrican, repeated-measure**

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## INTRODUCTION

Experiencing natural disasters can affect people both physically and psychologically. Past research have shown how experiencing natural disasters can affect public health outcomes such as mortality, injuries, infectious diseases, economic impact, and produce a range of psychosocial consequences (Shultz et al., 2005). Natural disasters such as hurricanes, earthquakes, and floods can lead to post-traumatic stress disorder (PTSD), depression, anxiety disorders, and even elevated rates of suicide (Madakasira and O'Brien, 1987; de la Fuente, 1990; Goenjian et al., 1994; David et al., 1996; Krug et al., 1998; Stimpson, 2005).

There is also a line of research focusing on how experiencing extreme weather can affect attitudes and pro-environmental concerns—the "experience-perception link" (Lang and Ryder, 2016). For example, van der Linden (2015) found that experiencing extreme weather events was positively related to environmental risk perception. Similarly, Li et al. (2011) reported that people were more likely to make pro-environmental donations after interpreting local temperature increases as evidence for global warming (see also Joireman et al., 2010).

Some studies do however show that experiencing extreme weather events do not increase environmental concern (e.g., Whitmarsh, 2008). A recent meta-analysis found that self-reported experiences with extreme weather only had a small positive effect on belief in climate change, while experiencing local weather change had a medium sized effect (Hornsey et al., 2016). These findings

may be interpreted as suggesting that extreme weather events increase attention to climate change under certain conditions; specifically, when extreme weather events are experienced as abnormal local temperatures (local warming), when extreme weather are temporarily proximal, or when extreme weather events are associated with financial damages (Sicso et al., 2017).

Studies examining the link between personal experience with climate change and subsequent beliefs and actions are just beginning, but there is some circumstantial evidence for an association. For example, Lang and Ryder (2016) used google trends (from 2006 to 2012) and found that search terms related to climate change intensified in the months following tropical cyclones, suggesting that people attributed extreme weather events to global warming. Another study compared student cohorts before vs. after an extreme weather event and found more favorable attitudes toward a climate-protecting politician and higher environmental concerns after the events (Rudman et al., 2013). Similarly, individuals affected by the UK winter flood in 2013/2014 reported stronger negative emotions, greater perceived vulnerability, increased salience of climate change, and higher risk perception compared to a nationally representative sample (Demski et al., 2017). More closely linked to pro-environmental actions, Rochford and Blocker (1991) found that people who perceived the flood in Tulsa, Oklahoma, in 1986 as preventable were more likely to get involved in flood-related activism. Results from a national survey across UK showed that first-hand experience of flooding was positively linked to environmental concern and even greater willingness to save energy to mitigate climate change (Spencer et al., 2011). Importantly, research on the experience-perception link seems to focus on cognitive consequences of experiencing climate change. However, as experiencing natural disasters can cause severe distress (e.g., Goenjian et al., 1994; van Willingen, 2001), we expect that such experiences will also affect emotions. For example, past research has found that U.S. mean temperature anomalies has been positively related to "worry about" climate change (Donner and McDaniels, 2013). Moreover, induced emotions have shown to increase pro-environmental policy acceptance (Lu and Schuldt, 2015), a link mediated by belief in anthropogenic causes natural disasters (Lu and Schuldt, 2016).

Although the experience-perception link of natural disasters has been tested before, past research is limited by measuring (retrospective) self-reported experience, and by using cross sectional designs or cohorts in before vs. after measures (see Reser et al., 2014, for a review). As a result, we know very little about the causal effects in the experience-perception link. For instance, previous beliefs on the causes of climate change may be attributed on the causes of climate-related natural events in order to align with the previous beliefs. In the first of its kind, the present study is a crossover design, recruiting the same participants before and after experiencing a natural disaster. This design enabled us to use repeated-measures in testing if experiencing extreme weather event influences beliefs about climate change, and intentions to take actions. Moreover, as experiencing a natural disaster have shown to result in severe distress (e.g., Goenjian et al., 1994; van Willingen, 2001), we hypothesized that after experiencing a natural disaster people would report stronger negative emotions such as fear when thinking about climate change. Hence, we suggest that when people think about climate change after experiencing extreme weather, climate change will be perceived with stronger negative emotional activation than before. In addition, we wanted to test the experience-perception link, suggesting that experiencing extreme weather positively affects pro-environmental concerns. To test our hypotheses we recruited residents of Florida, USA (without explicitly revealing the aim of the study) before and after hurricane Irma in Eleventh September, 2017.

# METHOD

## Participants

Using Amazon's Mechanical Turk (MTurk), we exclusively qualified participants that were located in Florida, USA, to take a survey "*…on your beliefs*" in exchange for $0.35. A total of 209 participants answered the first survey (from 8 to 10th of September, 2017) and were invited to take a follow-up survey in exchange for $2 during the 20–28th of September. Although participants were most likely aware of the approaching hurricane when answering the first survey, they had no direct experience of Irma. Therefore, the before- and after-design should validly test the hypothesis of experiencing extreme weather. In line with national and institutional guidelines, approval was not required. All participants gave written informed consent in accordance with the declaration of Helsinki. Because the study involved asking questions concerning a potentially negative experience, we scrutinized the questions making sure they were in accordance with the Swedish Ethical Review Act (2003:460) and that the questions could not, in any way be interpreted as offensive or causing negative affect. Respondents participating in the study were fully informed about the research objectives. Hence, an ethical approval was not required.

## Materials

Both surveys included a core set of measures based on Newman and Fernandes (2016):

- "Willingness to sacrifice" was included to assess participants willingness to reduce own resources as a means to promote pro-environmental outcomes. The scale included 3 items (e.g., *How willing would you be to pay much higher taxes in order to protect the environment? 1: Not at all willing-—5: Very willing*), showing acceptable reliability ($\alpha_{pre} = 0.92$, $\alpha_{post} = 0.93$).
- "Awareness of consequences" was included to assess participants' perceived danger of anthropogenic climate change. The scale included 6 items (e.g., *In general, do you think that a rise in the world's temperatures caused by climate change is … 1: Not at all dangerous for the environment – 5: Extremely dangerous for the environment*), showing acceptable reliability ($\alpha_{pre} = 0.86$, $\alpha_{post} = 0.88$).
- "Personal normative beliefs" was included to assess participants' personal normative aspects about climate change, such as what one "should do" and perceived "responsibility." The scale included 5 items (e.g., *I worry that the next generation will feel we didn't do enough to prevent*

*climate change. 1: Strongly disagree – 5: Strongly agree*), showing acceptable reliability ($\alpha_{pre} = 0.78$, $\alpha_{post} = 0.83$).

- "Progress vs. environment" was included to assess a perceived trade-off between prioritizing human progress or the future environment. The scale included 2 items (e.g., *People worry too much about human progress and not enough about the environment. 1: Strongly disagree – 5: Strongly agree),* showing low reliability ($\alpha_{pre} = 0.59$, $\alpha_{post} = 0.60$).

Participants were also asked how they felt when they "*…think about climate change*," this was measured with the eight emotions *fear*, *anger*, *hope* (R), *sadness*, *helplessness*, *guilt*, *shame*, *regret* on a scale from "*Very little (1)*" to "*Very much (7)*," showing acceptable reliability ($\alpha_{pre} = 0.90$, $\alpha_{post} = 0.92$). Participants' were also asked about their expectations about the hurricane using two items *"I think that the hurricane Irma will be. 1: Not at all severe—5: Extremely severe," I think that the hurricane Irma will strike. 1: Not at all close to me—5: Extremely close to me,"* and one item measured participants' perceived cause of the hurricane *"I think that the hurricane Irma is caused by global warming. 1: Strongly disagree-—5: Strongly agree."* Finally, participants provided demographic measures of age and gender and were given the opportunity to leave a comment.

The second survey included all the items in the first survey. However, when participants were asked about their perceived severity and closeness of Irma in the second survey, we modified the two items as follows: "*I think the hurricane l was…"* (1: *Not at all severe*—5: *Very severe*), and *"I think that Irma stroke…"* (1: *Not at all close to me*—5: *Extremely close to me*). As control- and demographic variables, the second survey also included perceived risks of natural disasters asking participants "*Over the next 20 years in Florida, USA, how likely do you think it is that global warming will cause each of the following? (a) Property damage, (b) Flooded streets, (c) Power outrage, (d) Decreased tourism, (e) Public distress, (f) Deaths, and (g) Public health problems." Three* items measured if people had taken actions as a consequence of Irma (e.g., *As a consequence of Irma, I have been forced to take actions*). Finally, three single-item questions measured environmental concern (*In general, how concerned are you about the environment?* 1: *Extremely unconcerned*—7: *Extremely concerned)*, political preferences (*I would describe myself as…* 1: *Extremely liberal*—7: *Extremely conservative)*, and subjective income *(Please rate your income: Extremely low, Low, Moderate to low, Moderate, Moderate to high, High, Extremely high).*

# RESULTS

## Sample and Attrition Analysis

One hundred and thirty one participants answered both the first and the second survey. Nine participants were excluded as they were not located in Florida or were outliers in response time when taking the survey. As a result, the final sample consisted of 122 participants (58.2% female, $M_{age} = 38$, range = 19–73). In political preferences, 34.5% reported being conservative, 41.9% being liberal, and 23.8% in-between conservative and liberal. When reporting subjective income, 39.5% reported extremely low, low, or moderate to low. 49.2% Reported having moderate income, and 10% reported moderate to high, high or extremely high. After experiencing Irma, 82.8% reported that the hurricane stroke very or extremely close to them in space. 87.7% reported taking actions or seeing others take actions as a consequence of Irma. Finally, after Irma, 80.2% reported being concerned about the environment and 82.8% reported that it is somewhat likely or very likely that global warming will cause societal and public health problems in Florida over the next 20 years.

Independent *t*-tests compared participants who answered both surveys to those only answering the first survey on the core set of measures, cause of Irma, emotions, severe, and closeness. No comparison reached significance (all $p$'s $> 0.05$) indicating that the attrition did not systematically skew the data.

## Pre- and Post-Measures

As our main analysis, we compared answers before vs. after Irma using paired-samples *t*-tests (see **Table 1**). Results showed that after experiencing Irma, participants reported stronger negative emotions when thinking about climate change compared to before [$t_{(121)} = 3.00$, $p = 0.003$, $d = 0.30$]. After Irma, participants were more willing to sacrifice (pay higher prices, pay higher tax, and accept cuts in standards of living) than before Irma [$t_{(121)} = 1.99$ $p = 0.049$, $d = 0.17$]. However, this effect seems to be driven by the willingness to pay higher taxes to protect the environment after Irma [$t_{(121)} = 2.45$, $p = 0.016$, $d = 0.24$], while the willingness to pay higher prices was not significant and showed a small effect size ($p = 0.066$, $d = 0.18$) and willingness to accept cuts in standards of living was not affected ($p = 0.909$, $d < 0.01$). Participants were more certain that Irma was caused by global warming after experiencing the hurricane compared to before [$t_{(107)} = 2.4$, $p = 0.018$, $d = 0.23$]. There was no evidence for change in personal normative belief before vs. after Irma [$t_{(106)} = 1.23$, $p = 0.223$, $d = 0.13$]. Although a positive tendency, the change for awareness of consequences did not reach statistical significance [$t_{(121)} = 1.71$ $p = 0.089$, $d = 0.17$]. Finally, a marginally significant unexpected negative effect of progress vs. the environment was observed [$t_{(121)} = -2.0$, $p = 0.050$, $d = -0.21$], indicating that participants were less willing to prioritize environmental actions over human progress after Irma (see **Table A1**, for correlations between all pre-and post-measures). Additional analyses found that neither political preference nor income moderated these repeated-measures effects significantly (all $p$'s $> 0.05$).

## Mediation

To explore the mechanisms driving change in willingness to pay higher taxes as a consequence of experiencing Irma, we wanted to test the role of emotions. Change scores (post—pre) were calculated for two variables showing significant change: emotions, and willingness to pay higher taxes. Although not significant, we also included the change scores for personal normative belief, as changes in normative belief may affect the relationship between emotions and willingness to pay higher taxes.

In order to explore possible antecedents of willingness to pay higher taxes, these three variables were correlated. Results

**TABLE 1 |** Effects of experiencing an extreme weather event presented in means and standard deviations for both pre- and post-measures, and *p*-values, effect sizes and confidence intervals for change between pre- and post-measures.

| Measure | $M_{T1}$ | $SD_{T1}$ | $M_{T2}$ | $SD_{T1}$ | *p*-value | $M_{diff}$ | 95% CI $M_{diff}$ | $d_{RM}$ |
|---|---|---|---|---|---|---|---|---|
| Emotions | 4.28 | 1.26 | 4.50 | 1.48 | 0.003 | 0.22 | 0.07, 0.36 | 0.30 |
| Cause of Irma | 3.41 | 1.25 | 3.61 | 1.29 | 0.018 | 0.20 | 0.04, 0.37 | 0.23 |
| Willingness to sacrifice | 3.10 | 1.13 | 3.20 | 1.15 | 0.049 | 0.11 | 0.01, 0.21 | 0.17 |
| **WILLINGNESS TO…** | | | | | | | | |
| Pay higher prices | 3.20 | 1.15 | 3.34 | 1.20 | 0.066 | 0.13 | −0.01, 0.27 | 0.18 |
| Pay higher taxes | 3.02 | 1.26 | 3.21 | 1.32 | 0.016 | 0.18 | 0.03, 0.33 | 0.24 |
| Cuts standards of living | 3.07 | 1.24 | 3.07 | 1.16 | 0.909 | 0.01 | −0.13, 0.15 | 0.00 |
| Awareness of consequences | 4.08 | 0.77 | 4.17 | 0.80 | 0.089 | 0.09 | −0.01, 0.19 | 0.17 |
| Personal normative belief | 3.87 | 0.82 | 3.93 | 0.91 | 0.223 | 0.06 | −0.04, 0.16 | 0.13 |
| Progress vs. the environment | 3.84 | 1.00 | 3.71 | 1.03 | 0.050 | −0.13 | −0.26, 0.01 | −0.21 |

*$M_{T1}$, Mean for time 1; $M_{T2}$, Mean for time 2; $SD_{T1}$, Standard deviation for time 1; $SD_{T2}$, Standard deviation for time 2; $M_{diff}$, Mean difference; 95% CI, 95% Confidence interval; $d_{RM}$, Cohen's d for repeated-measures.*

showed that change in willingness to pay higher taxes correlated significantly with change in emotions ($r = 0.20$, $p = 0.03$, $n = 122$) and change in personal normative belief ($r = 0.19$, $p = 0.045$, $n = 107$).

To further explore our main proposition, that perceiving Irma would increase willingness to pay higher taxes, we tested if the relationship between increased negative emotions and increased willingness to pay higher taxes was mediated by change in personal normative belief. Using the software *Process* 2018 in *SPSS* we ran a mediator analysis (Model 1). We entered change in personal normative belief as a mediator in the path between change in negative emotions and change in willingness to pay higher taxes. Results showed a significant model [$F_{(3,103)} = 3.06$, $p = 0.03$, $R^2 = 0.08$]. The model revealed a significant direct effect of emotions on willingness to pay higher taxes ($\beta = 0.21$, $t = 2.10$, $p = 0.04$, 95% CI [0.01,0.40]). However, neither the effect of personal normative belief ($\beta = 0.19$, $t = 1.24$, $p = 0.22$, 95% CI [−0.12,0.50]), nor the interaction term ($\beta = 0.06$, $t = 0.35$, $p = 0.72$, 95% CI [−0.26,0.37]) were significant.

In further exploring these data, the Johnson-Newman technique revealed that the effect of emotions on willingness to pay higher taxes was significantly mediated by change in personal normative belief within the regions of 0–0.56 (see **Table A2**). This suggests that for participants who expressed lower personal normative beliefs after Irma (−1.4–0), the relationship between negative emotions and willingness to pay higher taxes was non-significant. Only for participants showing an increase of personal normative belief (+0.14–+0.56) was strengthened negative emotions positively related to increased willingness to pay higher taxes. It should however be noted that for participants with stronger increase in personal normative belief (+0.59–1.40), the relationship between negative emotions and willingness to pay higher taxes was not significant. However, the descriptive tendency was that stronger increase in personal normative beliefs related to higher beta-values between negative emotions and willingness to pay higher taxes, (see **Figure 1**). This implies that when experiencing Irma induced heightened negative emotions while at the same time not decreasing personal normative beliefs (for example, worrying that we did not do enough to prevent climate change for the next generation) respondents also show stronger willingness to pay higher taxes for the sake of the environment.

Taken together, this suggests that in order for extreme weather experiences to result in pro-environmental actions, people need to feel that this experience was negative and think that they ought to do something about it.

## DISCUSSION

Climate change is a difficult threat for humans to cope with in a constructive manner. The problems associated with climate change are abstract and large scale, and they differ from the more immediate threats that humans are adapted to respond to. The abstract and long-term characteristic of climate change can also promote psychological rationalizations for not taking action to mitigate and prepare (Gifford, 2011). But there are moments when the consequences of climate change are readily apparent. In the present research, we examine the impact of personal experience with an extreme weather event, and the impact of this experience on beliefs about climate change, and intentions to take actions that can help prepare for and mitigate the consequences.

In a unique before and after study, we examined changes in beliefs about climate change and intentions to support or take actions before and after hurricane Irma. We found that respondents expressed stronger negative emotions toward climate change, were more certain that the hurricane was caused by global warming, and were more willing to pay higher taxes after experiencing Irma. These results support previous research on self-reported experiences (Reser et al., 2014) suggesting that experience of extreme weather events influences beliefs about climate change and intentions to mitigate its effect.

Among the variables measuring willingness to sacrifice, respondents were more willing to pay higher taxes after Irma, while there was no change in willingness to accept cuts in standards of living. One explanation for this could be that while it may seem reasonable to pay higher taxes to support mitigation and adaptation, accepting cuts in standard of living while coping with restoring the effects of the hurricane is less reasonable. A

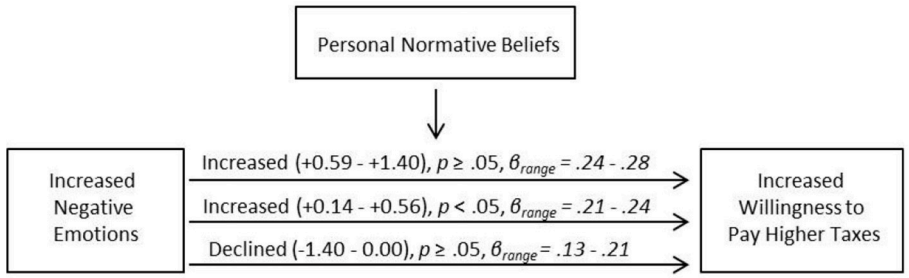


**FIGURE 1 |** Mediational model for positive relationships between increased negative emotions and increased willingness to pay higher taxes at given levels of change in personal normative beliefs.

similar explanation can be given for the results on the "progress vs. environment," which revealed a negative effect, showing that participants were more likely to prioritize human progress over the environment after Irma. Human progress may in this case be interpreted as restoring societal functions after Irma. That is, for people living in areas damaged by natural disasters, restoration may be perceived as more important than prioritizing pro-environmental actions. As some factors are more strongly related to climate change adaptation behaviors than others (van Valengoed and Steg, 2019), we would like to encourage future research to explore under which conditions extreme weather experience cause people to prioritize climate change adaptation behaviors over human progress and vice versa.

In an explorative mediation analysis, we found that heightened negative emotions as a consequence of experience extreme weather events have a direct effect of peoples' willingness to pay higher taxes. Importantly, we also found a mediating effect showing that this relationship was affected by if people though they ought to do something about the climate. More specifically, strengthened negative emotions were related to increased willingness to pay higher taxes only for people who showed stronger or unchanged personal normative beliefs. This finding has practical implications as it suggests that policy supports (i.e., pay higher taxes) as a result of experiencing extreme weather events, depends both on peoples emotional response and normative considerations (for example, thinking the next generation feels that "we did not do enough to prevent climate change").

One possible limitation when drawing conclusions of the results is that observed changes may partially be attributed to media coverage about the hurricane. Since no control group in areas not affected by the hurricane was used, the influence of such media exposure cannot be ruled out. We encourage future research, examining the experience-perception link, to add a control group which may be exposed to media reports, but not having first-hand experience of the extreme weather.

Future research should investigate other types of extreme weather events in order to corroborate the results in this study. Extreme weather events come in many shapes; flooding, hurricanes and drafts can all be observable potential climate impacts that may influence beliefs and intentions. The relationships between different types of weather events and peoples' reaction to these in terms of connection to climate change may differ however, and should be studied using before and after designs.

## CONCLUSION

In a unique repeated-measures design, we examined the experience-perception link of climate disasters, and conclude that experience matters. Experiencing the hurricane Irma intensified Floridians negative emotions toward climate change, strengthened their beliefs in that Irma was actually caused by global warming, and fostered a willingness to sacrifice to reach environmental solutions.

## AUTHOR CONTRIBUTIONS

MB developed the surveys in discussion with AN. MB collected and analyzed the data with input from AN and PS. All authors contributed in writing the manuscript and all authors approved the final version of the manuscript for submission.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.00220/full#supplementary-material

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# Our Environmental Value Orientations Influence How We Respond to Climate Change

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People variably respond to global change in their beliefs, behaviors, and grief (associated with losses incurred). People that are less likely to believe in climate change, adopt pro-environmental behaviors, or report ecological grief are assumed to have different psycho-cultural orientations, and do not perceive changes in environmental condition or any impact upon themselves. We test these assumptions within the context of the Great Barrier Reef (GBR), a region currently experiencing significant climate change impacts in the form of coral reef bleaching and increasingly severe cyclones. We develop knowledge of environmental cultural services with the Environmental Schwartz Value Survey (ESVS) into four human value orientations that can explain individuals' environmental beliefs and behaviors: biospheric (i.e., concern for environment), altruistic (i.e., concern for others, and intrinsic values), egoistic (i.e., concern for personal resources) and hedonic values (i.e., concern for pleasure, comfort, esthetic, and spirituality). Using face-to-face quantitative survey techniques, where 1,934 residents were asked to agree or disagree with a range of statements on a scale of 1–10, we investigate people's (i) environmental values and value orientations, (ii) perceptions of environmental condition, and (iii) perceptions of impact on self. We show how they relate to the following climate change responses; (i) beliefs at a global and local scale, (ii) participation in pro-environmental behaviors, and (iii) levels of grief associated with ecological change, as measured by respective single survey questions. Results suggest that biospheric and altruistic values influenced all climate change responses. Egoistic values were only influential on grief responses. Perception of environmental change was important in influencing beliefs and grief, and perceptions of impact on self were only important in influencing beliefs. These results suggest that environmental managers could use people's environmental value orientations to more effectively influence climate change responses toward environmental stewardship and

sustainability. Communications that target or encourage altruism (through understanding and empathy), biospherism (through information on climate change impacts on the environment), and egoism (through emphasizing the benefits, health and wellbeing derived from a natural resource in good condition), could work.

**Keywords: environmental behavior, cultural ecosystem services, ecological grief, natural resource management, communication, Great Barrier Reef, Australia, coastal communities**

## INTRODUCTION

Climate change perceptions and beliefs are changing, globally. Extreme events such as flooding, and slow, relentless chronic events such as drought mean that people are experiencing, first hand, climate change impacts on the special places within which they live and work (Devine-Wright, 2013; Heimann and Mallick, 2016; Nicolosi and Corbett, 2018). Increasingly, it is recognized that people's experiences with these local scale impacts provides an important impetus to review and update their global climate change beliefs and risk perceptions (Myers et al., 2012; Hansen and Cramer, 2015; Lee et al., 2015). Specifically, people are beginning to connect local events to human behaviors and causes at a global level, despite massive resistance and denial to this concept (van der Linden, 2015). However, changes in perceptions and beliefs have been extremely slow to develop, and whilst a momentum is gradually growing, acceptance that climate change is a human-caused phenomenon, and that behavior change is urgently required, still has far to go. For example, in New Zealand, Milfont et al. (2015) profiled over 6,000 residents as: those who believe in the reality of climate change and its human cause (53%), those undecided (30%), the complete skeptics (10%), and those who believe the climate is changing but is not caused by human activity (7%) (Milfont et al., 2015).

Most typically, acceptance of climate change is higher among younger females with pro-environmental or longer-term outlooks and characterized by significantly lower levels of right wing authoritarian and social dominance beliefs (Joireman and Liu, 2014; Devine-Wright et al., 2015). At least within developed county contexts, a very clear "conservative white male" effect has concurrently emerged, which doubts the science of human-caused climate change (Devine-Wright et al., 2015; Milfont et al., 2015). Nonetheless, around the world, even in industries in which it has been detrimental to acknowledge human driven climate change, a majority of people are now in agreement. In 2012, for example, Rogers et al. (2012a) reported that most rural landholders in south-eastern Australia were no longer climate change "deniers," with 70% agreeing with the statement, "The climate is changing and that human activity is a major influence" (Rogers et al., 2012a).

Concurrent with growing awareness of climate change, researchers are also reporting increasing levels of concern (Gatersleben et al., 2010). Well-documented responses to perceived catastrophic and large scale impacts and threats include a sense of disempowerment and helplessness (O'Neill and Nicholson-Cole, 2009), and even anxiety and depression (Searle and Gow, 2010). Walker et al. (2015), having surveyed over 5,000 people, reported that about one-third of Australians believed environmental quality was worsening as a result of climate change and felt angry about it (Walker et al., 2015). Marshall et al. (2019) have reported that around half of coastal residents, tourists and tourist operators, and almost one quarter of commercial fishers in the catchments of the Great Barrier Reef, expressed significant grief after reports of the degrading state of the Great Barrier Reef (GBR) resulting from climate change-related events (Marshall et al., 2019). Ecological grief is a phenomenon that needs to be better acknowledged in order to better understand the range of responses that occur in response to understanding what the consequences of climate change mean (Barnett et al., 2016). Ecological grief describes the emotional suffering associated with losses to valued species, ecosystems and landscapes that occur as a result of climate change (Benham, 2016; Bartual, 2017; Cunsolo and Ellis, 2018). Indeed, researchers are considering a new science, a science of loss, to document and make sense of the feelings associated with the devastation that climate change is causing (Barnett et al., 2016).

The extent to which people recognize that the environment is degrading as a result of climate change related events, and the extent to which people expect to be impacted, are also likely to be an important influence on people's perceptions of, and response to, climate change (Marshall et al., 2013). The premise is, if people recognize changes in the environment, then they are better placed to respond. If people are worried that the environmental changes will impact upon them either physically, financially, socially, or emotionally, then they may be more likely to develop their climate change awareness. Marshall et al. (2013) found that people that had limited climate change awareness appeared to be restricted in their ability to manage the risks associated with climate change, plan for change or be interested in undertaking behavior change.

Pro-environmental behavior is essential both within urban and rural settings. In the United Kingdom for example, 40% of carbon emissions are attributed to household and transport behavior (Gatersleben et al., 2010; Fudge and Peters, 2011; Poortinga et al., 2012). Similarly, agricultural practices are major contributors to greenhouse gas emissions (Fleming and Vanclay, 2011). Yet, whilst people are beginning to acknowledge the need for behavior change in order to both mitigate and adapt to the effects of climate change, there appears to be an obvious lag in observing any real behavior change (Fudge and Peters, 2011; Ortega-Egea et al., 2014; Wynveen and Sutton, 2017). In the United Kingdom, Gatersleben et al. (2010) found that on the one hand, quite a number of people expressed both high levels of concern for climate change, but on the other hand, reported high levels of materialism, suggesting that people have not as yet articulated how they want to respond to the reality of climate

change. That is, whilst shifting societal attitudes toward accepting climate as a major problem is critical for climate awareness and for changing behavior toward both mitigation and adaptation actions, behavior change has been slow. This may be because climate change is not necessarily seen as "interesting" even by highly engaged people (Howell, 2013).

Influencing pro-environmental behavior is becoming particularly important as the impacts of climate change worsen (Wynveen and Sutton, 2017). Belief in, and knowledge of, climate change have been linked to the adoption of more strategic adaptations in some resource-dependent industries (Rogers et al., 2012b; Marshall et al., 2013), and work inspired from Stern's value-belief-norm (VBN) theory of environmentalism suggests that perceiving adverse effects from global warming could promote mitigation behaviors (Chen, 2015). However, a growing literature is suggesting that concern about the environment should not be the main message to communicate to people in order to influence their behavior, as it may not be a primary motivation for change (Cook and Ma, 2014). Researchers are suggesting that the key catalysts for change encompass factors such as social justice, community, frugality, personal integrity, health, and beliefs in self-efficacy (Bostrom et al., 2013; Howell, 2013), in addition to the way in which climate change messaging is framed to reflect cultural values (Corner et al., 2014; Baldwin and Lammers, 2016). It appears that having a positive attitude is important, believing that the climate has been changing over the previous 30 years, and having a stronger belief in human activities influencing the climate (Cook and Ma, 2014). Women are more likely than men to adopt pro-environmental behaviors (Howell, 2013; Joireman and Liu, 2014), and so are people in societies characterized by higher levels of trust, belief in internal control, and with higher levels of individualism and "looseness" (Kalamas et al., 2014; Tam and Chan, 2017). More recent thinking suggests that the decision to adopt appropriate pro-environmental behaviors will reflect some general psychological orientations, or values, that are culturally patterned (Fielding and Hornsey, 2016; Tam and Chan, 2017).

Our purpose is to explore and add to the developing momentum of knowledge suggesting that psycho-cultural factors or value orientations shape the varied responses to climate change (Price et al., 2014; Leombruni, 2015; van der Linden, 2015; Bouman et al., 2018). We merge psycho-cultural perspectives with cultural ecosystem services through the framing of the Environmental Schwartz Value Survey (ESVS) (Bouman et al., 2018), in which four human value orientations are used to explain individuals' environmental beliefs and behaviors: biospheric (i.e., concern for environment), altruistic (i.e., concern for others), egoistic (i.e., concern for personal resources) and hedonic values (i.e., concern for pleasure and comfort). Other authors have tested for reliability and validity across a range of studies and suggested that the four categories offer a useful approach to assessing values, with expected validity issues, such as women value benevolence more than men (Lindeman and Verkasalo, 2005). Drawing on Marshall et al. (2018)'s framework of human-environment cultural values and that of Hicks et al. (2015), who independently provided value clusters for cultural ecosystem services, we examine different meanings or values that people hold for the GBR and organize them according to the ESVS, as such (Hicks et al., 2015; Marshall et al., 2018):

(1) Biospheric (appreciation of biodiversity, and scientific heritage benefits)
(2) Altruistic (appreciation of intrinsic values, and Traditional Owner heritage),
(3) Egoistic (appreciation of health benefits, wisdom and way of life, economic values, wellbeing, and lifestyle)
(4) Hedonic (appreciation of spiritual, artistic, and esthetic opportunities)

Our aims were to explore the influence of these value orientations on each of the following climate change responses: (i) global and local climate change beliefs, (ii) level of ecological grief in response to climate change related environmental degradation, and (iii) pro-environmental behaviors that are climate change specific. In doing so, we control for both perceptions of environmental impact (personal experience) and perceptions of the impact on self. As such, we expected to develop important insights into how people respond to climate change and the value orientations that influence their response. Specifically, we explore the influence of these psycho-cultural factors on how people respond to climate change and test each of the following hypotheses:

(1) Reef Grief is affected by value orientations
(2) Climate change beliefs are affected by value orientations
(3) Pro-environmental behaviors are affected by value orientations.

## CASE STUDY CONTEXT

We examine these hypotheses within the context of the GBR, a region currently experiencing significant ecological, economic and social change. The GBR is the largest coral reef ecosystem on Earth, spanning 2,300 km along the east coast of Queensland, Australia. It is one of the most inspiring landscapes within Australia (Marshall et al., 2016; Goldberg J.A. et al., 2018) and is an important part of the identity of people not only residing in Queensland but also in Australia and overseas (Gurney et al., 2017). It supports a community of nearly 800,000 people, and produces around $6.4 billion per year of economic activity (Deloitte Access Economics, 2017). The GBR is a vital contribution to the wellbeing of the local people, as well as for Australians more broadly (Larson et al., 2013, 2015). Recent surveys have documented the rich and diverse relationship that local residents, Australians, tourists, commercial fishers and tourism operators have with the GBR including use, attitudes, perceptions of threats, experiences, values, aspirations, and levels of satisfaction (Gurney et al., 2017; Marshall et al., 2017). For example, 90% of local residents in the region felt that the GBR had outstanding beauty, and were proud of its World Heritage Area status.

Following a spate of severe and cumulative regional-scale impacts related to climate change, including tropical cyclones,

and mass coral bleaching (in both 2016 and 2017), and an ongoing outbreak of coral-eating crown of thorns starfish, recent ecological monitoring suggests that the proportion of live coral coverage across all regions of the World Heritage Area have undergone a steep decline, to an extent not observed in the historical record (AIMS Long-Term Monitoring Program 2018, available at https://www.aims.gov.au/reef-monitoring/gbr-condition-summary-2017-2018). Accordingly, there has been intense media coverage surrounding the events, and sometimes misleading information around climate change threats and impacts, where the "normal" background variability in extreme climate impacts such as cyclones has made it problematic to determine whether an individual event (such as a cyclone, bush fire, drought even coral bleaching) is directly attributable to climate change (Lankester et al., 2015).

Recent research has highlighted the high level of ecological grief, or "reef grief" that is currently thus being experienced by local people (Marshall et al., 2019). However, and importantly, the impacts of global climate change on the GBR are difficult to observe at the local level given the considerable spatial and temporal variability in the patterns of impacts that occur. Impacts cannot be personally experienced across large spatial scales, unless (potentially), viewed aerially. Hence, many local people have not directly observed the effects of climate change on the Great Barrier Reef, and instead must depend on various media sources for information and knowledge of current state and status of the GBR (Lankester et al., 2015).

# MATERIALS AND METHODS

Survey data were obtained from the Social and Economic Long Term Monitoring Program (SELTMP) for the GBR (Marshall et al., 2016). Data are publically available at www.csiro.au/seltmp.

## Survey Design

A single survey statement was used to assess each of (i) perceptions of environmental impact, (ii) perceptions of impact on self, and (iii) reef grief (**Figure 1**). These questions are presented in **Figure 1**. Whilst we recognize that a single survey statement is unlikely to adequately represent the complexity of each of the concepts, we were practically limited, and suggest that any results are indicative of each concept only. Twelve survey questions were used to understand what values were important to people, and were categorized according to the ESVS. These survey questions are also presented in **Figure 1**. Survey participants were asked to agree or disagree with each survey statement on a ten-point scale where a rating of 1 represented "very strongly disagree" and 10 represented, "very strongly agree." A weighted mean was developed for each value category using a principal component analysis, where the survey responses were forced into the one factor score, after internal reliability was confirmed. Pro-environmental behaviors were measured by asking people to agree with each of four statements about environmental behavior. Given that all behaviors were correlated (Pearson correlations = 0.223**,

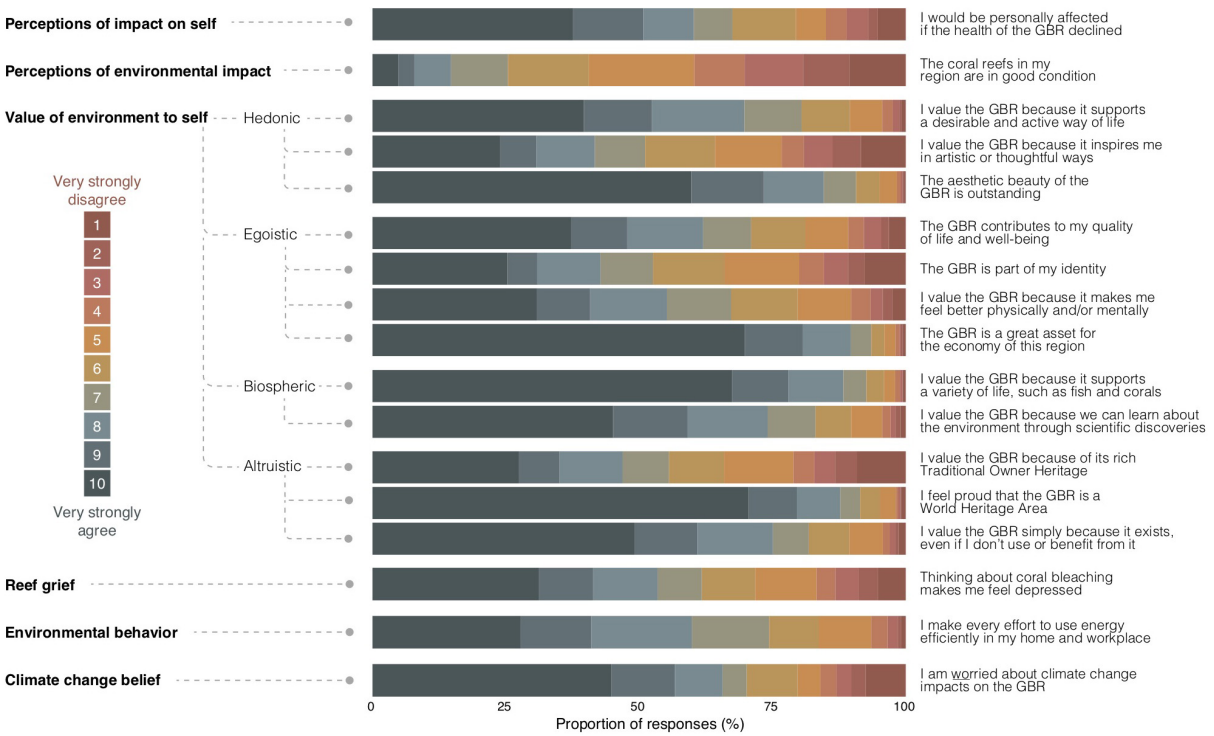


**FIGURE 1 |** Participant responses to the survey questions designed to capture each value orientation and each climate change response. Survey participants were asked to agree or disagree with each survey statement on a ten-point scale where a rating of 1 represented "very strongly disagree" and 10 represented, "very strongly agree" ($n$ = 1923).

0.288**, and 0.398**), we only used the following statement to represent all pro-environmental behaviors; "I make every effort to use energy efficiently in my home and workplace." We also quantified age and gender. Global climate change beliefs were elicited through asking participants to describe which of the given statements best reflected their views on climate change (**Figure 1**). Given that global climate change beliefs were significantly correlated with local climate change beliefs (0.285**), we only used local climate change beliefs in analyses.

## Survey Administration

Interviews were undertaken on an Apple mini-iPad loaded with an iSurvey application in public places such as parks, shopping centers, market places, airports, marinas, sporting areas, festivals, information centers, museums, jetties, caravan parks, lookouts, and other public spaces. We used a mix of "convenience sampling" and "quota sampling" (Bryman, 2012) in which we attempted to capture an approximately representative sample of people across demographic categories such as age, gender and income. A total of 1,934 local residents were surveyed, obtaining a response rate of over 50%. Not all questions were answered by all respondents. Residents were defined as people who live within the Reef catchment (East of Great Dividing Range, from Bundaberg to Cape York), while tourists lived anywhere outside of that area, either elsewhere in Australia or internationally (Marshall et al., 2016). All participants were over 18 years old and informed and verbal consent was obtained. Their information was recorded using iPads, and written consent would have been inappropriate and impractical.

## Data Analysis

In order to test our hypotheses, we fitted the value orientations and demographic factors (covariates) as fixed effects in multiple linear regression models in *R* (one for each climate change response: reef grief, environmental behavior and climate change beliefs). The significances of individual terms were tested at $\alpha = 0.05$. The variance inflation factor was systematically smaller than 5, indicating low level of collinearity among covariates. Assumptions of linearity, homoscedasticity, and normality of residuals were checked by visual assessment of plots.

## A Description of the Sample Population

A description of the participants that agreed to partake in the study is presented in **Tables 1**, **2**.

**TABLE 1 |** A description of the survey population.

| 2017 | GBR region coastal residents (*n* = 1934) |
|---|---|
| Mean age (±SE; range) | 38.0 ( ± 0.37; 17–91) |
| Gender (F:M; %) | 55:45 |
| Years living in GBR region (±SE; range) | 17.2 (±0.38; 1 month – 90 years) |
| Visited the GBR in lifetime? | 94% |
| Visited the GBR in previous 12 months? | 91% |
| Median household income (category) | $60,001–$100,000 |

**TABLE 2 |** Results describing climate change beliefs at the global scale for residents of the Great Barrier Reef.

| | % Residents (*n* = 1934) |
|---|---|
| Climate change is an immediate threat requiring immediate action | 68.4 |
| Climate change is a serious threat, but the impacts are too distant for immediate concern | 13.2 |
| I need more evidence to be convinced of the problem | 11.8 |
| I believe that climate change is not a threat at all | 2.8 |
| I do not have a view on climate change | 3.8 |

# RESULTS

## Value Orientations Within the Great Barrier Reef and Responses to Climate Change

The extent to which residents valued the GBR for biospheric, altruistic, egoistic and hedonic reasons are presented in **Figure 1**. Nearly 80% of coastal residents suggested that they would be personally affected if the health of the GBR declined, where over 37% provided 10 out of 10 for being affected (**Figure 1**). Some 37.6% of residents perceived that the coral reefs in their region were in good condition. Many respondents were not sure about coral reef condition, given that 18.4% recorded a 5/10 for their agreement with the statement, "the coral reefs in my region are in good condition" (**Figure 1**).

Nearly 82% of residents thought that global climate change was either an immediate or serious threat where over 68% of residents thought that climate change was an immediate threat requiring immediate action. Over 13% thought that climate change was a serious threat (**Table 2**). At a local scale, nearly 80% of residents were worried about climate change impacts on the GBR (**Figure 1**). A Pearson correlation analysis suggested that global and local perceptions of climate change were highly significantly correlated at the 0.01 level (2-tailed) (Pearson correlation = 0.285**). Residents reported a mean level of Reef Grief of 7.14 on a scale of 1–10 ($SD = 2.8$).

## Hypotheses Testing

Reef Grief was affected by three values (biospheric, altruistic, and egoistic), as well as by perception of environmental impact, and age and gender (**Figure 2**). Beliefs in climate change are influenced by two values (biospheric and altruistic), perceived personal impact, and perceived environmental impact, as well as age. Pro-environmental behaviors are influenced by two values (altruistic and biospheric), as well as age and gender (All climate change responses were highly significantly correlated with each other ($P < 0.01$) suggesting that people that believe in climate change are more likely to feel reef grief, and more likely to undertake pro-environmental behaviors).

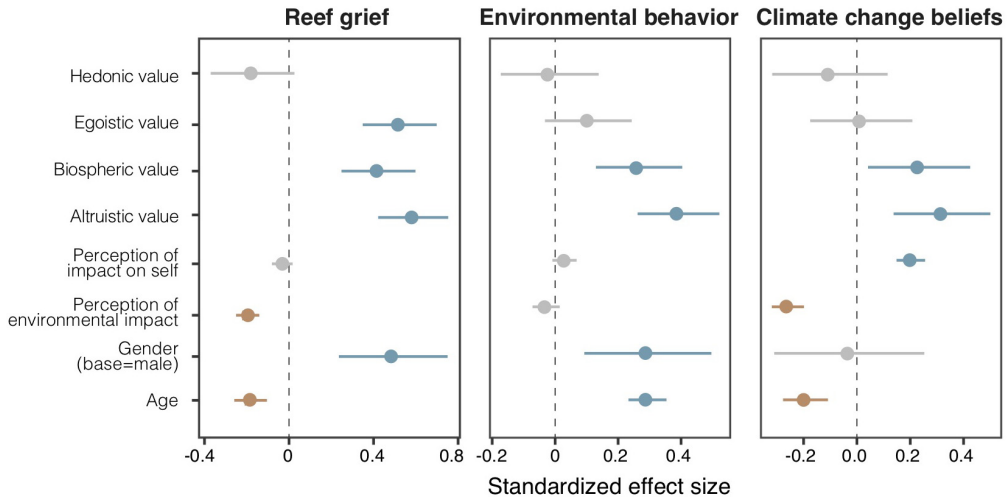


**FIGURE 2 |** Regression plots showing the significance of cultural values, perceptions of impact (on self and environment), and demographic variables on each climate change response (reef grief, behavior, and beliefs).

## DISCUSSION

Our work suggests that there is a strong internal relationship between the dimensions characterizing how people respond to change (beliefs, grief, and behavior). People that believe in climate change are more likely to feel reef grief, and more likely to undertake pro-environmental behaviors. Biospheric and altruistic values were important descriptors of each response. Egoistic values were important in describing reef grief. Age was also important in describing all responses, and gender was important to describe reef grief as well pro-environmental behaviors. Whether people perceived any environmental impact from climate change was correlated with reef grief and climate change beliefs. Whether people perceived that they would be affected by climate change was related only to their climate change beliefs.

An important tenet to this work is the observation that in 2013 51.7% of people believed that climate change was as an immediate threat requiring action (Marshall et al., 2016), whereas results from this study indicate that this percentage has increased significantly to 68.4%, suggesting that factors other than those measured in this study were important, or that the 2016 and 2017 bleaching events provided more awareness of the impacts of climate change for local residents. Given the importance of biospheric values in influencing how people respond to climate change, it is likely that people with biospheric values experienced, or were more interested in learning about climate change, where the events enabled a public discourse about environmental issues to occur. If so, then experiencing, or communicating about, climate change and its impacts can inspire behavior change in people with biospheric values, which were a very significant proportion of the local population in this study. Altruistic values, on the other hand, are perhaps more difficult to manage given that it unlikely that people might be persuaded to more highly rate intrinsic values (Howell and Allen, 2017). Perhaps though the use of communications that focuses on information and empathy (refs), it might be possible to inspire people to more highly value Traditional Owner heritage within the region and learn to develop altruistic values more broadly. Egoistic values, which were found here to be strongly correlated with reef grief, might be encouraged by communications that more broadly focus on the coastal hazard protection, health, lifestyle and wellbeing benefits associated with having natural resources such as the Great Barrier Reef, in great condition (Baldwin and Lammers, 2016). "Protect the Reef that protects us" campaigns would be powerful for those with high levels of egoistic values.

Regardless of any management intervention or communications, we can expect that, through time, the segment of society that sees climate change as an immediate threat requiring action will slowly grow. This momentum will, according to our results, occur as people more clearly experience local impacts and recognize environmental change. Older people and particularly conservative people, are unlikely to significantly contribute to society's shift toward climate change acceptance and action in the near future, but it is possible if their environmental value-orientations are better understood (Goldberg J. et al., 2018; Goldberg J.A. et al., 2018). Marshall et al. (2018) recently showed that commercial fishers in the Great Barrier Reef, a typical conservative white male cohort, did in fact shift their perceptions of the urgency of climate change from 17% in 2013 to 26% in 2017 (Marshall et al., 2016, 2018). Targeting communication efforts toward the cultural values that people hold for natural resources is likely to be more effective in shifting people's climate change attitudes and responses than trying to swing conservative white male denialism.

In sum, our hypotheses have been largely supported. Whilst we did not expressly set out to assess the influence of recognizing climate change impacts on the environment or on oneself, they both were important in influencing climate change response to some degree. We highlight that concepts such as grief

were measured using only one survey question, and that a comprehensive insight into grief is only likely through more developed future work. Nonetheless, our work suggests that a significant phenomenon is likely to be at play, and more attention to ecological grief is warranted. Further, like above, communications that highlight the impact of climate change on important natural resources such as the Great Barrier Reef, the role of such resources in providing benefits to people, as well as inspiring people to be more empathetic, such as through valuing traditional owners, it may be possible to use cultural values such as biospheric, altruistic and egoistic values to shift people toward environmental stewardship and toward responses to climate change that are more adaptive and sustainable (Evans et al., 2013).

Responding effectively to climate change through understanding its urgency (beliefs) and impacts (environmental perceptions), feeling grief (that is altruistically or egoistically driven) and adopting appropriate pro-environmental behaviors, is critical for successfully meeting the future. The certainty of an altered world where wellbeing cannot necessarily be associated with natural resource condition, is already becoming apparent (Barnett et al., 2016). Yet, people value many things about natural resources, particularly iconic resources such as the GBR (Stoeckl et al., 2014; Esparon et al., 2015; Farr et al., 2016). Natural resources support identity, pride, place, esthetic appeal, biodiversity, lifestyle, heritage, and agency (Marshall et al., 2018). Accordingly, whilst ecosystems indeed contribute to making human life possible, they also contribute to making life worth living (Costanza et al., 1997). Using cultural values may be a useful way to communicate with people and to manage our natural resources effectively.

## ETHICS STATEMENT

This work received Ethics Approval from the CSIRO Social Science Human Research Ethics Committee 050/17.

## AUTHOR CONTRIBUTIONS

All co-authors wrote the manuscript. NM collected the data and received the funds. LT, GG, and NM performed the data analysis.

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# Remembering and Communicating Climate Change Narratives – The Influence of World Views on Selective Recollection

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We examine how people remember stories about climate change and how they communicate these stories to others. Drawing on theories of reconstructive memory and cultural theory, we assume that recollection is systematically affected by an individual's world view as well as by the world view of the target audience. In an experimental study with a Norwegian representative sample ($N$ = 266), participants read a story about three politicians, in which each protagonist was described as holding a specific world view and as trying to tackle climate change with a corresponding strategy (individualistic/free market oriented, hierarchical/technology-oriented, or egalitarian/sustainability-oriented). After 1 day and then after 1 week, participants were asked to retell the story as if to somebody who was characterized as being either an individualist, a hierarchist, or an egalitarian; in addition, a neutral recall control condition without a specified audience was included. Participants' own world view was assessed and they were classified as endorsing individualism, or hierarchism, or egalitarianism. We hypothesized that retellings would be selectively reconstructed according to the world view of the participant, as well as tuned to the audience's world view. We assessed the cognitive structure of the recollected story, and, using methods from computational text analysis, we computed similarities among retellings and the original narrative, and among retellings and world views. Results suggest that (i) retellings become less accurate over time, (ii) retelling to an audience with an explicit world view leads to more strongly filtered retellings than recalling without a specified audience, but the filter operates in a non-specific manner with respect to world views, (iii) the cognitive structure of the recollected story shows small but systematic differences concerning the link between story problem and solution as a function of the participant's and the audience's world view. No interaction was found between the world view of the participant and that of the audience. Results emphasize the role of world views in communicating climate change, and might help to better understand phenomena such as polarization and echo chamber effects.

**Keywords: climate change, world views, narratives, story telling, constructive memory, audience effects, computational text analysis**

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## INTRODUCTION

Since Bartlett's seminal work on constructive memory (Bartlett, 1932), many studies have shown that people's recall of narrative information is not a literal record, but tends to be reconstructed according to one's acquired cultural knowledge. Recollections are not simply subject to random forgetting, but are the result of systematic modifications and alterations. The constructive aspect of memory has been explained by processes such as conventionalization, rationalization, simplification, assimilation, and distortion (Wagoner, 2017). What people typically remember is strongly influenced by the categories and schemata they utilize when interpreting their experiences.

Remembering also has a communicative function. We talk about our experiences, and we like to share our memories with others (Hirst and Echterhoff, 2012). Stories are the main carriers of socio-cultural knowledge and serve a social as well as an informative function (Schank and Abelson, 1995). In the process of telling stories to others, people take into account the kind of audience they are addressing; what people tell to others is influenced by their own intentions, for example, wanting to inform or to persuade, but is at the same time influenced by features of the audience they talk to, such as attitudes, expectations, or preferences (Marsh, 2007).

In this study, we apply the constructive memory framework to climate change narratives (Jones and Song, 2014; McBeth et al., 2014; Fløttum and Gjerstad, 2017; Sharman and Howarth, 2017). Concerning the climate change debate, a distinction often made is between people who endorse the assumption that climate change is happening and mainly of anthropogenic origin, and those who question that climate change is real or who consider it to be an entirely natural phenomenon (Poortinga et al., 2011; Hamilton et al., 2015). For the sake of brevity, we call these positions advocates and skeptics, respectively. Advocates and skeptics show substantial differences in their world views and political orientation, and in their beliefs about the causes and consequences of climate change. Between these camps, an increasing polarization has been observed, though the degree of polarization differs considerably between countries (Hoffman, 2011; Dunlap et al., 2016; Ceglarz et al., 2018).

Polarization may partly be attributable to so called 'echo chambers' or 'filter bubbles'; these metaphors mainly refer to social media such as Facebook and Twitter, where like-minded individuals communicate with each other, reinforcing their respective stance and evaluation of climate change (Jasny et al., 2015; Williams et al., 2015). Retelling a story about climate change to people who essentially agree with one's view may bolster this view in two ways: first, the speaker, holding world view X, adapts her retelling to her own world view; since the speaker and the listener hold the same world view, no conflict arises and the speaker's statements are likely to be accepted and reinforced by the listener. Second, the speaker tunes her retelling to the listener's world view X, and thus constructs a version that even more conforms to her own world view X. In a communication between like-minded, adaptation and tuning both enhance the correspondence between the communicators' world views and the content of the communication. We propose that such processes of constructive memory may partly account for the 'echo' in echo chambers, and for the polarization of the climate change debate.

We report a study using methods from computational text analysis (Welbers et al., 2017) to analyze participants' recollections of a narrative about climate change. This study contributes to a growing line of research which uses natural language texts or open-ended textual responses, that is, 'text as data' rather than quantitative survey questions, to investigate how people understand and evaluate climate change (Grimmer and Stewart, 2013; Paschen and Ison, 2014; Tvinnereim and Fløttum, 2015; Fløttum, 2017; Salway, 2017; Tvinnereim et al., 2017). Most research using text analysis employs a bottom-up approach, inducing regularities in massive collections of texts from online sources (Facebook, Twitter, etc.) by automated classification methods, such as clustering or topic modeling (Grimmer and Stewart, 2013; Roberts et al., 2014; Tvinnereim and Fløttum, 2015). We apply computational text analysis to data from an online experiment, analyzing quantitative characteristics of texts as a function of experimental manipulations in order to test hypotheses (Roberts et al., 2016).

Specifically, we test how the speaker's view and that of the audience shape how a story with a climate change theme is recollected and retold. In addition, we test how these recollections change over time. We hypothesize that story retellings will be adapted to the speaker's as well as to the listener's world view, and that the conformity will increase over time.

## THEORETICAL BACKGROUND

### Stories and Narratives

According to Schank and Abelson (1995), stories constitute the fundamental component of human knowledge. Stories are continuously heard from others, and told and retold to others, thereby constructing an individual's representation of his or her self and of the world (Beach et al., 2016). Stories typically follow a schematic structure (Mandler and Johnson, 1977; Mandler and Goodman, 1982). The narrative policy framework (Jones and McBeth, 2010; McBeth et al., 2014) distinguishes a setting, a plot, characters, and a moral or a solution to a problem. The characters are categorized as villains causing the problem, as victims being harmed, and as heroes solving the problem. Related approaches can be found in text linguistics (Fløttum and Gjerstad, 2013, 2017; Beach et al., 2016). Stories typically refer to an individual's experiences, whereas generalized stories that address common social or political phenomena are often called *narratives* (Mairal, 2008; Jovchelovitch, 2012; McBeth et al., 2014; Brown, 2017). In this paper, we do not strictly distinguish between stories and narratives, but use both terms for the most part synonymously.

### Climate Change Narratives and World Views

A climate change narrative represents people's understanding of the climate change issue, including political and scientific aspects. Whereas the vast majority of scientists agree about the scientific evidence concerning climate change, its dynamics and

its causes (IPCC, 2014), popular narratives may range from outright disbelief, regarding climate change as a hoax contrived by left-wing ecologists, to viewing climate change as the most pressing problem of humankind, caused by greedy and reckless capitalists. Evidence suggests that narratives rather than scientific facts represent people's understanding of climate change (Lowe et al., 2006; Fløttum and Gjerstad, 2013, 2017; Jones, 2014; Paschen and Ison, 2014; Brown, 2017). Important elements of narratives are (a) causal relations (e.g., what are the causes of climate change, how can climate change be mitigated?), (b) intentions of relevant actors (e.g., who is responsible for climate change?) (Böhm and Pfister, 2001, 2005, 2008; Bostrom et al., 2012), and (c) affective and moral evaluations of strategies to mitigate climate change as well as of consequences of climate change (Böhm et al., 2018; Doran et al., 2018).

Studies by Guber (2013) and Jones (2014) suggest that people's understanding of climate change is strongly based on their world views. World views can be considered as general cultural schemata which serve to assimilate particular experiences and stories about an issue such as climate change. We conceive of world views as serving the role of *cultural schemata* sensu Bartlett (1932), which control the way specific instances of stories are interpreted and adapted. Recent research has documented that world views as conceptualized in cultural theory (Douglas and Wildavsky, 1982; Thompson et al., 1990) play a significant role in climate change discourses and help to better understand the respective political debates about causes and strategies (Jones and Song, 2014).

We conceive of world views as the primary cultural schemata that shape how people understand social issues such as climate change. We employ the typology proposed by cultural theory (Douglas and Wildavsky, 1982; Thompson et al., 1990; Verweij et al., 2006) comprising four principal world views, each view representing a different stance concerning social relations and the relation between humans and nature: (i) The *egalitarian* view considers nature as fragile and unstable, and humans as being responsible for behaving in a sustainable way; this view is associated with a more liberal/left political orientation. (ii) The *hierarchical* view considers nature as basically stable, but vulnerable to human activities; a hierarchist relies on science and technical experts to solve problems and is moderately associated with a conservative political orientation. (iii) The *individualistic* view considers nature as robust and stable and largely immune to human activities, as long as nobody and no higher power interferes; this view is associated with a conservative political orientation, favoring free-markets and individual freedom. (iv) The *fatalist* view considers nature as well as society as unpredictable and humans as unable to influence the course of events; politically, a fatalist tends to be non-political and to refrain from political action, thinking that nothing can be done anyways. For variants on this typology see Kahan et al. (2011) or Kahan (2012).

Following Jones and Song (2014), we retain this classic approach in our study because it has proven to be a useful typology in climate change research (Jones, 2014; Jones and Song, 2014). We exclude the fatalist world view, for practical reasons and following an argument by Verweij et al. (2006; Jones and Song, 2014) that fatalists do not consistently participate in public debate about climate change simply because they are fatalists, and thus do not form a coherent schema that may influence recollections.

Typically, the type of narrative people endorse and people's political orientations are correlated (McCright et al., 2016; Ziegler, 2017). Individuals with a left-leaning political orientation (socialists, democrats, liberals, etc.) tend to show stronger belief that climate change is happening and caused by humans, and to show stronger support for strategies to mitigate climate change, than individuals with a right-leaning political orientation (conservatives, republicans, neo-liberal free-market advocates, etc.). We will take up the role of political orientations in the discussion.

## Audience Effects

Conversation is not a simple process of transmitting information. It follows rules that take into account characteristics of the speaker and the listener, and the common knowledge of speaker and listener (Grice, 1975). Much if not most of remembering occurs during social interactions and conversations, and is thus shaped by both individual memory processes (Roediger and DeSoto, 2015) and conversational rules. Depending on the social situation, what is remembered is changed and adapted to the affordances of the situation, including features of the audience (Hirst and Echterhoff, 2012; Rechdan et al., 2016). Remembering in a social context can thus be understood as a *co-construction* process (Pasupathi, 2001), whereby speakers are influenced by their schemata as well as by the requirements of the context and the expectations of the audience (Grice, 1975). Co-construction is an adaptive process characterized as audience tuning by Hellmann et al. (2011).

Thus, retelling a story to an audience is quite different from recalling a memory in isolation (Marsh, 2007). Retelling a story repeatedly alters the content and structure of the story progressively, because what is retold strengthens the memory traces of the retold information, and information that was not retold decays (Anderson et al., 2000). Repeated retelling makes the retold narrative increasingly coherent and conforming with the reteller's schema as well as with the audience schema; as a result, a retold story becomes simpler and its similarity to the original story or experience declines, while at the same time becoming increasingly coherent with respect to the endorsed cultural schemata. Echo chambers are a suitable metaphor describing this mutual reinforcing effect in the context of social media communities.

# RESEARCH QUESTIONS

Based on the theoretical background outlined above, we assume that climate change stories are shaped by the world views of people who tell such stories, as well as by the world views of the audience to whom the stories are told. World views are assumed to work as *reconstruction filters*, modifying stories when they are repeatedly told and retold. To our knowledge, the role of world views in memory and communicative processes in the context

of climate change has not yet been studied. The investigation of audience world views and their interaction with speakers' world views, in combination with applying computational text analysis, thus contributes to the novelty of this study.

Three research questions will be examined in more detail:

First, since reconstructive filtering implies simplification, we assume that over time stories will become simpler and thus less similar to the original story (*time effect*).

Second, a *schema conformity effect* is expected: stories will adapt to the speaker's world view (*speaker effect*) as well as to the audience's world view (*audience effect*). In particular, if both world views match, this effect will be especially strong and might possibly account for an echo chamber phenomenon.

Third, without an audience, retelling a story will basically be an isolated recall task; we assume that any filter mechanisms will apply to a significantly lesser degree in this situation compared to when an audience is present (*control group*).

To address these research questions, we included the speaker's and the audience's world view as independent variables. In addition, we had participants retell the story at two points in time. As there exists not the one accepted and valid method to assess story content and structure, we applied three approaches complementing each other: A sorting task of story related concepts (Coxon, 1999), and two methods from computational text analysis: similarity analysis (Kjell et al., 2019) and dictionary analysis (Welbers et al., 2017); for details see the method section.

# MATERIALS AND METHODS

An online study was conducted with a representative Norwegian sample. All manipulations and measurements were conducted online.

## Participants

The data collection was conducted by a commercial research company (Norstat). Participants were recruited from their online panel of adult (18 years and older) Norwegian citizens. The final sample consists of 266 participants that had completed all three stages of the study (presentation of the story and retelling at two points in time). Their age ranged from 18 to 82 years ($M$ = 44.5, $SD$ = 15.8); 121 were female and 145 male; 176 held a Bachelor or higher university degree.

Participants were recruited online. At the start of the study, participants were informed about the topic and aims of the study, the anonymity of their answers, and the right to withdraw at any time from their participation. Participants gave their consent to take part by clicking a button when following the link to the questionnaire.

## Design and Procedure

The experiment consisted of three stages. At Stage 0, all participants read the same original story (OS) about three politicians who set out to solve the climate change problem, but with very different strategies, leading to different consequences (see **Supplementary Material**). Participants later recollected the OS at two points in time, at Stage 1 after 1 day, and at Stage 2 after 1 week. At both points in time, there were four retelling conditions. Participants were either asked to recall the story in as complete a manner as possible (control condition without audience), or they were asked to retell the story to an audience holding a specific world view, that is, to a person who was depicted as either a typical individualist, hierarchist, or egalitarian. At the end of Stage 2, a questionnaire was administered measuring the participant's world view. Based on this questionnaire, participants were clustered into three distinct world view groups, representing individualism, hierarchism, or egalitarianism.

The experimental design is a 2 (Time) × 4 (Audience) × 3 (World View) three-factorial design, with a repeated measurement factor Time (two levels: Stage 1 and Stage 2), a between-subjects factor Audience (four levels: control, individualist, hierarchist, and egalitarian), and a quasi-experimental between-subjects factor World View (3 levels: individualism, hierarchism, and egalitarianism). Three types of dependent measures were taken: the recollected text served as the main dependent variable, a sorting task was used to measure the participants' cognitive representation of the story, and a set of further rating scales were used to assess participants' political orientation and attitude toward climate change.

## Materials

### The Original Climate Change Story

The main stimulus material consisted of a text (604 words) about three politicians who set out to tackle the problem of climate change (see **Supplementary Material**). One character Tom Brown was portrayed as a conservative relying on a technical solution, closely corresponding to a hierarchist's world view. A second character Matt Greene was portrayed as a left-wing politician with an egalitarian world view, trying to enforce stricter laws prohibiting unsustainable consumption. Bob Wayne, the third character, was portrayed as a free-market advocate with a typical individualist's world view, who promoted establishing free trade so that market forces would eventually solve the climate change issue. All three politicians encountered serious problems trying to implement their strategies; when finally some success showed up, a dispute arose among the three characters about whose strategy it was that was effective. The story ended with all three politicians being assassinated (the reader may recognize a reminiscence of Bartlett's classic story War of the Ghosts).

The story was intended to present a combination of three strategies to counter climate change, each strategy corresponding to a world view from cultural theory (individualism, hierarchism, and egalitarianism). This provided the opportunity for participants to select information corresponding to the audience's and their own world view. Due to the length and complexity of the story, after only one reading a substantial amount of forgetting was to be expected, providing room for selective recollection processes.

### Measures

At the end of Stage 2, the participant's world view was assessed, which served to classify each participant as belonging to one of

three world view groups. The recollection of the original story was assessed twice, at Stage 1 and at Stage 2. A sorting task was used to assess the cognitive representation of the story after Stage 2. Finally, at the end of the experiment, a set of judgments about political orientation and climate change attitude was elicited.

### *World views*

We assessed world view using a 20-item questionnaire in Norwegian adapted from Grendstad (2001; see **Supplementary Material**). Each world view was measured by five items, yielding scales for individualism, hierarchism, egalitarianism, and fatalism. Based on all 20 items, participants were grouped via cluster analysis (hierarchical-agglomerative using Ward's clustering algorithm) into three distinct clusters, corresponding roughly to the individualist, hierarchist, and egalitarian type. This one-to-one mapping of participant to world view serves as an approximation, in reality, most people do not represent pure types. Following Jones and Song (2014) we omitted the fatalism world view (see section "Climate Change Narratives and World Views").

### *Sorting task*

The sorting task aimed to provide a measurement of the cognitive structure of the story as mentally represented by the participant. The procedure closely followed that of Jones and Song (2014). Participants saw a list of 30 terms that were related to the original story. Participants were asked to carefully read the list of terms and then to sort them into boxes so that terms that belonged together in the story were placed together in the same box. The sorting task was done on screen via drag and drop. Participants were free to group all or only some terms into boxes, and to choose how many boxes to use. From the sorting task, we created for each participant a symmetric co-occurrence matrix with 30 rows and 30 columns, representing the 30 terms, and a 1 in each cell *i, j* if the terms i and j were placed together in the same box (otherwise 0). The aggregated co-occurrence matrix was used as an indicator of the relations among the key terms of the story as represented by the participants.

### *Retellings*

Each participant generated two recollections, the first 1 day after reading the original story, and the second after 1 week. Participants were asked to write down their recollection via keyboard in a text box shown on the screen. In the control condition, participants were asked to "write down how you remember the story, as completely as possible. It does not matter if you are uncertain about details." Thus, the control condition constitutes a free recall task. In the treatment conditions, participants read a description of ca. 100 words of a person named Jon. Depending on the condition, Jon was portrayed as an egalitarian, a hierarchist, or an individualist (for full instructions see **Supplementary Material**). After reading the description, participants were instructed to imagine what kind of person Jon is, and then asked to retell the story in a manner they would tell it if Jon were actually listening. The instruction and the full description of Jon were presented at both Stages 1 and 2. All three experimental conditions constitute a hypothetical social situation in which the participant as speaker (reteller) interacts with a particular type of listener (audience); control and treatment can be seen as contrasting a recalling with a retelling situation (Marsh, 2007).

### *Story transportation*

As controls, we measured transportation, that is, how seriously the story was read and how much participants were emotionally engaged. This was measured immediately after the story was read. Participants rated two questions: (a) 'I was mentally involved in the story while reading it,' and (b) 'The story affected me emotionally'; both on a seven-point rating scale (1 = not at all, 7 = very much).

### *Additional variables*

Participants answered a set of additional items which will not be analyzed here, such as judgments about the protagonists' strategies, ratings of participants' political orientation, and questions about climate change (all variables are included in the data set and script available online).

## RESULTS

We will first report on the classification of participants into world view clusters; this assignment of participants to world views will then be used as a quasi-experimental factor. Second, the sorting task will be analyzed in order to examine how participants' and audience world views are reflected in the participants' cognitive representations of the story. Third, we look at the textual retellings and examine via computational text analysis how the retellings' content changes as a function of the experimental factors (similarity analysis), and to what extent the retold stories conform to the speakers' and the audience's world views (dictionary analysis).

## World View Classification of Participants

To confirm the appropriateness of the four world view scales, a psychometric analysis of the 20 world view items was performed, yielding a clear four-factorial structure, explaining 39% of the variance (maximum likelihood factor analysis with varimax rotation, RMSEA = 0.049). Cronbach's alpha was 0.78 for individualism, 0.72 for egalitarianism, 0.62 for hierarchism, and 0.67 for fatalism.

Participants were then classified as individualist, hierarchist, or egalitarian, based on a cluster analysis. A distance matrix using Euclidean distances between all participants was computed from the matrix of *z*-scaled world view items. The distance matrix was subjected to a hierarchical-agglomerative clustering using Ward's algorithm (Everitt et al., 2011). The three-cluster level was selected to assign participants uniquely to one cluster, yielding an almost equal distribution of participants across clusters (individualism: 86, hierarchism: 90, and egalitarianism: 90). The mean scale value for each world view was computed for each cluster, and a cluster was labeled according to the maximum value of the world view scales (**Table 1**).

Individuals in each cluster are in fact mixtures of all world views. **Figure 1** depicts the similarities of the participants in a two-dimensional plane (fitted via ordinal multidimensional

**TABLE 1 |** Means of world view scales for three clusters.

| | Cluster | | |
|---|---|---|---|
| | 1 IND | 2 HIER | 3 EGAL |
| Individualism | *5.02* | 4.80 | 3.43 |
| Egalitarianism | 4.17 | 5.26 | *5.72* |
| Hierarchism | 4.21 | *4.55* | 3.64 |
| Fatalism | 3.11 | 3.86 | 2.80 |

*Maximum value for each world view is in italics.*

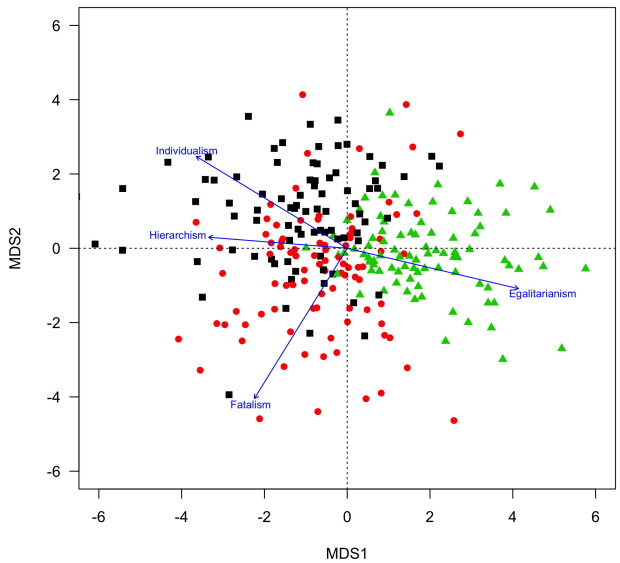


**FIGURE 1 |** Multidimensional scaling analysis of participants, based on their distance on world view items. Participants as points (black squares = individualists, red circles = hierarchists, green triangles = egalitarians), and world view scales fitted as directional vectors.

scaling of the distance matrix), with the world view scales fitted as directional vectors (Borg and Groenen, 2005). Each point represents a participant, and the projection of the point on a world view vector indicates how characteristic this world view is for this participant. The individualism and the hierarchism cluster appear as opposite to the egalitarianism cluster, and the hierarchism cluster shows substantial overlap with the individualists. **Table 1** shows that Cluster 2 is the cluster with the highest score on the hierarchism scale, though this is still less than the scores on both the individualism and the egalitarianism scale for this cluster. Note that this cluster assignment serves the aim to construct a quasi-experimental factor discriminating participants according to the three world views as defined *a priori* for experimental purposes.

## Story Representation Measured by the Sorting Task

The individual co-occurrence matrices (see section "Sorting task") for the sorting task terms were aggregated with respect to each condition of the Audience factor and of the World View factor. The aggregated matrices were converted to distance matrices by subtracting each cell frequency from the maximum value (number of participants), and subjected to a hierarchical cluster analysis using Ward's method (Everitt et al., 2011).

For interpretation, we inspected the dendrogram across all levels, closely following the approach applied by Jones and Song (2014). We interpreted aggregated clusters across Audience conditions and World View conditions, respectively, with respect to coherent sets of terms, and with respect to the role the terms play in the original story.

**Figure 2** shows the cluster dendrograms for the Audience conditions. The control condition (pure recall) yields four discernable clusters (from left to right): A cluster with terms referring to the 'chemical solution' (CHEM for short), a cluster containing terms about the 'free market' solution (FM for short) and terms signifying 'social crisis' (CRIS for short), a cluster containing all protagonists of the story including their pitiful deaths (PROT for short), and a cluster representing the 'sustainable solution' (SUST for short). In an abbreviated form, we can write for the control condition

$$\text{Control} = \text{CHEM} + \{\text{CRIS} + \text{FM}\} + \text{PROT} + \text{SUST}.$$

The individualistic audience condition yields five clusters which are largely parallel to the control condition, but with an important difference: the free market cluster is less closely connected to the crisis cluster, which appears related to the protagonists; also note that Matt Greene is part of the sustainable solution cluster. In short

$$\text{Individualist} = \text{CHEM} + \text{SUST} + \text{FM} + \{\text{CRIS} + \text{PROT}\}.$$

The hierarchical audience condition is very similar to the control condition, again linking the crisis and the free market cluster, and can be written as

$$\text{Hierarchist} = \text{CHEM} + \{\text{CRIS} + \text{FM}\} + \text{PROT} + \text{SUST}.$$

The egalitarian audience condition shows an analogous structure, but with notable differences. The crisis cluster is closely connected to the sustainability cluster, and the terms referring to the sustainable solution are grouped into a subcluster representing institutions (WHO, etc.), and another subcluster representing the political strategy (strict laws, etc.). In short

$$\text{Egalitarian} = \text{CHEM} + \text{FM} + \text{PROT} + [\{\text{SUST\_inst} + \text{SUST\_strat}\} + \text{CRIS}].$$

The audience effect shows mainly in the location of the crisis terms. In the recall condition, crisis is associated with terms indicating a free market solution; a similar clustering occurs for the hierarchist condition. Retelling the story to an individualist locates the crisis together with the story's protagonists, and retelling to an egalitarian locates the crisis close to the sustainable solution.

Comparing cluster dendrograms across World View conditions reveals a complementary pattern of crisis-solution associations (**Figure 3**). We find for individualism a structure

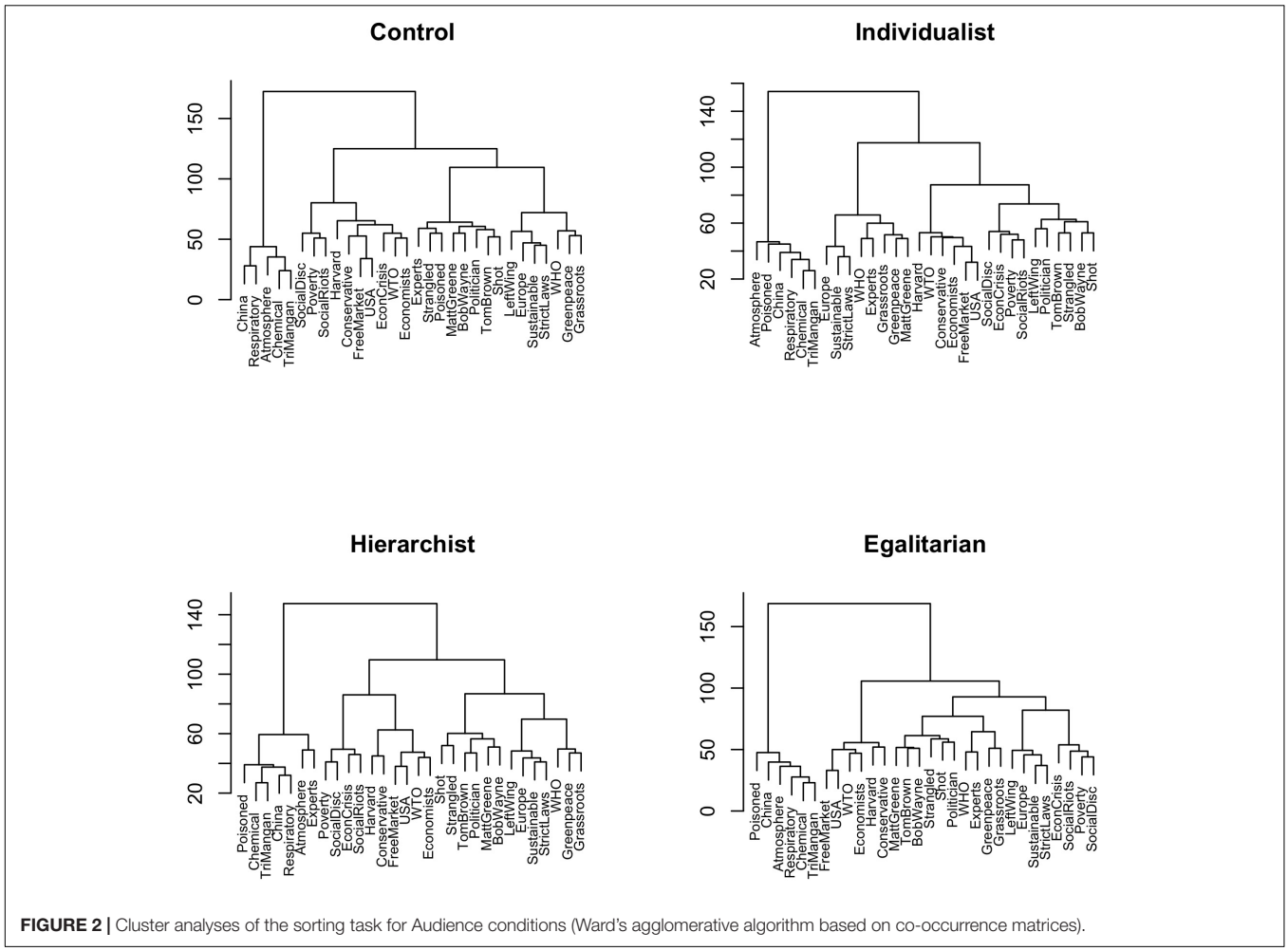


**FIGURE 2 |** Cluster analyses of the sorting task for Audience conditions (Ward's agglomerative algorithm based on co-occurrence matrices).

with a close connection of crisis and the sustainable solution. The protagonist cluster interestingly contains the WHO and the experts, subsuming abstract institutions as protagonists. In short

$$\text{Individualism} = \text{CHEM} + \text{FM} + \text{PROT} + \{\text{CRIS} + \text{SUST}\}.$$

Participants with a hierarchical world view show an interesting deviation. In addition to the typical clusters shown in the other conditions, a new cluster emerges containing terms such as 'expert,' 'politician,' and 'Harvard.' We label this cluster the expert cluster (EXP), possibly reflecting the hierarchist's view of the world as hierarchically structured with some kind of experts as a special group of people. Also, the crisis cluster is closely connected to the free market solution. In short

$$\text{Hierarchism} = \text{CHEM} + \{\text{FM} + \text{CRIS}\} + \text{SUST} + \text{PROT} + \text{EXP}.$$

Egalitarians yield a close connection of crisis, free market, and the protagonists of the story (except the egalitarian protagonist Matt Greene). As was found for the audience egalitarian condition, the sustainable cluster is divided into two subclusters, one containing institutions such as Greenpeace, one containing terms indicating strategies such as stricter laws. In short

$$\text{Egalitarianism} = \text{CHEM} + \{\text{SUST\_strat} + \text{SUST\_inst}\} + \{\text{FM} + \text{CRIS} + \text{PROT}\}.$$

As in the Audience conditions, the World View conditions differ mainly in the location of the crisis cluster. Individualistic participants see crisis as associated with sustainable solutions, hierarchical participants with free markets, and egalitarian participants with free markets and protagonists.

## Computational Text Analysis of Retellings

We obtained 532 = 2 × 266 recollections in textual form. For the original Norwegian texts, the mean number of words was 78.9 ($SD$ = 68.4, $Median$ = 59), with little difference between Stage 1 ($M$ = 80.1) and Stage 2 ($M$ = 77.7). Six recollections had zero words. For all analyses, the Norwegian texts were automatically translated to English, using the RYandexTranslate package (Chaware, 2016) for the R Computing System (R Core Team, 2018). For the translated English texts, the overall mean

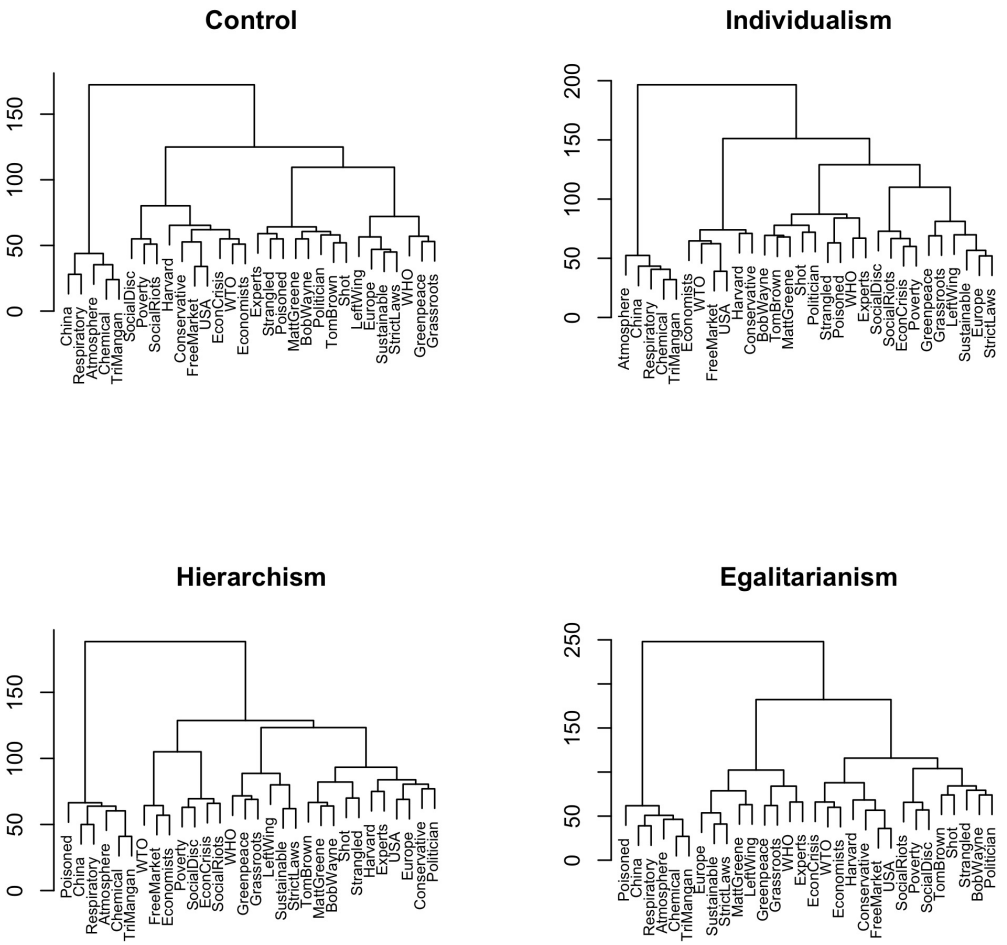


**FIGURE 3 |** Cluster analyses of the sorting task for World View conditions (Ward's agglomerative algorithm based on co-occurrence matrices). Note that the upper left dendrogram is from the Audience control condition, repeated from **Figure 2** to facilitate comparison.

number of words was 85.3 (*SD* = 75.2, *Median* = 64); for Stage 1 texts, the mean was 86.7, and for Stage 2 the mean was 83.9.

The story transportation measures indicated that participants felt moderately to highly involved while readings the story, *M* = 4.72 (*SD* = 1.50, *Median* = 5, on the 7-point scale), and that they were moderately emotionally affected by the story *M* = 3.68 (*SD* = 1.55, *Median* = 4).

The 532 translated text units served as the main text corpus. For analyses, texts were further processed using standard procedures such as lowercase conversion, deletion of stopwords, punctuation, and numbers, and stemming (Grimmer and Stewart, 2013; Welbers et al., 2017). According to the *bag-of-words* assumption, a text is viewed as a collection of words regardless of sequence and linguistic structures (Lucas et al., 2015); although this omits information, pertinent research has shown that this approach is able to capture much of the meaningful content. This reduction can be understood as a kind of normalization of texts, condensing natural text to its basic lexical content. For the reduced texts, mean word number was *M* = 40.9 per recollection (*SD* = 36.8, *Median* = 31), with little difference between Stage 1 (*M* = 41.5) and Stage 2 (*M* = 40.3). After normalization, 12 text units had zero words and were excluded from the following analyses.

## Similarity Analysis

We expected that recollections become less similar to the original story over time, due to time *per se* (Hypothesis 1). Audience effects are expected to lead to higher similarity between the retelling and the original story in the control condition than when an audience exists (Hypothesis 3); if audience and speaker world views conform, reconstructive filtering is expected to be maximal, leading to particularly low similarity of the retelling to the original story (Hypothesis 2).

As a measure of document similarity, we used the cosine similarity between two texts (Thada and Jaglan, 2013; Günther et al., 2015). The collection of terms from all text units constitutes the vocabulary of the text corpus. A single text can be represented as a vector of frequencies across the vocabulary, that is, for each term in the vocabulary, the vector indicates how often that term shows up in the text. The matrix of all text vectors, with the texts as rows and the terms as columns, represents the document-term matrix (DTM), which is used as the basic data structure. Given

two documents with text vectors $d_1$ and $d_2$ (two rows from the DTM), cosine similarity is defined as

$$s(d_1, d_2) = \frac{d_1 \cdot d_2}{|d_1| \times |d_2|}$$

Similarity ranges between 0 (no similarity, i.e., no common terms) and 1 (maximum similarity, i.e., identical text vectors). Cosine similarity $s(d_i, \text{OS})$ was computed for all 532 recollections $d_i$ with respect to the original story OS. Mean similarity was $M = 0.15$ ($SD = 0.12$; $Min = 0$, $Max = 0.55$).

An analysis of variance with similarity to the original story as the dependent variable and Audience (4 levels: Control, Egalitarian, Hierarchist, Individualist), World View (3 levels: Individualism, Hierarchism, and Egalitarianism), and Time (2 levels: Stage 1, Stage 2) as independent variables was conducted; Audience was varied between-subjects, Time was varied within-subjects, and World View was measured and served as a quasi-experimental between-subjects factor[1]. We found a main effect of Audience, $F(3,254) = 3.06$, $p = 0.029$, $\eta_p^2 = 0.03$, a main effect of Time, $F(1,254) = 9.76$, $p = 0.002$, $\eta_p^2 = 0.04$, and an interaction effect between Audience and Time, $F(3,254) = 3.22$, $p = 0.023$, $\eta_p^2 = 0.04$; overall $R^2 = 0.079$. No other significant effects or interactions emerged. Similarity as a function of Audience and World View is depicted in **Figure 4**, similarity as a function of Audience and Time is depicted in **Figure 5**. With respect to the main effect of Audience (**Figures 4**, **5**), contrast tests for the Audience factor showed that the control group was the only condition that differed significantly from the grand mean, $t(254) = 2.99$, $p = 0.003$, and, by implication, the control group differed from the three retelling conditions.

Hence, as can be seen in **Figures 4**, **5**, the main effect of Audience is based on the difference between the control condition (pure recall) and the retelling conditions. In the control condition, similarity to the OS is generally greater than in any of the retelling conditions, except among participants assigned to the hierarchism world view (**Figure 4**); no differences emerged between the three different retelling conditions. In addition, though the pattern is not significant ($p = 0.08$), we can see from **Figure 4** that for any world view, similarity is greatest if the person with that world view retells his or her story to a listener with the same world view, which is opposite to Hypothesis 2.

As expected, a significant effect of Time confirms that similarity to the original story generally declines over time (a 1 week interval). A simple effects analysis of Time across the levels of the Audience factor yields significant declines for the egalitarian condition, $t(65) = 2.52$, $p = 0.014$, and the individualist condition, $t = 2.73$, $p = 0.008$. The interaction effect between Audience and Time manifests as a significantly lower similarity at Stage 1 for the hierarchist condition, $t = -2.58$, $p = 0.011$ (**Figure 5**), in contrast to the other conditions.

In sum, similarity of retellings to the original story generally decreases over time and is higher if no particular audience is addressed than if an audience is imagined; however, no interaction of Time with the participants' world view was found, $F(2,254) = 0.72$, *ns*. On the level of overall story similarity, the assumption that retellings are specifically tailored to the combination of speaker's world view and the audience world view cannot be confirmed.

To obtain a more detailed assessment of story modifications that are specific to world views, we disentangled the original story into three story lines, one line for each central character. By construction, Tom Brown was portrayed for the most part as an individual with a hierarchical world view, Matt Green was portrayed as an egalitarian, and Bob Wayne as an individualist. Accordingly, for each character, only those text segments were selected that explicitly dealt with the actions of the respective character, yielding three partial stories (a Brown/hierarchist, a Greene/egalitarian, and a Wayne/individualist story). For each of the participants' retellings, similarity to each partial story was computed, using the cosine similarity measure as before; these three similarity scores constituted a new repeated measurement factor Story Character, with three levels; for simplicity, we call the levels Brown (the hierarchist), Greene (the egalitarian), and Wayne (the individualist). According to

[1]The model was estimated as a mixed-effects regression model with subjects as random factor (Judd et al., 2017), with the R package lme4 (Bates et al., 2015; R Core Team, 2018) using Satterthwaite's approximation.

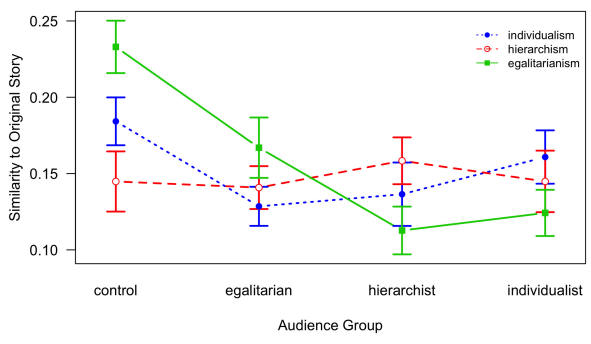


**FIGURE 4 |** Similarity of a retelling to the original story as a function of Audience and World View; lines denote World View conditions (error bars indicate standard errors; note that the *Y*-axis is shifted).

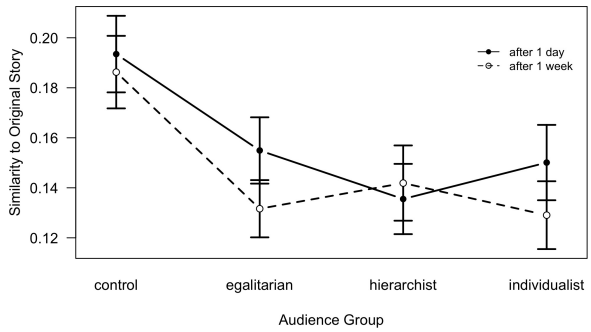


**FIGURE 5 |** Similarity of a retelling to the original story as a function of Time and Audience; lines denote Time conditions (error bars indicate standard errors; note that the *Y*-axis is shifted).

our schema model we predict an interaction between Story Character and World View, as well as between Story Character and Audience. Similarity of a retelling to each of the story characters should be particularly large if the character's world view corresponds to the participant's world view, or to the world view of the audience.

An analysis of variance with similarity as dependent variable and Time and Story Character as within-subject factors, Audience as between-subjects factor and World View as a quasi-experimental between-subjects factor was performed (for technical details see Footnote 1). Results show significant main effects for Time, $F(1,1305) = 4.95$, $p = 0.026$, $\eta_p^2 = 0.02$, for Audience, $F(3,254) = 3.34$, $p = 0.019$, $\eta_p^2 = 0.02$, and for Story Character, $F(2,1305) = 13.93$, $p < 0.001$, $\eta_p^2 = 0.04$. Also, as predicted, significant interactions were obtained between Story Character and Audience, $F(6,1305) = 3.68$, $p = 0.001$, $\eta_p^2 = 0.03$, and between Story Character and World View, $F(4,1305) = 2.39$, $p = 0.049$, $\eta_p^2 = 0.01$. Overall $R^2 = 0.085$ (**Figures 6**, **7**).

**Figure 6** shows that it is mainly the control condition yielding largest similarities to all of the three story characters; the three retelling conditions (egalitarian, hierarchist, and individualist) are basically indistinguishable and yield lower similarities; this finding corresponds to the results from the previous similarity analysis and further suggests an unspecific filter mechanism. Also, the interaction between Story Character and World View is not as expected (**Figure 7**) according to our schema conformity hypothesis.

## Dictionary Analysis

Another approach to check whether a text is related to a specific topic or theme is dictionary analysis (Welbers et al., 2017). Unlike similarity analysis, where similarity between two texts is defined across the entire vocabulary, dictionary analysis relies on a set of predefined words, and counts how often these words occur in a given text. If the collection of predefined words represents the essential meaning of a topic, a word count may serve as an indicator of how closely related the text is to the topic.

Accordingly, we classified the 30 terms from the sorting task (see section "Story Representation Measured by the Sorting Task") in four categories, corresponding to the three world views

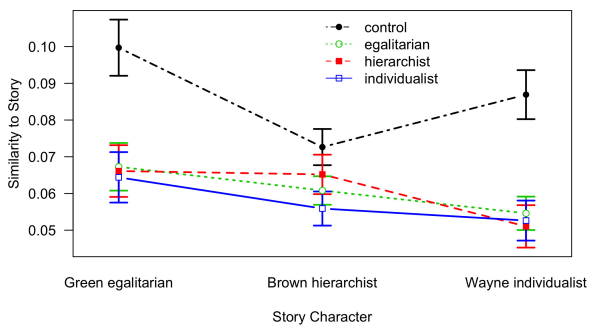


**FIGURE 6 |** Similarity of a retelling to each of the story characters as a function of Story Character and Audience; lines denote Audience conditions (error bars indicate standard errors; note that the *Y*-axis is shifted).

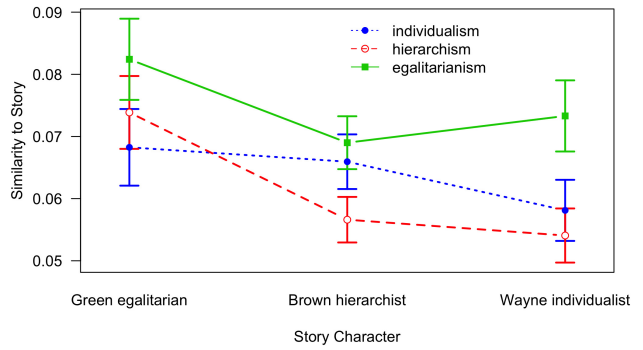


**FIGURE 7 |** Similarity of a retelling to each of the story characters as a function of Story Character and World View; lines denote World View conditions (error bars indicate standard errors; note that the *Y*-axis is shifted).

(and, consequently, to the central story characters), and to a 'crisis' category (**Table 2**). A dictionary analysis then counts, for each retelling, how many words from each category are used. We can then specifically test for interactions of each category count with Audience condition and with World View condition.

We conducted a dictionary analysis using the four categories of words as shown in **Table 2**. Term Category was defined as a factor with four levels (individualistic, hierarchical, egalitarian, and crisis), each level referring to the words of that category. A word count yielded the frequency of terms from a Term Category included in a retelling. For counting, word stems were used (e. g., law* included all instances such as law, laws, lawful, etc.; computational details can be found in the analysis script available online). Each category consisted of eight terms, except the crisis category which comprised only five terms. To compensate, the word count for each category was inversely weighted by the number of category terms; these weighted counts entered in the following analyses.

An analysis of variance was performed with proportion of words (=weighted word count for a category, divided by the total number of words of a text) as dependent variable and Term Category, Time, Audience, and World View as independent variables, yielding significant main effects for Time, $F(1,1786) = 6.17$, $p = 0.0129$, $\eta_p^2 = 0.04$, Term Category,

**TABLE 2 |** Word classification of the sorting task terms to four term categories.

| Term category | | | |
|---|---|---|---|
| **Individualist (Wayne)** | **Hierarchist (Brown)** | **Egalitarian (Greene)** | **Crisis** |
| Wayne | Brown | Greene | Crisis |
| WTO | Strangle | Law | Riot |
| Harvard | Poison | Sustainable | Poverty |
| Conservative | Chemical | WHO | Social |
| Economy | Respiration | Left | Discrimination |
| Free | Mangan | Europe | |
| United States | Atmosphere | Grassroot | |
| Market | China | Strict | |

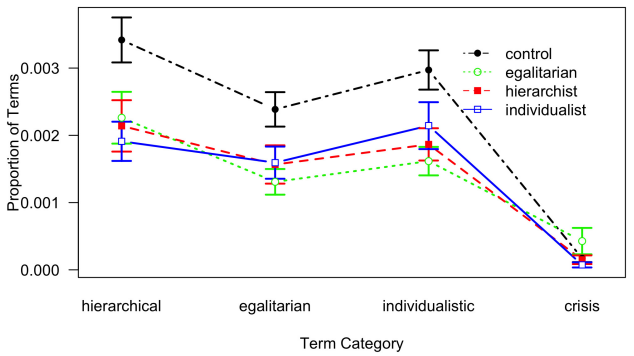


**FIGURE 8 |** Proportion of words from each category as a function of Term Category and Audience; lines denote Audience conditions (error bars indicate standard errors).

$F(3,1782) = 92.85$, $p < 0.001$, $\eta_p^2 = 0.17$, and Audience, $F(3,249) = 3.073$, $p = 0.028$, $\eta_p^2 = 0.03$, and a significant interaction between Term Category and Audience, $F(9,1782) = 2.33$, $p = 0.013$, $\eta_p^2 = 0.02$; overall $R^2 = 0.14$ for the model.

As can be seen in **Figure 8**, the main effect of Term Category is manifested in a slightly higher proportion of words for hierarchical words, $t(1782) = 8.63$, $p < 0.001$, and individualistic words, $t(1782) = 5.66$, $p < 0.001$, and a substantially lower proportion of words from the crisis category, $t(1782) = -15.16$, $p < 0.001$. For Audience, only the control condition differs significantly from the overall mean, $t(249) = 2.98$, $p = 0.003$; however, these findings are qualified by the significant interaction, indicating that all differences between audiences disappear for the Crisis condition.

## DISCUSSION

People's evaluation of contentious social issues such as climate change is often only to a small degree influenced by their factual knowledge about these issues; cultural values and world views often play a stronger role in shaping such evaluations (Kahan et al., 2011). When people communicate about an issue, they tell and retell narratives that embody their beliefs as well as appraisals of the causes and evaluations of the consequences, conferring meaning to the issue (McAdams and McLean, 2013; Brown, 2017). One reason why these narratives and associated evaluations are so persistent and resist change might be due to memory processes which are at work during the communication process. Repeated telling and retelling of narratives can be expected to strengthen those aspects that are told and to weaken those aspects left out. Consequently, narratives may become more and more coherent and compatible with the person's own core values and beliefs. Especially when conversing with like-minded people, a plausible assumption is that world views mutually reinforce each other and narratives are increasingly adjusted to these world views.

Climate change may serve as a prime example of this. Narratives about climate change provide explanations: whether the phenomenon exists at all, what its causes and its consequences are, what should be done. Narratives appear to be largely immune to scientific facts; given the large scientific consensus on climate change one might otherwise expect that all people would tell the same story. What happens is quite the contrary, narratives of climate change are quite diverse; some tell about villains who destroy the earth, others about conspiracies initiated in order to subdue the free world, and people align the moral of the story with their own basic beliefs and world views (Jones, 2014). Social media in particular may play the role of echo chambers, where communities of like-minded individuals mutually confirm their views about climate change (Jasny et al., 2015; Flaxman et al., 2016).

In this study we examined processes of constructive memory (Bartlett, 1932; Wagoner, 2017) as one possible factor shaping peoples' climate change narratives. World views, we assume, serve as cultural schemata that operate as filters when people recollect narrative information and share their narratives with others. World views filter meaningful components of a narrative, sifting out what is not compatible with one's world view. World views also operate when telling stories to others, in the sense that stories are tuned to the world view of the audience.

The focus of this study was on examining actual retellings, that is, texts generated by participants when asked to remember and retell a previously read narrative. We analyzed these natural language data by means of computational text analysis; specifically, we computed similarities between the retellings and the original story, between the retellings and partial aspects (story lines) of the story, and we computed the amount of specific world view-related topics occurring in the retellings via dictionary analysis (Welbers et al., 2017). Since what has been called the narrative turn in the social sciences, narratives have been mostly analyzed by qualitative methods (Riessman, 1993). In contrast, we attempted to quantify the main components of retold stories, and their interrelationships, aiming to capture important aspects of reconstructive processes. Additionally, we assessed the ensuing cognitive representation of the narrative by means of a more traditional sorting task method. Participants sorted the main terms from the narrative into groups, and a cluster analysis was employed to detect the underlying story representation from the derived co-occurrence matrices of terms.

The present study shows that world views exert a small though non-negligible influence on how climate change narratives are remembered and retold. An examination of the mental representation of a climate change story via a sorting task/cluster analysis approach revealed that although the general story structure is very similar across world views, the link between the problem component (a crisis due to climate change) and the proposed problem solutions (strategies to counteract climate change) varies systematically as a function of the audience's world view and of the speaker's world view. The audience effect indicates that speakers tune the retelling to the audience's world view and connect the problem with that solution which is preferred by the audience; for example, retelling the story to an egalitarian who is assumed to prefer a sustainable strategy yields a close association between crisis and sustainable strategy. Also,

the egalitarian structure contrasts to both the individualist and the hierarchist structure, the latter two being both more closely associated with a non-sustainable solution.

The effect of the speaker's world view, in contrast, indicates that speakers tend to connect the aspects of the crisis with that strategy which – from their point of view – is the cause and culprit of the crisis. Thus, unlike the audience effect, which links the crisis with a solution, the effect of the participant's world view is to link the crisis with the problem. Participants with an egalitarian world view closely associate the crisis with the free market, and with the respective protagonists. An individualistic participant, in contrast, associates the crisis with sustainable strategies. In sum, the findings from the cluster analyses suggest that the reteller's world view links the story problem with the 'villain' (as seen from the reteller's world view), whereas the audience effect tends to make the retelling compatible with the solution as seen from the audience's world view.

The computational text analysis examined three hypotheses: first, a time effect was expected, that is, retellings were assumed to become less similar to the original story over time. Second, we expected a schema conformity effect, consisting of an audience effect and a speaker effect: Retellings were expected to become more similar to the speaker's as well as to the audience's world view, and consequently become less similar to the original story. Third, we expected that in the control group, retellings would be least affected by reconstruction processes, due to the absence of an audience.

The similarity analyses yielded a time effect, but only in the somewhat trivial sense that people forget when time passes. We found an audience effect, but that was unspecific: in the control condition, when participants simply recalled the original story without telling it to an audience, retellings were most similar to the original story. If an audience was present, retellings decreased in their similarity to the original story, but more or less to the same degree across the various audiences, irrespective of the specific world view held by the listener. In fact, the decay over time was not significant for the control/recall condition. We assume that world views of an audience do in fact operate as filters, but in an unspecific manner, introducing alterations and omissions unrelated to the audience's specific world view, and distorting the original information in a somewhat random way. This finding suggests that talking to an audience of any kind activates a filter process so that the recollected story bears less resemblance to the original story than under pure recall without an audience. This is counter to our schema conformity hypothesis, which states that if speaker and listener share the same world view the filter effect would be amplified.

We find, however, some suggestive indication of schema conformity, though contrary to our hypothesis. Although the interaction between Audience and World View is not significant, $F(6,254) = 1.9$, $p = 0.08$, the interaction pattern suggests that identical world views of speaker and listener may increase story veridicality. When speaker's and listener's world views match, less filtering occurs and the narrative is more, rather than less, similar to the original story than when the world views of speaker and listener differ (**Figure 4**). A tentative explanation might be a common ground hypothesis (Clark and Brennan, 1991; Keysar et al., 1998), assuming that matching world views provide sufficient common ground for mutual understanding, making constructive processes and audience tuning superfluous. The motive to modify and adapt the recollection is low because no explanation or persuasion is needed and common ground is implicitly presumed. Interestingly, there is virtually no decline in similarity over time for the control/recall condition, suggesting that retelling to an audience not only decreases similarity due to audience tuning, but also makes the memory trace more fragile and amenable to deterioration over time.

Results of splitting up the story into its three story lines related to the three protagonists (Greene the egalitarian, Brown the hierarchist, and Wayne the individualist) are in line with the other findings. The control group yields largest similarities to all story characters, whereas the specific audience world views show no effect. However, an interesting interaction between story character and speakers' world view emerges: those participants who hold an egalitarian world view produce the most similar recollections with respect to all three central characters of the story (**Figure 7**). Correspondingly, all world view conditions generate retellings that are most similar to the egalitarian character Matt Greene. This pattern might be due to the egalitarian world view being closest to the dominant politically correct view, as presumably seen by many people in Norway. A possible explanation could be that dominant world views operate as weak filters, generating little reconstructive modifications; conversely, minority world views might operate as strong filters and generate more substantial modifications and distortions.

The dictionary analysis largely confirms the findings from the similarity analysis. The pattern of word counts for different term categories does not support the hypothesis that those terms are recollected relatively more often which conform to the participant's world view or to the audience's world view. Instead, we find the opposite – no interaction between Term Category and World View, and the interaction between Audience and Term Category yields greater proportions for the control condition with respect to all categories, which is again in line with assuming an unspecific filter mechanism. In addition, the dictionary analysis shows virtually identical and very low proportions for all Audience conditions with respect to the crisis category. A plausible explanation might be that the crisis topic is a story feature that does not discriminate between the story characters and their strategies.

It should be noted that retelling a previously heard story is essentially a memory task and might be expected to substantially depend on age. However, including age as a covariate had virtually no effect on the results; in fact, age *per se* turned out to be not significantly related to any dependent measure. The task of retelling a semantically rich narrative is quite different from rote learning; although older people usually experience a decline in short term memory, memory loss is less pronounced or absent for personally relevant episodes and similar tasks (Schacter, 1996). Furthermore, since the amount of correctly remembered information from the original story was quite low generally, it could also be a floor effect obliterating age differences.

In sum, we find mixed evidence on how world views operate on the comprehension, recollection, and communication of climate change narratives. Results from the sorting task suggest that there is a small but systematic effect of world views on how people connect the problem of a story with its possible solutions. Results from the text analyses suggest that world views largely operate in a non-specific manner; irrespective of the audience's world view, people modify their recollections whenever an audience is present (retelling conditions) in contrast to recalling a story in isolation (Marsh, 2007).

Several limitations of this study should be noted. The validity and reliability of narrative analyses has often been questioned (Riessman, 1993; Grimmer and Stewart, 2013; Brown, 2017). A direct written recording of recollections, as used in our study, yields extremely noisy data. After normalization, the mean number of words of a text unit was about 40, whereas the original story had approximately 600 words; some retellings consisted of just a few words. This constitutes an enormous loss of information that cannot be explained by a systematic influence of schemata on the reconstruction. The similarities between retellings and the original story are generally very low and the signal/noise ratio might be too low to detect substantial effects; especially when splitting the retellings according to the three story lines, this effect might be exacerbated. It may be questioned whether a completely open response format is capable of capturing the conceptual content of peoples' recollection with sufficiently high precision; it may be that the requirement to articulate and write down one's recollection simply generates a large amount of noise. Also, measuring similarity via a cosine similarity measure based on common word frequencies has its drawbacks. For example, in some conditions participants might rephrase the original wording using synonyms, which would lead to low similarity just because different words are used for the same concepts.

The sorting task, on the other hand, provides a kind of scaffold that guides recollection and blocks noisy intrusions, yielding a more stable measurement of the story's representation, albeit in a less direct way. Providing the relevant concepts in the sorting task might artificially increase recollection, independent of experimental condition, and thus yield homogenous representations and obscure real differences. Also, it is somewhat unclear how strongly the sorting process depends on the recollected story; it might mainly be driven by the general world knowledge and understanding of the presented concepts. How to best measure narrative content and the dynamics of narrative change remains an open question and a challenge for future research.

Can memory processes explain echo chamber effects? If we view echo chambers as closed systems, that is, as a collection of like-minded individuals communicating only with each other, we would predict that any story would be distorted and fragmented over time, with little information remaining the same over time. However, the assumption that echo chambers operate as filter bubbles (Flaxman et al., 2016), systematically extracting compatible and distorting incompatible information, might be too strong. Our data indicate that the simple process of retelling, no matter to whom, generates a loss of information that is unsystematic. Furthermore, what we tentatively called a common ground hypothesis suggests that like-minded individuals have no motive to systematically reconstruct the stories that they tell each other, simply because they are like-minded and share a common world view in the first place. In contrast, when confronted with individuals from a different echo chamber, some adjustments in communicated content might well occur; our findings suggest that at least the key components of a story – Who is the villain? Who caused the problem? – might be constructed according to the speaker's and the listener's world views. These effects were small, though, in our study and they have also typically been small in other research (Jones and Song, 2014; Williams et al., 2015; Flaxman et al., 2016; Quattrociocchi et al., 2016). The existence of echo chambers appears to be an obvious phenomenon, and there is evidence that people tend to engage in social media activities with like-minded others, albeit not exclusively so (Williams et al., 2015; Flaxman et al., 2016). However, tapping into the specific processes that may lead to increasing polarization between echo chambers through transformation of discourse content, and studying these processes in a systematic scientific manner, may be more challenging than anticipated.

Potential implications of this study might go in two directions. First, we think that it contributes to the understanding of echo chamber effects, shedding some light on the role of reconstructive memory processes. Second, we hope to advance the understanding of computational text analyses in the study of narratives and to contribute to its methodological development.

## ETHICS STATEMENT

This empirical study complied with the Norwegian Social Science Data Services (NSD) privacy regulations and the ethical principles of research by the National Committee for Research Ethics in the Social Sciences and the Humanities (NESH). The NSD has approved that the project complies to these rules and regulations (project number 44066).

## AUTHOR CONTRIBUTIONS

GB and H-RP contributed conception and design of the study. GB, H-RP, and AS performed the statistical analyses. H-RP wrote the first draft of the manuscript. H-RP and GB wrote sections of the manuscript. All authors contributed ideas to manuscript revision, read and discussed the manuscript, and approved the submission.

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## SUPPLEMENTARY MATERIAL

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# Affective Images of Climate Change

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Climate change is not only a scientific phenomenon, but also a cultural one. Individuals' opinions on climate change are often based on emotion rather than on scientific evidence. Therefore, research into the emotional characteristics of the imagery that the non-expert public find relevant to climate change is important in order to build a database of effective climate change imagery, which can then be used by scientists, policymakers, and practitioners in mobilizing climate adaptation and resilience efforts. To this end, we collected ratings of relevance to climate change as well as emotional arousal and valence on 320 images to assess the relationship between relevance to climate change and the emotional qualities of the image. In addition, participants' environmental beliefs were measured, to investigate the relationship between beliefs and image ratings. The results suggest that images rated highly relevant to climate change are higher in negative emotional valence and emotional arousal. Overall, images were rated as being more relevant to climate change by participants with higher pro-environmental disposition. Critically, we have compiled the mean relevance, valence, and arousal ratings of each of these 320 images into a database that is posted online and freely available (https://affectiveclimateimages.weebly.com; https://www.nmu.edu/affectiveclimateimages) for use in future research on climate change visuals.

**Keywords: climate change, global warming, image database, environmental attitudes, emotion**

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## INTRODUCTION

In October 2018, the Intergovernmental Panel on Climate Change (IPCC) published a special report on the impact of a 1.5°C global temperature increase. The report, written by 91 authors, cites more than 6,000 scientific references and includes hundreds of scientific images illustrating the consequences of extreme weather, rising sea levels, diminishing Arctic ice, and irreversible ecosystem changes. The main argument in the IPCC's special report is that limiting warming to 1.5°C will require that policymakers and practitioners make immediate and far-reaching changes in land, energy, industry, building, transportation, and urban policies in order to reduce human-caused emissions by 45% in the next 12 years. Arguably, over the past decade, climate change has turned from a scientific phenomenon to a cultural one (Nerlich et al., 2010) and individuals' opinions are more likely based on values and emotions than on scientific evidence and data (Mckie and Galloway, 2007). Exploring the emotional characteristics of the imagery that the non-expert public find relevant to climate change is important in order to build a database of effective climate change imagery, which can then be used by scientists, policymakers, and practitioners in mobilizing climate adaptation and resilience efforts. Such a database is

equally useful for experimental research and investigations of climate change imagery and messaging effectiveness.

Scholars in many disciplines have analyzed visual representations of the environment and specifically, images were used to communicate about climate change (e.g., Lester and Cottle, 2009; Hansen and Machin, 2013; Duan et al., 2017), but as Hansen and Machin (2013) noted, there is still a shortage in studies of the image's impact on audiences and the audience's affective responses to such images. Past studies have found that imagery involving melting glaciers, polar bears, and destruction from natural disasters are most commonly reported by participants when asked to mentally visualize climate change (Nicholson-Cole, 2005; Leiserowitz, 2006; O'Neill and Nicholson-Cole, 2009), and that images depicting dramatic outcomes of climate change, such as dried up lakes or flooding, are most commonly reported as making climate change seem most important (O'Neill and Nicholson-Cole, 2009; O'Neill et al., 2013). The emotional qualities of these images were only directly measured in one of these studies, which analyzed emotional valence, meaning how "positive" or "negative" a stimulus is perceived (Posner et al., 2005). Participants rated the valence of their mental representation of climate change from −5 to +5, and the average valence rating was reported for each of the most common category of climate images (Leiserowitz, 2006). However, participants only rated the valence of their own mental imagery—every "image" is not rated by every participant, limiting the objectivity of these images and their valence scores.

Emotion is not directly, objectively measured in the majority of past research on climate change imagery. Images' affect as described in the research is based on participants' reactions to and descriptions of the images. For example, images of climate change impact is determined to be negative by participants describing them in interviews as "very scary" (O'Neill and Nicholson-Cole, 2009) and "horrific" (O'Neill et al., 2013). Ranking images based on these descriptions becomes impossible due to the subjectivity: it is unclear whether a "horrific" image has greater negative affect than a "very scary" image, while an image rated as −5 in affect is certainly more negative than an image rated as −1 (e.g., Leiserowitz, 2006).

There is also no way to replicate the climate change imagery evaluated in these studies, as often the imagery was mental visualizations by participants (e.g., Leiserowitz, 2006; O'Neill and Nicholson-Cole, 2009). When the images were collected from permanent sources for participants to assess (e.g., O'Neill and Hulme, 2009; O'Neill et al., 2013), they were not made accessible for readers to view let alone use. Research on imagery in newspaper stories about climate change has also not made the images in question accessible (e.g., DiFrancesco and Young, 2011; O'Neill, 2013; Hart and Feldman, 2016; Duan et al., 2017). This lack of standardization of images and their limited accessibility for use in experiments thus calls for a dedicated stimulus set for climate images, similar to the Face Place (as used in Righi et al., 2012) and International Affective Picture System (IAPS; Lang et al., 1997).

A library of images called Climate Visuals was recently published containing over 1,000 photographs best suited for use in climate change communications based on non-expert perceptions (Chapman et al., 2016). Participants were interviewed on their opinions of 49 climate-related images, chosen with help of experts, in international focus groups (Chapman et al., 2016). A large sample of international participants were surveyed on 30 of those images, rating them on a number of variables, including affect on a scale of −5 to +5 (Chapman et al., 2016). The results from this study showed that participants found typical climate imagery—melting ice, polar bears—to be "cliché," though they were the most understood and most easily recognizable as being climate images in the survey portion (Chapman et al., 2016). Images depicting climate change solutions were generally rated as having positive affect but decreased personal motivation to make climate-beneficial behavioral changes, while images of climate change causes were generally rated as having negative affect but more likely to be shared by and motivate participants to make personal changes (Chapman et al., 2016). Chapman and colleagues therefore recommend images depicting non-staged people and large-scale causes of climate change over commonly used visual themes like melting ice when adding visuals to climate change communications (Corner et al., 2015). The images that make up the Climate Visuals public database thus reflect these qualities determined through their research to best communicate climate messages.

The Climate Visuals library is intended for use by climate change advocacy organizations, bloggers, and journalists, (Chapman et al., 2016) and was designed accordingly. For experimental research, however, it is less ideal: only 30 images used in the survey phase of the experiment were rated for affect (i.e., valence), and participants only rated six of those images each (Chapman et al., 2016). Although images were rated on emotional valence, the arousal dimension (i.e., excitement or physiological arousal) was not assessed. Therefore, potential differences in image processing related to valence vs. arousal cannot be determined with this existing database. In addition, all images were high relevance images. No low relevance images underwent the same rating procedure. The images used in the survey—or a similar image, when usage rights were not obtained—along with their mean ratings, including affect, are presented in a downloadable appendix on the Climate Visuals website[1]. As in past studies, not every image was rated by every participant, and a majority of the images included in the library were not rated at all.

A different database is necessary for further experimental research on climate imagery in order to promote consistency in stimuli used, so that the direct comparison of results using these stimuli is possible. We have created such a database. We began by collecting a large number of images (see Method for details) and then invited non-expert participants to rate the images' affective qualities and their relevance to climate change. Measuring images' climate relevance is necessary to have both experimental and control stimuli in this database for use in future research. Images' affect was measured using a dimensional model of emotion, with arousal (calming/exciting)

[1]www.climatevisuals.org

and valence (negative/positive) as the two dimensions on a scale from 1 to 9, as this has been determined to be most efficient and more objective than using common emotion words like "happy" or "sad" (Russell, 1980). This model is supported by other similar image-rating tasks such as the IAPS (Lang et al., 1997).

Additionally, we measured participants' environmental beliefs. Past studies have tended not to record participants' environmental beliefs or opinions (e.g., O'Neill and Nicholson-Cole, 2009) or not report on them in relation to their findings on climate imagery (e.g., Leiserowitz, 2006; O'Neill and Hulme, 2009; O'Neill et al., 2013). Only Chapman and colleagues surveyed participants' skepticism toward climate change and reported finding that skepticism impacted participants' feelings toward images of climate solutions (Chapman et al., 2016). Individual differences in environmental beliefs and opinions (whether broadly or specifically toward climate change) are important to account for, as individuals' environmental concern has been shown to be a positive predictor of self-reported pro-environmental behavior (e.g., Steel, 1996; Olli et al., 2001; Clark et al., 2003; Kim and Choi, 2005) and have a positive relationship with environmental policy support and adoption (Brace et al., 2002; Johnson et al., 2005; Dietz et al., 2007). Participants' environmental beliefs were measured using the New Ecological Paradigm Scale (NEP; Dunlap et al., 2000), as it is recommended as the standard for this measure (Hawcroft and Milfont, 2010) and has been widely used both in the US and internationally (see Dunlap, 2008).

## Hypotheses

This study aims to create an accessible database of images for use in climate research, with image ratings performed by a sample of non-experts in order to be more suited for use with non-expert audiences. Images are rated on three variables—relevance to climate change, arousal, and valence—and we predict:

1. images rated highly relevant to climate change will also be more likely to be rated as being high-arousal and low-valence, given how images depicting dramatic, negative themes have consistently been found to be more salient to people regarding climate change (Leiserowitz, 2006; O'Neill and Nicholson-Cole, 2009; O'Neill et al., 2013) and
2. there will be a positive relationship between beliefs about the environment and image ratings of relevance, arousal, and valence, given the NEP Scale's predictive validity in correlating positively with respondents' other environmental views (Dunlap et al., 2000).

# MATERIALS AND METHODS

## Participants

Participants for this experiment consisted of 67 males ($n$ = 30) and females ($n$ = 37) between the ages of 18 and 38 years old ($M$ = 20.373, $SD$ = 3.789), with normal or corrected-to-normal vision. They were recruited primarily through undergraduate psychology classes on Northern Michigan University's campus, receiving course credit for their participation. Informed consent was obtained from participants before beginning the experiment, and the research protocol was approved by the Institutional Review Board of Northern Michigan University.

## Procedure

### Image-Rating Stimuli

A total of 320 images were gathered from a Google search using the following terms involving climate change: (1) "climate change," (2) "climate change causes," (3) "climate change solutions," (4) "climate change negative," and (5) "climate change positive." Search results were filtered to only include high resolution images not containing clipart that were labeled for reuse. We selected the top 100 images from each of these five searches, which resulted in 500 images. Images that were redundant across multiple searches were only included once and images of artwork were removed. The resulting number of images included was 320.

### Image-Rating Task

The image-rating task was designed using E-Prime2 software (Psychology Software Tools, Pittsburg, PA). The image-rating task began with participants seated 59 cm from the computer screen. They were told that they were going to be shown pictures and asked to rate them on a scale of 1–9 for each of the variables given on the screen. Images were displayed above a question and rating scale for each variable. For each image, participants were asked how relevant or irrelevant it was to climate change (relevance), how calming or exciting it made participants feel (arousal), and how negative or positive the image appeared (valence), in that order consistently. Each image was presented for each variable scale before the next image was shown in a random order (**Figure 1**). Participants used the computer's keyboard number pad to input their ratings. The task was not timed, and took participants approximately an hour to complete.

### Questionnaire

Immediately after finishing the image rating task, participants were asked to complete the New Ecological Paradigm Scale (Dunlap et al., 2000). This was done after the image-rating task in order to avoid potentially priming participants to think about environmental issues before rating the images on climate change relevance. Their responses were given on a 5-point Likert scale from "strongly agree" to "strongly disagree." The items on this questionnaire are meant to gauge the participants' views on the environment as a whole, and human beings' impact on the Earth (for full scale, see Dunlap et al., 2000). The 15-item questionnaire with 5-point response scale is used for this study as recommended based on meta-analysis of 30 years of NEP Scale usage (Hawcroft and Milfont, 2010). This questionnaire has high internal consistency, $\alpha$ = 0.83, as determined through a representative sample of Washington state residents (Dunlap et al., 2000).


**FIGURE 1 |** Image-rating task screens. Participants were asked to rate the stimulus on its **(A)** relevance to climate change, **(B)** arousal, and **(C)** valence. Participants rated each stimulus on each variable before the next stimulus was presented.

## Data Analysis

### Image-Rating Task

The mean rating of each variable (relevance, arousal, and valence) was collected for each of the 320 images. Pearson correlations were performed to test for positive relationships between (1) relevance and arousal, (2) relevance and valence, and (3) arousal and valence. The significance level was set to $p < 0.05$, two-tailed.

### Questionnaire

Participants' responses from 1 to 5 on the NEP Scale were made into composite scores, with reverse scoring performed for even numbered items as detailed by Dunlap et al. (2000). The highest possible composite score is 75, indicating greater pro-environmental beliefs as well as interest in and concern for the environment, particularly its ability to be disrupted by human beings (Dunlap et al., 2000). The lowest possible composite score is 15, indicating feelings of human beings' dominance over nature and less concern for the environment, or lesser pro-environmental beliefs (Dunlap et al., 2000).

### Image-Rating Task + Questionnaire

The relationship between participants' image ratings and NEP Scale questionnaire responses is also of interest. In order to accurately determine the potential relationship between participants' ratings of climate image relevance and their beliefs about the environment, each participant's average ratings for relevance, arousal, and valence of the 10% of images determined to be *most* relevant and the 10% of images determined to be *least* relevant ($n_{total} = 64$) were correlated with their response for each NEP Scale item using Pearson correlations. The significance level was set to $p < 0.05$, two-tailed. Correlation strength is interpreted based on Cohen's conventions (i.e., small $r = |0.1|$, medium $r = |0.3|$, and large $r = |0.5|$; Cohen, 1988).

# RESULTS

## Image-Rating Task

The average relevance ratings of the images ($M = 5.909$, $SD = 1.033$) were positively correlated with the average arousal ratings of the images ($M = 4.651$, $SD = 0.531$), $r(318) = 0.621$, $p < 0.001$. The correlation was strong, showing that the images determined to be most relevant to climate change were also rated by participants as being highly arousing, or exciting to look at (**Figure 2A**).

The average relevance ratings were also negatively correlated with the average valence ratings of the images ($M = 4.793$, $SD = 1.382$), $r(318) = -0.432$, $p < 0.001$. The correlation is moderate, and shows that the images most relevant to climate change were also rated as having low valence, or as being very negative (**Figure 2B**).

There was also a moderate, negative correlation between the average arousal ratings and the average valence ratings of the images, $r(318) = -0.394$, $p < 0.001$, showing that the images that were rated as most exciting were also some of the most negative (**Figure 2C**). This is not surprising given the results of similar image ratings in the IAPS, which initially reported having very few images, which were rated as unpleasant yet also un-arousing (Lang et al., 1997).

We also selected the 10% *most relevant* images ($n = 32$; $M = 7.537$, $SD = 1.304$) and the 10% *least relevant* images ($n = 32$; $M = 4.121$, $SD = 1.678$) to be used in further correlation analyses. Common themes depicted in the *most relevant* images were polar bears, ice floes, industrial smog, and outcomes of natural disasters (**Figure 3**), while common themes depicted in the *least relevant* images were landscapes, buildings, and people (**Figure 4**).

## Questionnaire

Of the 67 total participants, 62 completed the NEP Scale questionnaire following the image rating task. The highest score recorded in this experiment was 74 and the lowest was 32, out of a maximum 75 and minimum 15 ($M = 53.177$, $SD = 8.434$). Internal consistency for this sample was high, $\alpha = 0.84$.

## Image Ratings + Questionnaire Responses

There were two significant relationships found between image ratings and questionnaire responses. There was a moderate positive correlation between the average relevance ratings of the *most relevant* images and participants' NEP Scale scores, $r(60) = 0.419$, $p = 0.001$. This shows that participants with more pro-environmental beliefs or more interest in the environment were more likely to give the *most relevant* images their high relevance ratings (**Figure 5A**). There was also a moderate positive correlation between the average relevance ratings of the *least relevant* images and participants' NEP Scale

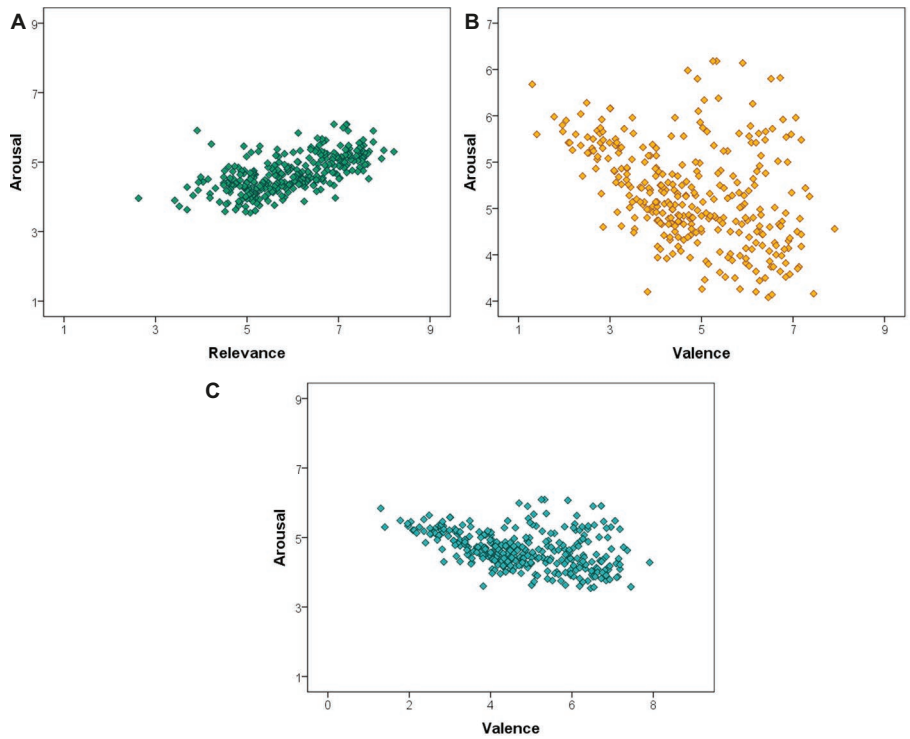


**FIGURE 2 | (A)** There was a strong, positive correlation between images rated high in relevance to climate change and images rated high in arousal. **(B)** There was a moderately strong, negative correlation between images that were rated high in relevance to climate change and images that were rated low in valence. **(C)** There was a moderate, negative correlation between images that were rated low in valence and images that were rated high in arousal.

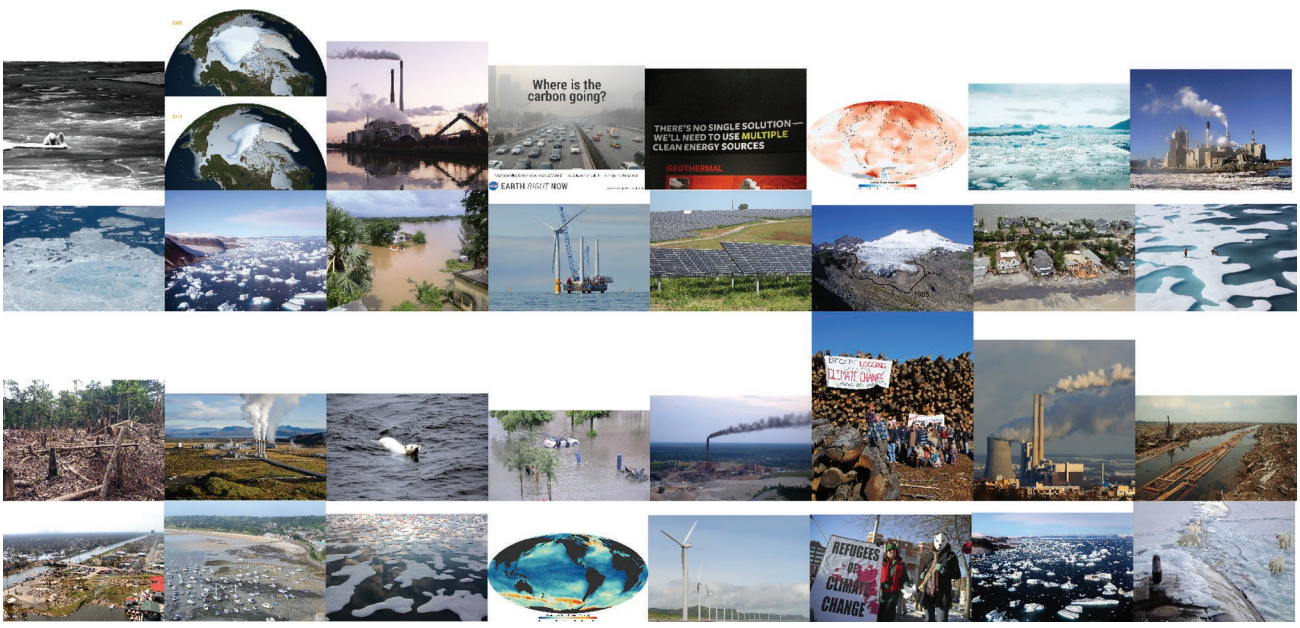


**FIGURE 3 |** The 32 images rated highest in relevance to climate change, read from top left to bottom right.

scores, $r(60) = 0.31$, $p = 0.003$. This shows that participants with more pro-environmental beliefs, again, more likely to give the *least relevant* images their low relevance ratings (**Figure 5B**).

There were no significant correlations between environmental beliefs and arousal scores, $r(60) = 0.001$, $p = 0.994$, or valence scores, $r(60) = -0.174$, $p = 0.175$, for the *most* relevant images.

**FIGURE 4 |** The 32 images rated lowest in relevance to climate change, read from bottom right to top left.

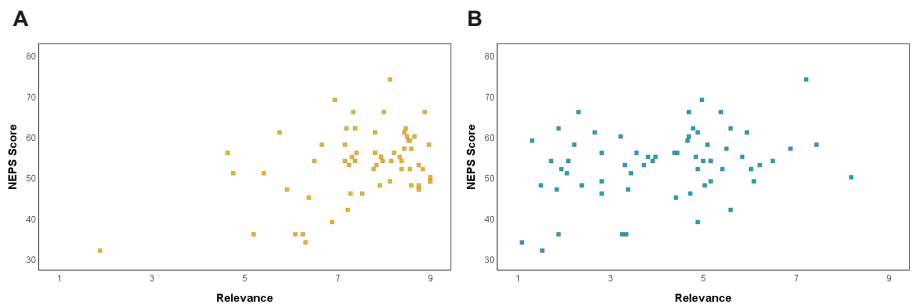


**FIGURE 5 | (A)** There was a strong, positive relationship between the average relevance ratings of the images determined to be *most relevant* to climate change and participants' score on the NEP Scale. **(B)** There was a moderate, positive relationship between the average relevance ratings of the images determined to be *least relevant* to climate change and participants' score on the NEP Scale.

Nor were there significant correlations between environmental beliefs and arousal scores, $r(60) = -0.041$, $p = 0.751$, or valence scores, $r(60) = 0.005$, $p = 0.969$, of the *least* relevant images. This suggests that participants' ecological views may not have been related to their opinions on the emotional qualities of the images[2], only their opinions on the images' relevance to climate change.

## DISCUSSION

From the image-rating task, relevance to climate change and arousal were significantly positively correlated, as were relevance and valence. Arousal and valence were significantly negatively correlated. Therefore, images that were rated as highly relevant to climate change also tended to be rated as highly arousing and low in valence, while images that were rated high in arousal tended to be rated as low in valence in general. The 64 images that were rated *most* and *least* relevant to climate change were then selected for further correlation analyses.

[2]Analyses of curvilinearity (i.e., a quadratic trend) between environmental beliefs and valence scores of the *most* relevant images ($p = 0.87$) and the *least* relevant images ($p = 0.14$) were also not significant. This indicates no relationship between environmental beliefs and extreme emotionality, either positive or negative.

We found from the questionnaires that participants had varying levels of pro-environmental beliefs according to their scores on the NEP Scale, with high scores indicating greater pro-environmental beliefs and interest in the environment and low scores indicating less interest and fewer pro-environmental beliefs. Pro-environmental beliefs were found to be significantly positively correlated with the relevance scores of the 32 *most* relevant images and the 32 *least* relevant images, but not with arousal scores or valence scores. Higher pro-environmental beliefs were associated with higher relevance scores, among both the images rated *most* relevant to climate change and those rated *least* relevant to climate change.

## Hypothesis 1

Our first hypothesis was supported by our findings. The strong positive relationships between relevance and arousal show that generally, the images determined to be most relevant to climate change were also determined to be the most arousing or exciting. The negative relationship between relevance and valence showed that the images most relevant to climate change also tended to be the most negative images, emotionally. Exciting, emotionally negative images being rated as the most relevant to climate change in our study is also in line with previous research which has indicated that non-expert individuals tend to find alarming and upsetting imagery most salient when thinking about climate change and global warming (Leiserowitz, 2006; O'Neill and Nicholson-Cole, 2009; O'Neill et al., 2013).

The primary subject matter of the images found to be *most* relevant to climate change in this study included ice, outcomes of natural disasters, and industrial buildings or smog (see **Figure 3**). According to previous research, these three themes were among those that first came to mind to individuals thinking about climate change and global warming (Leiserowitz, 2006; O'Neill and Nicholson-Cole, 2009), and were also determined by individuals to make climate change seem most important (O'Neill and Nicholson-Cole, 2009; O'Neill et al., 2013). Images depicting the outcomes of natural disasters exemplify what is meant by high-arousal/low-valence imagery in this study: they are dramatic and distinctly negative in affect.

The image rated most relevant to climate change overall depicted polar bears on small ice floes in the water, though only three of the 32 *most* relevant images depicted polar bears. Polar bears are a popular visual symbol for climate change (Manzo, 2010), and in one study they were the climate icon participants were most drawn to and able to understand (O'Neill and Hulme, 2009). While this type of imagery was found to be "cliché" or overused by participants surveyed by Chapman et al. (2016), it was also determined to be easy to understand as relating to climate change. This is most important to our database—images included are intended to be used in experimental research on climate change, thus images need to be easily recognizable as climate-relevant to participants. We have also chosen not to investigate participants' feelings of self-efficacy regarding the images as some past research has done, as those results indicate that imagery rated high in self-efficacy, or the ability to enact change against climate change, tend to be rated low in climate-relevance (e.g., O'Neill and Nicholson-Cole, 2009; O'Neill et al., 2013). Images' relevance to climate change was prioritized in this study, though others using this database in continued research are encouraged to investigate measures of self-efficacy.

The subject matter of the images found to be *least* relevant to climate change in this study included landscapes or nature, people, and buildings (see **Figure 4**). Past research has found that images with similar themes, such as buildings and landscapes, have been ranked as making climate change seem least important (O'Neill and Nicholson-Cole, 2009), as have images of people, particularly if they are identifiable (O'Neill et al., 2013). This may explain, then, why a photo of US politician Al Gore was determined by our participants to be one of the least relevant images to climate change, despite having won the 2007 Nobel Peace Prize jointly with the IPCC for his work spreading awareness about the anthropogenic nature of climate change (Gibbs and Lyall, 2007). The ages of our participants ($M = 20.373$, $SD = 3.789$) may also be salient, however, as it is possible that they were simply unfamiliar with Gore.

The subject matter present in the images that were rated *most* and *least* relevant to climate change in this study shows that the high-arousal/low-valence, dramatic and negative, imagery that was correctly predicted to be most relevant to climate change was mainly represented by scenes of natural disaster outcomes. Images of ice floes and industrial buildings with smog were also common themes in this category, although an image of polar bears on ice was rated as the image most relevant to climate change overall. The images rated *most* relevant consisted primarily of causes and consequences of climate change, with potential solutions represented very little, which replicates previous findings (e.g., Leiserowitz, 2006; O'Neill and Nicholson-Cole, 2009; O'Neill et al., 2013) and suggests that the high-arousal/low-valence combination of emotional characteristics is particularly necessary for images to beseen as relevant to climate change. (However, potential solutions were represented much more in the top 50% of climate-relevant images).

Meanwhile, many of the images in the *least* relevant category seem self-explanatory, such as a photo of a squirrel. However, images of people are frequently found not to be salient to climate change, as represented in our findings, despite being the most common category of picture attached to news media coverage of climate change (both in print and digitally; DiFrancesco and Young, 2011; O'Neill, 2013) and endorsed as visuals for climate communication (Corner et al., 2015). While this may appear to contradict past results like those of the Climate Visuals library (Chapman et al., 2016), depictions of people in the top 50% of climate-relevant images are generally in line with the recommendations used to compile the Climate Visuals library: these images are mostly of groups of protesters, photos which show "real people" in situations that are not "staged" (Corner et al., 2015). So, while images depicting people were more likely to be rated as irrelevant to climate change in general, those that were rated more relevant to climate change possessed the attributes that current research recommends when portraying climate change.

## Hypothesis 2

Our second hypothesis was partially supported by our findings. There were significant positive correlations between the participants' environmental beliefs (as determined by NEP score) and their relevance ratings toward both the *most* and *least* relevant images, so it appears that environmental views were linked to participants' ratings of the images' relevance to climate change. Individuals with greater pro-environmental beliefs appeared more likely to give high relevance ratings to the images that were subsequently determined to be *most* relevant to climate change, as well as appearing to be more likely to give higher relevance ratings to the images that were subsequently determined to be *least* relevant to climate change. This seems to show that individuals who were highly concerned about the environment tended to find the images overall more relevant to climate change than participants who were not as concerned about the environment.

On the other hand, as there were no significant relationships between environmental beliefs and arousal or valence scores of the images both *most* and *least* relevant to climate change, it appears that we were not correct in predicting that individuals' environmental views are related to their ratings of images' affective characteristics. Meaning, exciting and negative images seemed exciting and negative to participants regardless of how they felt about the environment.

These findings address the lack of consideration for environmental beliefs in previous research done on climate change imagery. For example, some previous studies have recorded participants' attitudes toward climate change, but have not investigated these attitudes and how participants rated images as salient or self-efficacious regarding climate change (O'Neill and Hulme, 2009; O'Neill et al., 2013). In both cases, a sample with varied climate attitudes was desired and achieved, yet appears not to have been applied to the image ratings. Our findings that individuals' environmental beliefs, as measured by the NEP scale, were related to their ratings of the images as being relevant to climate change partially supports our prediction for this study, and also attempts to fill a gap in literature on climate imagery.

## Strengths and Limitations

Of course, there were limitations to our study that may have attributed to some of our findings, or lack thereof. Given that scores on the New Ecological Paradigm Scale have been positively correlated with both age and education (Dunlap et al., 2000; Hawcroft and Milfont, 2010), if only slightly, our student sample may have had an effect on the image rating results. However, student samples have been found to be quite comparable to more representative samples when using the NEP (Hawcroft and Milfont, 2010). In addition, although we report the relationship between environmental disposition and image ratings, future research could specifically assess the relationship between climate change attitudes and ratings for climate images. There are also some limitations regarding the images that we used for this study. Specifically, results from the image-rating task have shown that very few images have been rated as both low-arousal and low-valence. As these images and their ratings are being used in a database, we would prefer to have an equal spread of images with all combinations of affective characteristics so that future users can choose images with qualities that meet their needs. However, this was also a problem encountered by IAPS in its early stages (Lang et al., 1997). In addition, open access images of climate change may be of lesser quality than those of professional photographers that restricted usage rights (although it should be noted that our search was filtered to only include high resolution images). These limitations could potentially be rectified by expanding our sample size, both of participants and of images. Future replication of this experiment using these same images with a wider, more diverse range of participants is necessary.

There were also many strengths to this study, most notably our appeal to climate change non-experts, both as participants and as an audience for climate change communication. Scholars recommend that this communication be shaped according to the audience (Leiserowitz, 2006), appealing to what they find meaningful (Nerlich et al., 2010). Given that climate change communication and scientific communication in general, often uses visual imagery to illustrate these messages (Trumbo, 1999; Nicholson-Cole, 2005), we chose to explore what visual imagery is meaningful to our non-expert participants. It is also recommended that climate communication should involve non-experts' understanding, emotions, and behavior (Ockwell et al., 2009), which we have done by having participants rate the images' relevance to climate change (understanding) and arousal and valence (emotions), and then surveying their environmental beliefs (behavior). In this way our images and their ratings should be particularly suited for future use with other non-expert audiences.

Our study also adds further evidence to support an apparent gap between what imagery non-expert individuals feel is relevant to and best represents the importance of climate change, and what imagery is used by news media when covering climate change. For example, print and digital newspapers in the Canada, US, the UK, and Australia all primarily use images of people, particularly politicians, to accompany these articles (DiFrancesco and Young, 2011; O'Neill, 2013), despite our study finding these types of images most commonly rated least relevant to climate change, and another finding them to make climate change seem the least important across participants in three countries (O'Neill et al., 2013). As this type of media seems to be most non-experts' primary source of information on climate change (Wilson, 2000; Nicholson-Cole, 2005; Sundblad et al., 2009), this gap is concerning. Clearly news media's climate communications are not attending to what their audiences find important in ways recommended by scholars in the field, and our results seem to add support to this.

As scientific language and colloquial language often use the same words with different meanings, the language used in climate change communication can create confusion rather than convey the facts, depending on the audience (Nerlich et al., 2010). Because of this, we utilized commonly-used language in

our rating systems (calming or exciting, negative or positive) that still properly expressed our objective variables (arousal, valence), lessening the opportunities for misinterpretation by non-expert participants.

The objectiveness of these variables is another strength of our study; by using quantitative ratings of relevance to climate change, arousal, and valence, these images can be definitively measured against each other according to each variable. Past studies have only ranked images based on relevance, though not with numerical value (O'Neill and Hulme, 2009; O'Neill and Nicholson-Cole, 2009; O'Neill et al., 2013), with only subjective descriptions of the images' emotional qualities. Additionally, these ratings were performed on each image by each participant, as opposed to each participant rating only their own personally-relevant climate imagery on its affect (Leiserowitz, 2006). Because of this, our images' ratings come from a larger sample, and are thus more objective.

Since this is one of the first research-generated databases of visual experimental stimuli related to climate change, previous research has relied on mental imagery elicited from participants (Leiserowitz, 2006; O'Neill and Nicholson-Cole, 2009) or images gathered from expert scientific sources (O'Neill and Hulme, 2009) and newspapers (O'Neill et al., 2013), none of which have been made available online or are included in publications. A recent climate image database has since emerged, but is not appropriate for experimental research both in subject matter and in image data availability: images in the Climate Visuals library have been selected based on their ability to promote audience engagement and as such the library primarily contains photographs of people. While these are useful for climate communications and media, we have found that this type of image alone is not seen as relevant to climate change, and thus are not appropriate for use as stimuli in climate change research where they would be devoid of any context. In addition, many Climate Visuals photos are available online with descriptions of the photos' contents, but do not include any data from the creators' research, such as how the image made participants feel about climate change, as not every image was rated in the initial study. While there are links for acquiring each image included as well, not all images are available for free or to be reused, limiting the library's utility as a stimulus set.

Because of this, our database is accessible online with all images available for download and reuse, and with climate-relevance and affective characteristic ratings shown for each image[3]. These ratings have been completed by a non-expert audience in order to best be used as experimental (and control) stimuli in further research on climate change imagery, with climate-relevance determined based on the image alone. Our rating system ensures that any future studies using these images will have the ability for direct comparison, and eliminates any confounds in comparing the results of two studies due to different stimulus sets used. Understanding the cognitive processes associated with climate change (including those related to processing climate images) is important for understanding people's climate change relevant behavior. For example, we recently used stimuli from this database to demonstrate that images with high relevance to climate change facilitate reaction times and capture observers' attention compared to low relevance images and this attentional bias is heightened in individuals with pro-environmental attitudes (Carlson et al., 2019).

[3]https://affectiveclimateimages.weebly.com; www.nmu.edu/affectiveclimateimages

## CONCLUSION

Our goal for this study was to gather objective, quantitative data on how individuals' viewed the affective characteristics of climate-related imagery in order to create an accessible database of stimuli for use in experimental research on climate imagery. We achieved this goal while also supporting the findings of previous, similar studies on this subject that there are common subjects and emotional aspects that are most salient to people when visualizing climate change. We also found that individuals' interest in the environment has effects on the way they rate images as being relevant or irrelevant to climate change. Non-expert opinions were prioritized in this study, and it was carried out in such a way that it should generalize to non-expert audiences viewing and using these images in future studies.

## ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Northern Michigan University Institutional Review Board with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Northern Michigan University Institutional Review Board.

## AUTHOR CONTRIBUTIONS

JC, JT, and SD conceived the idea for the study and designed the study. BL collected and analyzed the data. BL drafted the manuscript. All authors critically revised the initial draft and approved the final version.

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