

U. S. Adults Regulate Emotional Responses to Climate Change Information:
Physiology, Subjective Experience, and Climate Change Solutions

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Abstract

Humans evolved emotion processes to help deal with perceptible problems in adaptive ways. Climate change is hard to perceive, but it is nonetheless a problem. Emotions related to climate change can drive adaptive behavior, however, people often want to change emotions to feel better. If people don't feel negative about climate change, they may lose motivation to solve the problem. In this work, I conceptualized the climate change situation as information and described how emotion processes might link to climate change solutions. Then, I conducted three empirical studies based on that framework to explore emotional responses to climate change information, and how people can manage those responses for better or for worse. First, I designed climate change information stimuli with scientific statements from a report from the Intergovernmental Panel on Climate Change (WG II, 2022). In Study 1, participants in the lab viewed the information while physiological responses were recorded, and self-reported emotional responses and uninstructed regulation. In Study 2, online, participants who believed and did not believe in climate change viewed the same information and reported responses as in Study 1. People who believed in climate change reported more emotions and regulation; for them, regulation was negatively associated with financial donations to a pro-environmental organization. In Study 3, I recruited only participants who believed in climate change and used a randomized controlled experiment to test cognitive reappraisal (increase and decrease negative emotions) and mindful acceptance in a simulated climate change risk social dilemma. Cognitive reappraisal to decrease negative emotion was hedonically effective and reduced the donations to mitigate climate change risk in the simulated social dilemma. In another condition, I changed the simulation so the partner barely donated (a "free-rider"), which elicited more trial donations, rather than conditional cooperation. Interestingly, both increasing and decreasing negative emotions with cognitive reappraisal reduced donations pro-environmental donations after the simulation. In sum, climate change information is an affective situation and emotion regulation

can affect climate change solutions. These three studies collectively support the framework and lay the foundation for future work on translating climate change information into climate change solutions through affective processing.

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I use the pronoun “we” throughout this dissertation because, although I am responsible for this document, the work reported in it, and any mistakes or errors, there is no way that I could have done this work alone.

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General Introduction

Anthropogenic climate change is the effect of human activity on the Earth's temperature (i.e., global warming). Climate change cannot be perceived like many other threats (e.g., snakes, bears, uncontrolled fires, human enemies). Climate change is long term, intangible, and statistical (Weber, 2006). Instead of sensory perception, people often use more abstract information, such as that obtained through science, to understand climate change. The most established scientific information on climate change is published in the reports from the Intergovernmental Panel on Climate Change (IPCC) and takes into account the empirical evidence, as well as the agreement among scientists and confidence in their claims (The Core Writing Team, IPCC, 2023). Although there are critiques of scientific consensus messaging, scientific consensus is a critical part of a modern understanding of anthropogenic climate change (Bayes et al., 2020; van der Linden, 2021).

In brief, people have caused global warming (i.e., climate change) primarily by causing “greenhouse gases” (i.e., carbon dioxide [CO₂] and methane) to move from below the surface of the Earth to the atmosphere, often by burning fossil fuels (Höök & Tang, 2013). Early quantitative models of global warming caused by CO₂ began more than a century ago (Arrhenius, 1896). Since then, scientific confidence in global warming caused by the release of greenhouse gases from human activity has become unequivocal, but the exact nature of the negative consequences of global warming on humanity remains uncertain (IPCC WG II). For example, there is uncertainty in the magnitude, spatial, and temporal dimensions of climate change, as well as the future ability of human civilization to adapt to a warmer climate (IPCC WG II). Many facts about climate change are supported by scientific consensus, but there are differences in scientific confidence and people perceive climate change differently.

Climate change perceptions and subsequent climate change solutions involve climate change-related emotions (Brosch, 2021; Marczak, Wierzba, Kossowski, et al., 2023; Marczak,

Wierzba, Zaremba, et al., 2023; Ogunbode et al., 2022; Verplanken et al., 2020; Wang et al., 2018). Much research does not consider climate change solutions, but instead focuses on mental health challenges associated with climate emotions (e.g., Ogunbode et al., 2023). Although emotion has been neglected in climate change solutions, compared to topics such as economics, governance, technology, and engineering (Davidson & Kecinski, 2021), some social scientists have been interested in climate change emotions for years (e.g., Weber, 2020). Here we define climate change emotions as related to climate change information (i.e., a specific type of situation) and occurring with multiple components that include attention, appraisals, subjective feelings and physiological changes. Emotions may lead to adaptive or maladaptive responses to climate change, depending not only on the aspects of the person prior to the situation, but also the experience itself and the context.

In many approaches to emotion (Moors, 2017; Russell, 2021; Scherer, 2022), one critical aspect of emotion is its valence – the feeling of pleasantness or unpleasantness associated with the emotional experience. When we name emotions associated with climate change, those with a negative valence include fear, anxiety, anger, and guilt (Marczak, Wierzba, Zaremba, et al., 2023). Negative emotions can be associated with climate change solutions (e.g. Stollberg & Jonas, 2021). Yet, promoting negative emotions may not be the most effective way to promote climate change mitigation (e.g., Palosaari et al., 2023). For one reason, negative emotions can lead to single actions to reduce the negative emotions, whereas the climate change problem requires sustained action over long periods of time (Weber, 2020). Researchers are increasingly thinking about climate change emotions that can be characterized by more pleasant valence, such as positive and transcendental emotions (Schneider et al., 2021; Zelenski & Desrochers, 2021). Positive emotions can also be associated with climate change solutions (e.g., Marlon et al., 2019; van der Linden, 2018).

To understand climate change solutions, psychology, and behavioral sciences more broadly, often focus on behavior as an outcome; behavior is expressed by individuals (i.e., consumer behavior), but at larger scales, individuals can form organizations or participate in political systems (Nielsen et al., 2021; Whitmarsh et al., 2021). Causally “upstream”, cognitive sciences often focus on the precursors to behavior, such as belief and decision-making processes (Aron, 2019; Siders & Pierce, 2021). The systems level includes laws and regulations, plus norms and other factors that are distinguishable from individual belief and behavior (e.g., Cialdini & Jacobson, 2021; Nachmany et al., 2014). The systems level is both upstream from cognition and downstream from behavior. Climate change solutions benefit from multiple perspectives, for example by integrating social sciences in a philosophically grounded, dynamic framework (Weber et al., 2023). Affective science is exceptionally positioned to embrace the complexities of climate change mitigation and adaptation and, fundamentally, motivate solutions (Dukes et al., 2021).

In light of the variety of information about climate change available, it is important to explicitly describe the logical foundations of the current research. Our social science approach focuses on human responses to climate change information. We consider how human responses occur in a complex system, including how people’s decisions and behavior could be considered solutions to the problem of anthropogenic climate change. Our priors rely heavily on the following five premises:

1. Anthropogenic climate change is occurring (scientific consensus).
2. Anthropogenic climate change will be bad for people and is therefore a problem that should be solved (scientific consensus).
3. Climate change solutions include instances when people or groups adapt to or mitigate anthropogenic climate change through decision making or action (assumption).

4. People or groups must have access to information about climate change to solve the climate change problem through decisions or actions (assumption).
5. When people or groups encounter climate change information, emotion generation and regulation can influence subsequent decisions and behavior (current framework).

This dissertation begins with a conceptual framework, then reports three empirical studies. In Study 1, we recruited participants into the lab and measured physiological and subjective emotional responses to climate change information. Under the assumption that our new stimuli would elicit emotional responses, we expected to find evidence for physiological dynamics and subjective emotion processes in response to climate change information.

In Study 2, we recruited participants online, oversampling those people who did not believe in climate change, and exposed them to climate change information. Consistent with previous research, we expected to find associations between climate change belief and emotional responses to the climate change information. We further hypothesized that emotion regulation use would differ based on belief. Finally, we expected to find that both climate change belief and emotion-related variables would be associated with three measures of climate change solutions. Two measures were surrogate outcomes for real, large-scale climate change solutions (i.e., support for climate change policies and self-reported pro-environmental behavior for, respectively, political and consumer behavior). The final measure was the amount of a small bonus that each participant donated to a real pro-environmental organization.

In Study 3, we recruited participants online who believed in climate change and tested whether they could regulate emotional responses to climate change information in ways that also affect decision making. We measured negative emotion in response to each information presentation. We also embedded the information presentation in a decision making task in which participants donated money to mitigate the risk of climate change disaster in a simulated two-person social dilemma (adapted from Milinski et al., 2008). Regardless of the outcomes in

the gamified task, we provided the same bonus to all participants and allowed them to donate any portion of the money to a pro-environmental organization.

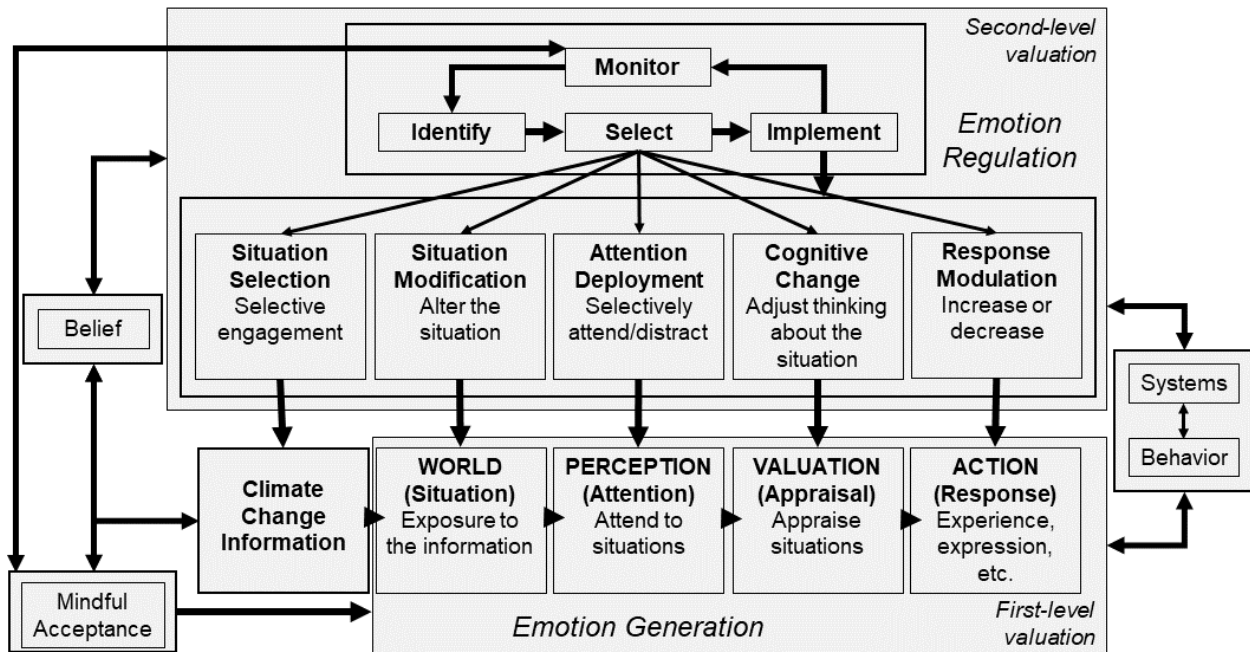
To scaffold the empirical studies, we first outline our conceptual framework of emotion generative and regulatory processes as applied to climate change situations.

Climate Emotion Generation and Regulation: Applying the Extended Process Model

Emotions emerge from an emotion generation cycle which, in the Extended Process Model, can be described as occurring in four interlocking stages: World (situation), Perception (attention), Valuation (appraisal), and Action (emotional response: Gross, 2015)¹. The World, Perception, and Valuation stages collectively lead to Action in each period. Thus, these stages are similar to processes that are defined in many theories of emotion (Scherer, 2022)². Discrete climate emotions have been broadly defined as any affective phenomena related to climate change and prototypical examples of these subjective feelings include surprise, worry, anger, or empowerment (Pihkala, 2022). Subjective feelings and other essential components of emotion episodes (e.g., appraisals of situations, physiological responses) occur during the Valuation and Action stages of the generative cycle (Scherer & Moors, 2019) and are distinct from the World and Perception stages that initiate emotion generation. In the current conceptual framework (Figure 1), climate change information is the situation that has the potential to initiate emotion generative processes that can be affected by emotion regulation.

¹ The stages World, Perception, Valuation, and Action are capitalized when they are used as formal terms that refer to stages of the model.

² Note that in this conceptualization, the Action stage is considered motivational and could be behavioral in terms of emotional expression but does not refer to behaviors that occur outside the emotion generative process.

Figure 1*Mitigating Climate Change with Emotion Regulation and Mindful Acceptance*

Note. The solid lines correspond to proposed paths in the conceptual framework. Climate emotions are initiated by exposure to climate change information (which can be external or internal). Emotion regulation affects emotion generation and both emotion and its regulation interact with beliefs, behavior, and systems related to climate change. The box around emotion generation does not encompass the climate change information as there is an opportunity for emotion regulation via situation selection prior to exposure to climate change information. Each emotion regulation strategy that targets the emotion generative cycle (level one) is subject to a higher order (level two) process by which the need for emotion regulation is identified, a strategy is selected and implemented, and feedback occurs through emotion regulation monitoring. Mindful acceptance, in theory affects emotion generation and is bidirectionally associated with belief, climate change information exposure, and monitoring for the need to regulate emotion, but not directly associated with identification of a need for change, or selection or implementation of emotion regulation strategies.

In our framework, emotion regulation refers to processes characterized by implicit or explicit goals to change emotional experience. More specifically, emotion regulation refers to processes that are responsible for altering emotion generation, most commonly thought of as the implementation of regulatory strategies (Gross, 2013, 2015; Gross & John, 2003).

Implementation is theorized as a second level process in emotion regulation, occurring in sequence and conjunction with identification (of a need to regulate), selection (of a strategy or

tactic) and monitoring (to adjust the strategy or tactic currently in use: McRae & Gross, 2020; Sheppes, 2020). Emotion regulation strategies are theorized to target different stages of the emotion generative process. At the World stage, situation selection can facilitate engagement with (or avoidance of) emotionally evocative situations and may be particularly helpful for people who experience high levels of emotion or struggle to regulate in other ways (Webb et al., 2018). Situation modification also targets the World stage but only targets those situations which are external, such as changes to the lighting or other aspects of the external, sensory-perceptible world (Quoidbach et al., 2015).

After exposure to a situation comes the Perception stage, which can be targeted for emotion regulation through attentional deployment, such as distraction from unpleasant situations (Ferri et al., 2016; Wadlinger & Isaacowitz, 2011). Perception is followed by Valuation. Emotion regulation at the Valuation stage occurs by cognitive change; one typical type of cognitive change is reappraisal, which can be implemented by changing the interpretation – the appraisal – of an external or internal situation (Waugh et al., 2022). There are numerous aspects of appraisals that can be altered, such as the relevance, valence, likelihood, agency, and coping potential (Yih et al., 2019). Finally, in addition to strategies that target antecedents of an emotional response, response modulation targets the Action stage itself – experience, expression, or physiology (Gross, 2015).

Limited research has examined the regulation of climate emotions. There is some evidence of selective engagement with climate change messaging based on emotional content, which might be considered situation selection, if the participants were selecting messages to change their emotional experience (e.g., Skurka et al., 2022). Situation modification could involve leaving the room when climate change information appears on television or turning off

the news when climate change is being discussed to change emotional experience³. If a situation is not modified beyond perception, then emotion regulation strategies that target the Perception stage are possible. There are extensive studies of distraction and engagement in climate change (Melanidis & Hagerman, 2022; Waters et al., 2023), but it is not clear that distraction and engagement were in the service of emotional change (i.e., attentional deployment emotion regulation strategies).

Among emotion regulation strategies pertaining to climate emotions and mitigation, the most research is available on cognitive change. One way to discuss cognitive change over longer periods of time (i.e., many iterations of emotion regulation/generation cycles) is through the idea of coping with stressors (Lazarus & Folkman, 1984). There is some research on coping with climate change among Swedish children (Ojala, 2012; Wullenkord & Ojala, 2023). In a sample of children around 12 years old, both meaning-focused coping (e.g., “I have faith in humanity; we can fix all problems”) and problem-focused coping (e.g., “I talk with my family and friends about what one can do to help”) were positively associated with self-reported pro-environmental behavior (Ojala, 2012). On the other hand, de-emphasizing the problem (e.g., “Climate change is something positive because the summers will get warmer”) had an inverse association with pro-environmental behavior (Ojala, 2012). For high school students, problem-focused coping mediated the association between worry about climate change and pro-environmental behavior (Wullenkord & Ojala, 2023).

Cognitive reappraisal is not synonymous with a specific type of coping, but, similar to meaning-focused and problem-focused coping, there have been positive associations between

³ One might think that climate situation modification would literally involve changing the world and be synonymous with climate change mitigation, but it's important to remember that the situation is climate change information (sensory-perceptible) rather than climate change itself (a large-scale, statistical, imperceptible phenomenon).

self-reported tendencies to use cognitive reappraisal (not specific to climate change) and pro-environmental behavior (Panno et al., 2015, 2020). On the other hand, there is some evidence that effectively reducing negative feelings about the threat of climate change on biodiversity (i.e., to bumblebees), without a focus on problem-solving, is associated with reduced conservation behavior (Wenzel, Rowland, et al., 2023). These studies suggest that there are multiple ways that reappraisal could be associated with climate solutions.

After appraisal or reappraisal, there is an emotional response at the Action stage. Response modulation emotion regulation strategies target the Action stage directly, rather than targeting the stages leading to the response. Modulating an emotional response to climate change could involve repressing feelings of doom, or hiding a frown when exposed to information about climate change that conflicts with current beliefs. Although the extended process model posits families of emotion regulation strategies that target specific stages of the emotion generation process, there may be other ways to regulate emotion, such as with mindfulness.

Emotion Regulation and Mindful Acceptance

Mindfulness is tightly linked with emotion regulation (Chambers et al., 2009; Tang et al., 2015). Mindful acceptance is one aspect of mindfulness which can be compared to emotion regulation (e.g., Kober et al., 2019; Teper & Inzlicht, 2014). The acceptance aspect of mindfulness can be considered “a mental attitude of nonjudgment, openness and receptivity, and equanimity toward internal and external experiences” (Lindsay & Creswell, 2017, p. 50). Mindfulness, and specifically mindful acceptance, could influence emotional experience at multiple points in the emotion generation cycle (e.g., Hayes et al., 2006; Simone & Saldarini, 2023). Specifically, early in the emotion generative process, mindful acceptance relies on other aspects of mindfulness, such as attentive awareness to climate change information. Along with attentive awareness at the Perception stage, mindful acceptance relies on appraisals to

evaluate situations without a desire for more pleasantness or less unpleasantness at the Valuation stage. Furthermore, there may be downstream effects on emotional responses at the Action stage. For example, although earlier processes are essential, mindful acceptance continues through emotional experience, as one “experiences emotion and allows it to pass” or “notices emotion, and lets it go”.

However, mindful acceptance influences emotion generation through mechanisms that are theoretically different than intentional emotion regulation⁴. Mindful acceptance is different than emotional regulation in at least one important way – mindfulness does not entail a goal of emotional change⁵. For example, mindful acceptance and rumination might overlap via attentional monitoring at the Perception stage, but whereas rumination results in greater motivation to attend to negativity, mindful acceptance does not encourage one emotional experience over another. For another, mindful acceptance and cognitive reappraisal both affect the Valuation stage, but whereas cognitive reappraisal facilitates desired changes in appraisals, mindful acceptance may inhibit the appraisal process itself, such as with an attitude of nonjudgment. Rather than a reappraisal of a situation, mindful acceptance might be described as generating less influential initial appraisals, or inhibiting reactions to initial appraisals.

Nonjudgement in this context could also be termed equanimity, which refers to balanced appraisals of situations – not biased toward experience based on the characteristics of affective experience or goals to influence affective experience. Although nonjudgment or equanimity that is characteristic of mindful acceptance does not involve emotional goals, there could be metacognitive monitoring goals involved with mindful acceptance, which are likely similar to the

⁴ Although, at the second level of emotion regulation, monitoring processes that are responsible for identifying the need to regulate emotion could overlap with those involved with early stage processes underlying mindful acceptance.

⁵ Here, we define emotional regulation by characterizing processes involved with implicit or explicit goals to change emotional experience.

metacognitive process involved with monitoring for the need to regulate emotion and the success of strategy use. Because mindful acceptance may affect multiple stages of the emotion generation cycle, regardless of metacognitive similarities, it may be prudent to avoid any tendency to classify mindful acceptance as a stage-specific regulation strategy.

In fact, mindful acceptance may target emotional experience directly and reduce the potential influence of a level-two emotion regulation system on the emotion generation cycle. Mindful acceptance is one of four ways that people could approach their emotional experience that we explored in these studies, along with more classic emotion regulation strategies of distraction, cognitive reappraisal, and suppression.

Current Research

Across the three studies in this dissertation, an overarching goal is to explore how the regulation of climate change emotions could be associated with climate change mitigation and adaptation (i.e., climate change solutions). Climate emotions are elicited by situations (i.e., the World stage of emotion generation) in which features of the perceptible external environment and activated internal representations are related to climate change (Figure 1). Therefore, the studies are about the emotions people experience and how they regulate them when faced with climate change information, and how these emotions and emotion-regulatory responses relate to climate change mitigation and adaptation. In the discourse of the IPCC, this dissertation bridges the contributions of Working Group II and Working Group III, examining how the facts about climate change can functionally translate to mitigation via social science (Box TS.11, AR6 WGIII) through a multilayer affective lens, beginning with the human body.

The focus of Study 1 is psychophysiological responses to climate change information. Study 2 examines associations between climate change belief, emotional responses to climate change information, and climate change solutions. Study 3 extends the first two studies by

testing the consequences of regulating negative emotions with mindful acceptance and cognitive reappraisal on emotional responses and climate change solutions.

Study 1

Introduction

Subjectively, emotions co-occur with bodily responses and many theories attempt to make sense of emotions as both subjective experiences and bodily phenomena. For example, emotions have been conceptualized as evolved, motivationally relevant mechanisms that facilitate survival and reproduction by bringing forth appetitive and defensive responses (Lang et al., 1998). The autonomic nervous system is of interest when people attempt to understand emotions in the body (e.g., Damasio et al., 1996; Ellsworth, 1994; James, 1884; Klorman et al., 1977). However, the autonomic nervous system is not one simple mechanism. The autonomic nervous system is composed of multiple interlocking nervous systems, including the most discussed sympathetic and parasympathetic branches. The branches can appear to activate in unison, against each other, or tangentially (Berntson et al., 2016).

Modern research suggests that despite some consistency in autonomic nervous system responses associated with emotion categories, autonomic nervous system activation can be similar for different emotional experiences and different for similar emotional experiences (Siegel et al., 2018). For instance, autonomic nervous system activity can be associated with both pleasant and unpleasant emotions (Kreibig, 2010), despite competing ideas about whether the autonomic nervous system reflects functions unique to specific discrete emotions (Levenson, 2014). A recent meta-analysis suggested that positive emotions were generally associated with weak (i.e., small effect sizes) and/or heterogeneous (i.e., effect sizes were different between or within studies) patterns in both sympathetic and parasympathetic nervous system activation (Behnke et al., 2022). On the other hand, there is more robust evidence of

autonomic nervous activity associated with negative emotional experiences (Cannon, 1915; Siegel et al., 2018; Stemmler, 2004).

Electrodermal Activity

Electrodermal activity (i.e., sweat gland activity) is an example of a physiological response that is associated primarily with the sympathetic nervous system (Dawson et al., 2016). One way to measure electrodermal activity is through skin conductance. Skin conductance can fluctuate relatively slowly (skin conductance level, tonic electrodermal activity) but can also change in shorter spurts (skin conductance response, phasic electrodermal activity). The magnitude of the tonic skin conductance and the skin conductance response, among the many effects of the autonomic nervous system, are considered a measure which directly reflects sympathetic nervous system activity (Dawson et al., 2016).

Substantial research (e.g., Lang et al., 1993) has reported higher skin conductance levels alongside greater emotional arousal. A more recent study showed participants positive and negative environmental and non-environmental images. When viewing positive environmental images compared to other positive images, greater biospheric values (i.e., cares about the environment) were associated with greater skin conductance (Conte et al., 2023). Another recent study assessed sympathetic activity to a climate change solution – renewable energy infrastructure. The change in the number of skin conductance responses from baseline to during 30s videos was higher when viewing videos of landscapes with windmills, compared to the same videos without windmills, although participants preferred landscapes without windmills (Spielhofer et al., 2021).

Cardiovascular Activity

In addition to sweat gland activity near the surface of the body, the cardiovascular system is also regulated by the autonomic nervous system. One common measurement of cardiovascular activity is heart rate, which can increase or decrease as the body adapts to the

environment. When the sympathetic nervous system prompts an increase in heart rate, it is often accompanied by decreases in parasympathetic activity; as the heart rate slows, or when at rest, there are increases in parasympathetic activity (Gordan et al., 2015). Therefore, the parasympathetic nervous system is generally considered to be an inhibitory system on heart rate, having a regulatory effect.

Respiratory Sinus Arrhythmia (RSA). Heart rate increases during inhalation and decreases during exhalation (Yasuma & Hayano, 2004). The changes in heart rate that are linked to respiration are called RSA. One measure of RSA is high-frequency heart rate variability (HF HRV), which signals regulation of cardiovascular activity by vagal nerves (Mestanik et al., 2019). In general, RSA decreases during emotionally challenging situations and an individual's lower RSA has been linked to emotion dysregulation and associated psychopathological symptoms (Beauchaine, 2015).

However, laboratory procedures designed to elicit negative emotion might not reliably affect RSA (Allen et al., 2014; Seddon et al., 2020; Yim et al., 2015). Recently, new methods to analyze changes in RSA at a more precise time-scale have facilitated a greater understanding of the momentary fluctuations in RSA (Gates et al., 2015). Changes in RSA in response to emotional situations could provide valuable insight into the activity of the parasympathetic nervous system to complement the electrodermal activity that signals sympathetic nervous system activation, and the heart rate itself, which is modulated by both the sympathetic and parasympathetic branches of the autonomic nervous system.

There is a paucity of studies on parasympathetic nervous system responses to climate change information. Even a related topic with more research – the effects of nature itself – has yielded mixed results. For example, a laboratory study reported increases in parasympathetic control of the cardiovascular system through vagal control when viewing slideshows of natural, compared to built environments (Gladwell et al., 2012). Another study reported increases in

resting heart rate and reduced vagus-mediated parasympathetic control when participants were in the midst of a 5-day nature excursion (Scott et al., 2021). A preprinted abstract suggests that there is ongoing research on the physiological effects of climate change-related imagery, compared to other negative affective stimuli such as those related to terrorism (Tedaldi et al., 2022).

Current Research

In sum, the primary objective of Study 1 was to provide preliminary validation that our climate change information presentation procedure elicited a degree of physiological responsiveness. We also aimed to determine how people felt about the information, and how they naturally regulated emotional responses. Some of the information was positive, but more was negative, and each statement had a scientific confidence level attached. The outcomes included measurements of autonomic nervous system (i.e., skin conductance, heart rate, and RSA) and self-reported emotion and emotion regulation.

If climate change information prompts emotional responses that activate the sympathetic nervous system, then we should see increases in skin conductance relative to baseline. If climate change information activates the parasympathetic nervous system, then we should see increases in RSA relative to baseline. If climate change information promotes sympathetic more than parasympathetic activation, we should see increases in heart rate. If climate change information elicits a range of subjective positive and negative feelings, then we should see those distributions in the evaluative space grid, and if participants use one or more emotion regulation strategies more than one or more of the others, we should see differences in their reported use.

Method

Statement of Transparency

All studies in this dissertation were approved by the Tufts University Social, Behavioral and Educational Research Institutional Review Board under the research protocol number

STUDY00003522. For all studies in this dissertation, statistical analyses and visualizations were conducted in the R programming language (R Core Team, 2023) with packages `data.table` (Barrett et al., 2024), `psych` (Revelle, 2024), `MASS` (Ripley et al., 2024) `lme4` (Bates et al., 2024), `lmerTest` (Kuznetsova et al., 2020), `emmeans` (Lenth et al., 2024), `car` (Fox et al., 2023), `interactions` (Long, 2021), `performance` (Lüdtke, Makowski, et al., 2024), `dplyr` (Wickham et al., 2023), `sjPlot` (Lüdtke, Bartel, et al., 2024), `ggplot2` (Wickham et al., 2024), `ggdist` (Kay & Wiernik, 2024), `ggstatsplot` (Patil & Powell, 2024), `patchwork` (Pedersen, 2024), `flextable` (Gohel et al., 2024), `lavaan` (Rosseel et al., 2024), `semTools` (Jorgensen et al., 2022), and `BFpack` (Mulder et al., 2019). Versions of each package used are shown at the beginning of each markdown file on OSF.

Participants in Study 1 completed the study procedures between 17 April 2023 and 4 May 2023. Hypotheses, analysis plans, and exclusion criteria were not preregistered. Informed consent was provided after viewing the consent form in an online survey and having an opportunity to ask the researchers questions before taking part in any research procedures. Information was presented and responses solicited using the PsychoPy Builder interface (Peirce et al., 2019). The PsychoPy task was programmed to send relevant signals to AcqKnowledge software via a BIOPAC MP150 and BBTk USB TTL module.

Data and materials for this study are publicly available at osf.io/kefsb. More data are available than were analyzed for this report. In a simplified sensitivity test to approximate change in physiology from baseline, a within-subjects effect size slightly greater than medium ($d = .66$) would be detectable 80% of the time.

Design

We used an experimental task that included information slide stimuli that varied on two characteristics within-subjects: scientific confidence and valence. Dependent variables included peripheral physiology and ratings of emotion and emotion regulation. These conditions were

designed to be fit with regression models that were multi-level and maximal, with a priority to account for variability (i.e., clustering) at the participant level.

Participants

In Spring 2022, we recruited as many participants as possible in one semester ($N = 20$) for a 60-minute study. Participants were students who were compensated with course credit via the SONA system. Participants ranged in age from 18 to 41, with a median age of 19. Participants in this sample reported predominantly liberal ideology ($M = 2.70$, $SD = 1.22$) on a Likert-style scale⁶ from one (extremely liberal) to seven (extremely conservative). In two open-ended prompts, we asked participants to provide a word or phrase that best describes their gender and their race and/or ethnicity. In footnotes, we edited spelling and capitalization and removed hyphens/dashes or replaced them with forward slashes; otherwise, we report the open-ended responses exactly as entered by the participants. In the main text, we collapsed the responses to the race and/or ethnicity question and report the breakdown according to the groups described in the U.S. census.

All participants reported one binary gender, either woman ($n = 7$) or man ($n = 13$)⁷. Participants reported race and/or ethnicity as Hispanic or Latino ($n = 1$), White alone non-Hispanic ($n = 12$), Black or African American alone non-Hispanic ($n = 1$), American Indian or Alaska Native alone non-Hispanic ($n = 0$), Asian alone non-Hispanic ($n = 5$), Native Hawaiian

⁶ Political ideology was assessed with a question from the U.S. General Social Survey: “We hear a lot of talk these days about liberals and conservatives. Here is a 7-point scale on which the political views that people might hold are arranged from extremely liberal to extremely conservative. Where would you place yourself on this scale?”. There were seven text-labelled Likert-style response options ranging from “Extremely liberal” to “Moderate, middle of the road” and “Extremely conservative”.

⁷ Two of the men used the term “male” rather than man to describe their gender.

and Other Pacific Islander alone non-Hispanic ($n = 0$), some other race alone non-Hispanic ($n = 0$), and multiracial non-Hispanic ($n = 1$)⁸.

Materials

Climate Change Information Stimuli. For this dissertation, we designed climate change information stimuli based on statements from the IPCC (see examples in Figure 2). We rephrased semantic information, including confidence statements, from an IPCC report (IPCC WG II), and paired each phrase with an image to operationalize climate change as a situation which can be perceived through basic sensory and conceptual processes. All statements included human causation. Considering the threatening nature of climate change, the stimuli focus on negative information, and statements had a reported scientific confidence level. There were nine negative slides and three positive slides; four slides each had medium, high, and very high scientific confidence, according to the IPCC (Table 1). Most images had previous valence ratings from the French Affective Images of Climate Change database (Ottavi et al., 2021), which were considered in the determination of valence. However, we did not obtain any affective ratings for the semantic information or the combination of semantic information with imagery prior to the studies reported in this document.

⁸ Without collapsing by the census categories, participants reported race and/or ethnicity as Asian ($n = 3$), Black ($n = 1$), South Asian ($n = 1$), Southeast Asian (Indian) ($n = 1$), White ($n = 11$), White/Japanese ($n = 1$), White/Caucasian ($n = 1$), and White/Hispanic ($n = 1$).

Table 1*Emotion and Emotion Regulation by Climate Change Information Stimuli*

stimulus number	valence	scientific confidence	negative emotion		positive emotion		distraction		mindful acceptance		cognitive reappraisal		suppression	
			<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
4	negative	medium	2.78	2.78	0.55	0.93	1.02	1.12	3.25	0.99	1.93	1.22	0.68	0.99
5	negative	medium	4.25	4.25	0.20	0.46	1.00	1.30	3.25	1.24	2.20	1.22	1.45	1.27
11	negative	medium	3.50	3.50	0.10	0.30	1.32	1.26	3.17	1.26	1.52	1.18	0.98	1.15
1	negative	high	4.45	4.45	0.17	0.45	1.02	1.11	3.40	1.38	1.38	1.16	1.15	1.19
2	negative	high	3.98	3.98	0.15	0.36	0.80	1.07	3.38	1.31	1.62	1.05	0.82	1.10
3	negative	high	3.72	3.72	0.30	0.52	0.90	0.93	3.78	1.19	1.35	1.19	0.80	0.82
6	negative	very high	4.90	4.90	0.03	0.16	1.80	1.59	3.33	1.29	1.27	1.18	1.32	1.39
7	negative	very high	3.92	3.92	0.15	0.36	1.10	0.94	3.40	1.53	1.80	1.37	1.20	1.02
12	negative	very high	4.68	4.68	0.00	0.00	1.38	1.69	3.20	1.45	1.50	1.30	1.48	1.36
10	positive	medium	1.75	1.75	2.72	1.24	0.38	0.53	2.80	1.09	2.35	1.06	0.42	0.61
8	positive	high	2.75	2.75	2.50	1.62	0.65	0.78	3.12	0.96	2.45	1.31	0.42	0.61
9	positive	very high	1.38	1.38	3.48	1.85	0.70	0.83	3.20	1.33	2.40	1.49	0.58	0.85
average			3.50		0.86		1.01		3.27		1.81		0.94	

Note. Emotion and regulation measures are on a scale from 0 to 6. Each participant viewed each information slide stimulus twice and responses were averaged by participant before being averaged by stimulus. Stimulus number was assigned in chronological order, as the IPCC statements of fact were selected, paraphrased, and paired with images.

Figure 2

Climate Change Information Stimuli Examples



Note. Each slide contains one statement from the 2022 IPCC report, paired with a related image. Six slides are shown here and all 12 slides are in Appendix A.

Physiological Measurements. For a resting period and during the climate change information task, we took continuous measurements of both parasympathetic and sympathetic autonomic nervous system activation, using electrodermal (EDA), electrocardiography (ECG), and plethysmography (PPG) recording. We also assessed somatic nervous system activation with continuous electromyographical (EMG) measurements of two facial muscles, the corrugator and zygomaticus major. Finally, we used eye-tracking to monitor gaze patterns during the climate change information task using predetermined regions of interest⁹.

⁹ PPG, EMG, and eye tracking data are available, but are not discussed except to describe how they were recorded. In our current approach, PPG data would be redundant with metrics obtained through

All signals except eye-tracking were collected with electrodes on the surface of the skin and amplified with a BIOPAC MP150 system and individual amplifiers. EDA was recorded via the electrodermal activity amplifier module with two disposable snap electrodes (Ag/AgCl, 11mm contact diameter) with pinch leads, positive on the distal phalanges of the middle finger and negative on the ring finger. ECG was recorded via the electrocardiogram amplifier module with two disposable snap electrodes (Ag/AgCl, 11mm contact diameter) with pinch leads, positive under the left clavicle and negative under the right clavicle, and one ground electrode on the back of the neck.¹⁰ PPG was recorded via the photoplethysmogram amplifier module with an optical method (matched infrared emitter and photo diode detector). EMG was recorded via two evoked response amplifier modules with two reusable, shielded electrodes (Ag/AgCl, 4mm contact diameter) placed along each muscle, and filled with a tensile adhesive conductive gel. Eye gaze was monitored and recorded with an EyeLink Portable Duo device, using target stickers without a chinrest and calibrated for each participant¹¹.

Physiological Data Processing. Raw physiological signals were collected continuously at a sampling rate of 2000 Hz during a resting state period and during the climate change information task¹² described below. The resting state and task data were concatenated, and data were processed in Python. After processing, for each signal, data were flagged by trial (epoched) for analyses and downsampled to 1 Hz.

For EDA, first, a polynomial detrend was applied with the `signal_detrend` function from the NeuroKit2 package, using an automatic procedure to find the polynomial order that

ECG. We have concerns about the quality of the EMG data and have not yet examined the eye tracking data.

¹⁰ The ground ECG electrode served as a backup, as participants were grounded through connection to the EDA amplifier module.

¹¹ The camera position was adjusted for each participant as necessary, following the EyeLink software requirements for positioning and calibration.

¹² Eye-tracking was only recorded during the information task.

minimized the RMSE. The mean of the EDA signal before detrending was added back to the data. The detrending removed session-level variability in skin conductance measurements. Then, the signal was cleaned using the NeuroKit2 `eda_process` function. The `eda_process` function calls the `eda_clean` function which uses a low-pass filter with a 3 Hz cutoff frequency and a Butterworth filter (order 4). Phasic (skin conductance response, SCR) and tonic (skin conductance level, SCL) EDA metrics were extracted from the continuous signals.

The ECG signals were first processed using the NeuroKit2 (Makowski et al., 2021) `ecg_process` function. A modified `ecg_process` function used `ecg_clean` with the 'neurokit' default method for cleaning the signal, i.e., a 0.5 Hz high-pass Butterworth filter (order 5), followed by a powerline filter at 60 Hz. Then the `ecg_peaks` function was implemented to identify QRS complexes based on the “steepness of the absolute gradient of the ECG signal” and subsequently detect R-peaks as the local maxima¹³. As a quality control measure, we applied the `correct_peaks` function from the `systole` package to remove any extra peaks and add any missing peaks (Legrand & Allen, 2022; Lipponen & Tarvainen, 2019). Before correcting peaks, we removed baseline drift with the `remove_baseline_wander` function from the `heartpy` package using a 0.05Hz notch filter¹⁴, applied a polynomial detrend with the `signal_detrend` function from the NeuroKit2 package, and then added the mean of the ECG signal back in. Continuous beats per minute (BPM) were calculated with a NeuroKit2 function (`ecg_rate`) and RR (R peak interval) with `signal_period`. Outliers were flagged as those RR intervals outside +/- 3 times the median.

¹³ <https://github.com/JanCBrammer/biopeaks/issues/23>

¹⁴ https://python-heart-rate-analysis-toolkit.readthedocs.io/en/latest/heartpy.heartpy.html?highlight=remove_baseline_wander#heartpy.remove_baseline_wander

RSA was calculated based on the cleaned ECG signal using the NeuroKit2 `hrv_rsa` function. Specifically, we used the method from Gates et al. (2015) to compute moment-by-moment changes in spectral power in the respiratory frequency range (0.12 – 0.40 Hz) based on sliding windows of approximately 30 seconds of data. Outliers were flagged as RSA measurements outside ± 3 times the median. If outliers were detected, they were removed and interpolated using a generic interpolation function from the *numpy* python package¹⁵. Nine of twenty participants had any RSA outliers corrected. Less than 1% of the RSA signal was corrected for six of those nine participants, and less than 2% for the other three participants.

Emotion and Emotion Regulation. As illustrated in Figure 3, participants reported their subjective experience of positive and negative emotion on a 7x7 grid with axes from “Not at all” to “Extremely” after each information stimulus. We might assume that reported emotional responses account for the regulation that was measured after the responses were reported, but there is no way to clearly distinguish emotional experience from emotion regulation in this study design. After indicating their subjective emotional experience on the grid, participants reported how much they used four emotion regulation strategies while viewing the stimulus: distraction, cognitive reappraisal, mindful acceptance, and expressive suppression. Each strategy was probed with a 7-point Likert-style slider from “Not at all” to “Extremely”.

Procedure

Participants scheduled an experiment session for course credit using the university’s SONA credit system, available to those students enrolled in Introductory Psychology. After providing informed consent, participants were fit with physiological monitoring electrodes, usually in the following order: four 2 mm EMG electrodes on two facial muscles, 2 disposable

¹⁵ <https://numpy.org/doc/stable/reference/generated/numpy.interp.html>

ECG electrodes on the right and left clavicles, 1 disposable ECG electrode as a backup ground on the back of the neck, two isotonic EDA electrodes on the middle and ring fingers of the left hand, and a pulse plethysmograph on the index finger of the left hand. Participants were seated, upright, and were asked to minimize movement at any point during the study, except to use the computer mouse and keyboard as necessary.

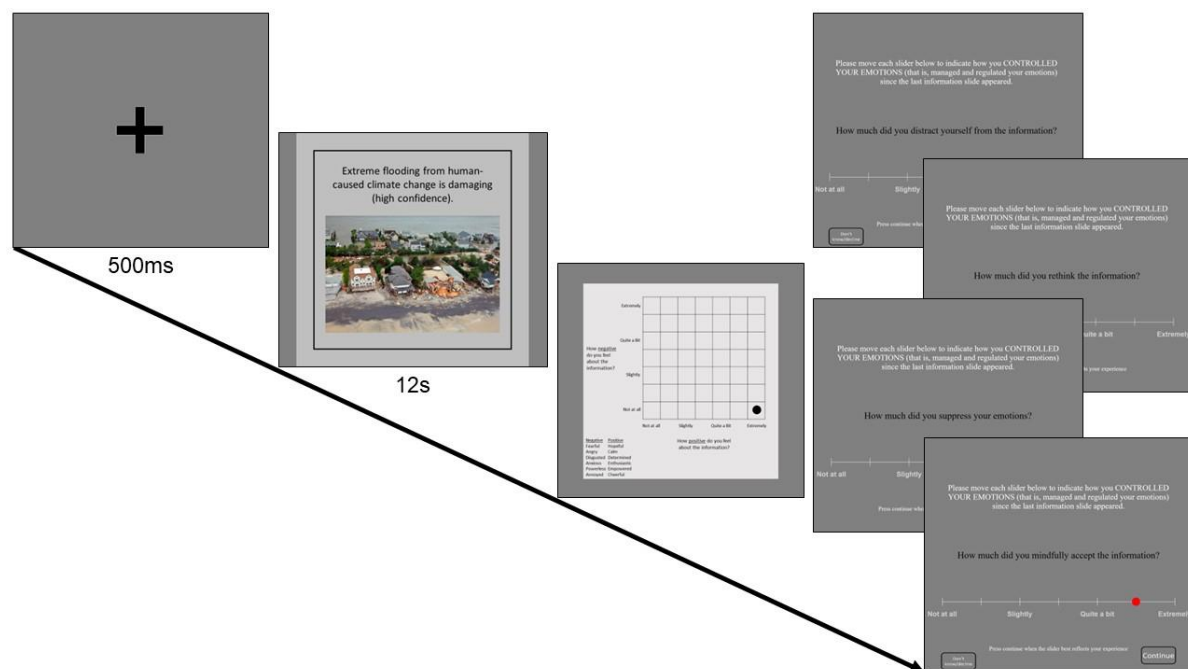
After being fit with the physiological sensors, participants completed a baseline survey on Qualtrics. Then the participants were instructed to sit at rest for a brief period (approximately three minutes). Following that resting period, participants completed the climate change information task, including instructions and practice responses. Task instructions included a brief explanation of scientific confidence as the amount of evidence and consensus among scientists. Instructions also included practice responses on the emotion grid and the emotion regulation sliders. During the task instructions, we tried to balance between ensuring that participants understood what we were asking them about their emotion regulation and not prompting people to regulate emotions in any specific way. To do this, we first told participants that they could do certain things to change the way they feel (Table 2, row 1). Then, we provided brief descriptions of four emotion regulation strategies (Table 2, row 2) in a multiple-choice knowledge test to be sure participants understood these concepts when making their ratings.

Table 2*Regulatory Strategy Descriptions*

row	distraction	mindful acceptance	cognitive reappraisal	suppression
1	Distract yourself from the information	Mindfully accept the information	Rethink the information	Suppress your feelings or facial expressions
2	Think about something unrelated to the situation or your feelings about the information; look away from the screen	Notice your feelings without trying to change them; observe feelings without judgment and allow them to pass	Change the way you think about the situation to change the way you feel; reconsider thoughts that make you feel a certain way	Change the way your feelings appear on your face; stop the feelings that you experience

Note. Row 1 contains the first descriptions of each regulation process that the participants saw in Studies 1 and 2. Each process was described as a way to “control (that is, regulate and manage) your emotions as you view the words and pictures”. After viewing the first descriptions from Row 1 on one page, there were four sequential multiple-choice questions to increase participants’ familiarity with the language in the studies. All four descriptions (row 2) were presented as response options to the question “Which of the following options describes [distraction/mindful acceptance/rethinking/suppression]?”. For both correct (feedback: “Correct!”) and incorrect (feedback: “Oops! That’s not quite right.”) responses, the question was shown again, with the correct description. At the bottom of the screen with the feedback was “Press ‘c’ when you’ve done your best to understand this idea”.

Each information slide (with words and a picture) was presented for 12 seconds after a 500ms fixation cross (see Figure 3). The words were considered the foundation of each information slide, and the pictures complemented each scientific statement. Participants reported the amount of positive and negative emotions on the grid after stimulus presentation. The emotion regulation questions were presented one at a time in a random order after each emotion response was reported.

Figure 3*Climate Change Information Task Trial Diagram*

Note. Twelve unique information slides were shown for 12 seconds each, following a 500ms fixation screen. After each stimulus presentation, participants completed a self-paced rating of their positive and negative emotions on a version of the evaluative space grid (Larsen et al., 2009). Then, four emotion regulation probes were presented in a random order for each trial (distraction, mindful acceptance, cognitive reappraisal, and suppression).

After the information task, participants completed a second survey on Qualtrics, including age, political ideology, and open-ended questions about gender and race and/or ethnicity.

Results

The first three regression models use a physiological signal as the outcome, binned in single second intervals across the twelve trial seconds. The valence of the stimulus factor was simple contrast coded such that the estimates are the difference from the grand mean. The confidence of the stimulus was repeated contrast coded such that each level (medium, high, very high) was compared to the lower level. The trial second factor was ordered. All interactions

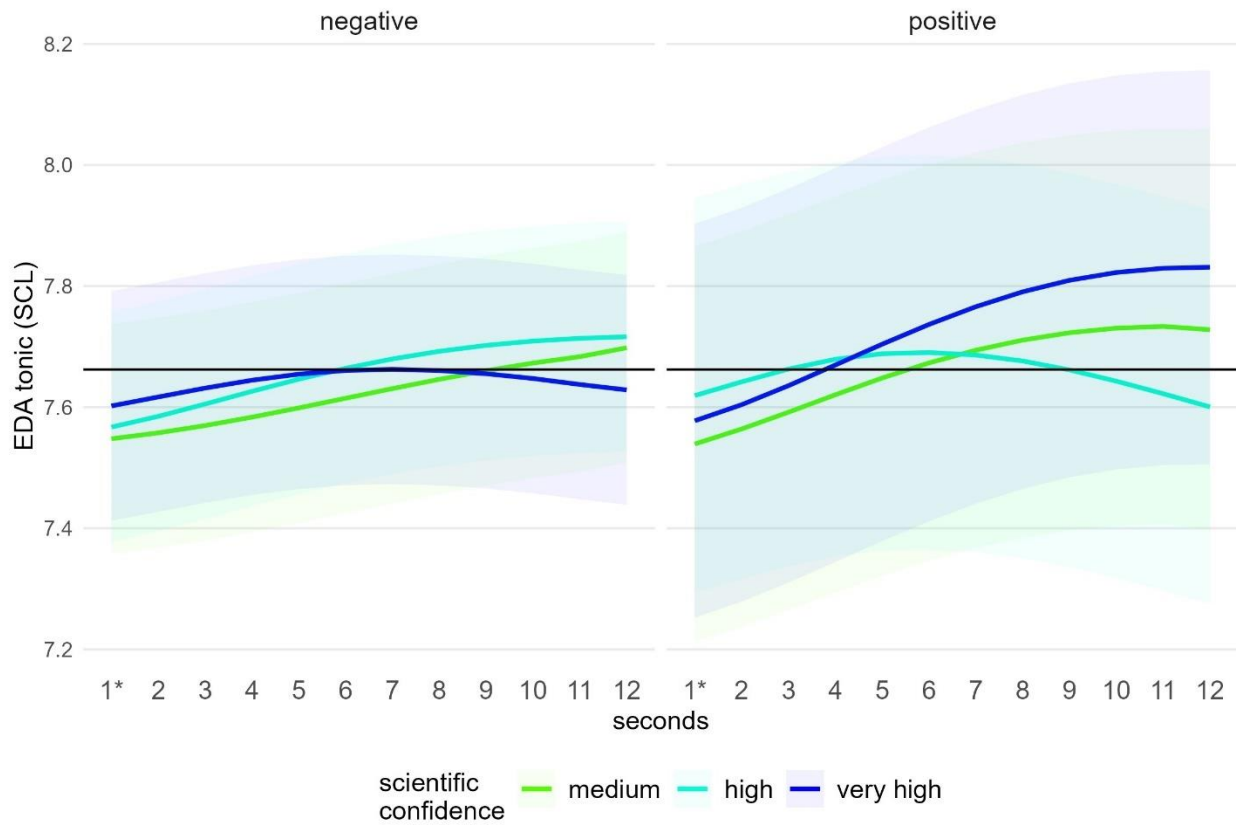
between both stimulus characteristics and trial seconds were included. Random intercepts¹⁶ were included for participants and stimulus; these intercepts allow each participant and each stimulus to have a unique intercept term. Measures for each physiological signal were also included as covariates. Grand-mean centered person-level signals at rest controlled for the variability between participants (i.e., baseline individual differences) and person-mean centered trial level signals at baseline controlled for the variability between trials (i.e., baseline trial differences).

After examining the physiological signals, we examined the feelings that people reported and the frequency of emotion regulation strategy use.

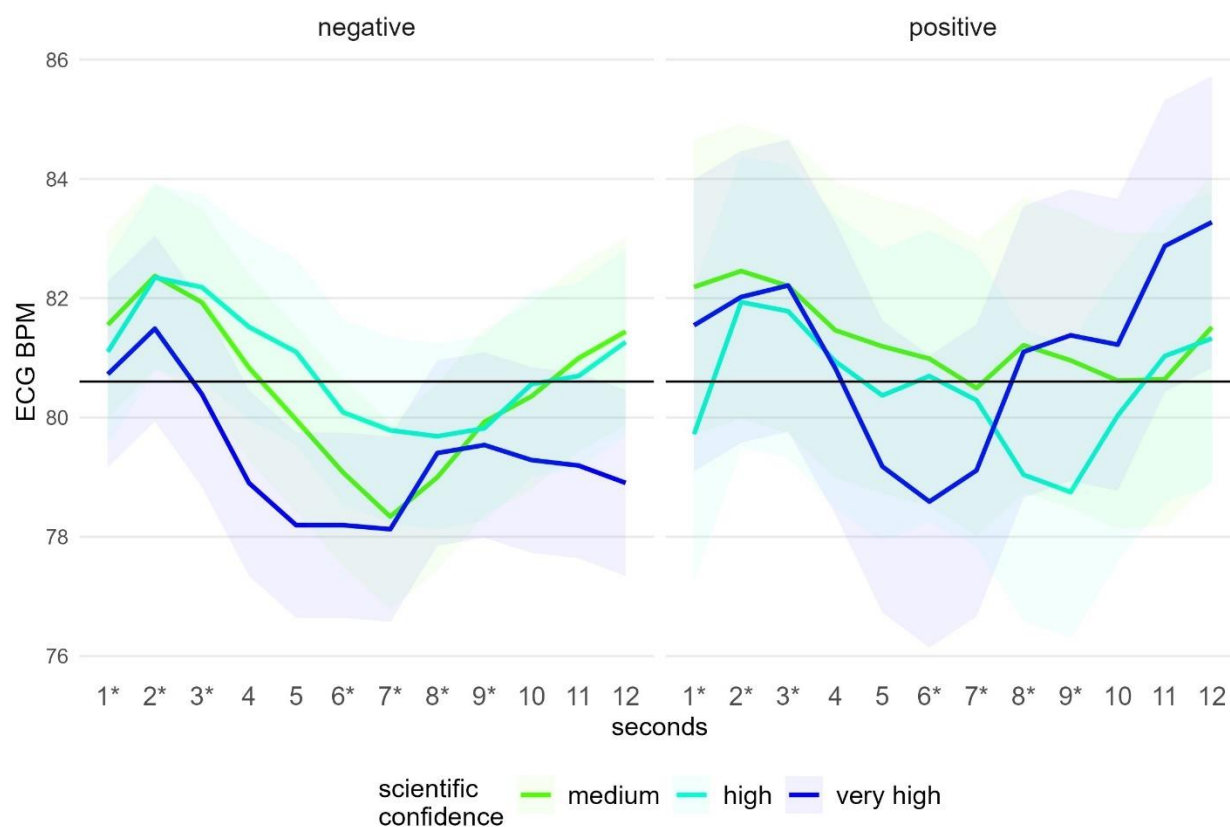
Physiological Responses

Upon initial visual inspections, climate change information appeared to elicit fluctuations in tonic EDA, heart rate in beats per minute (BPM), and RSA (Figures 4-6). Potentially due to the limited number of SCRs, models used to assess changes in phasic EDA displayed singular fit and were therefore not reported. All models used the same structure to examine how each physiological signal changed during the seconds of the trial by comparison to the mean signal and the predicted marginal means visually represent the signal dynamics in Table 3.

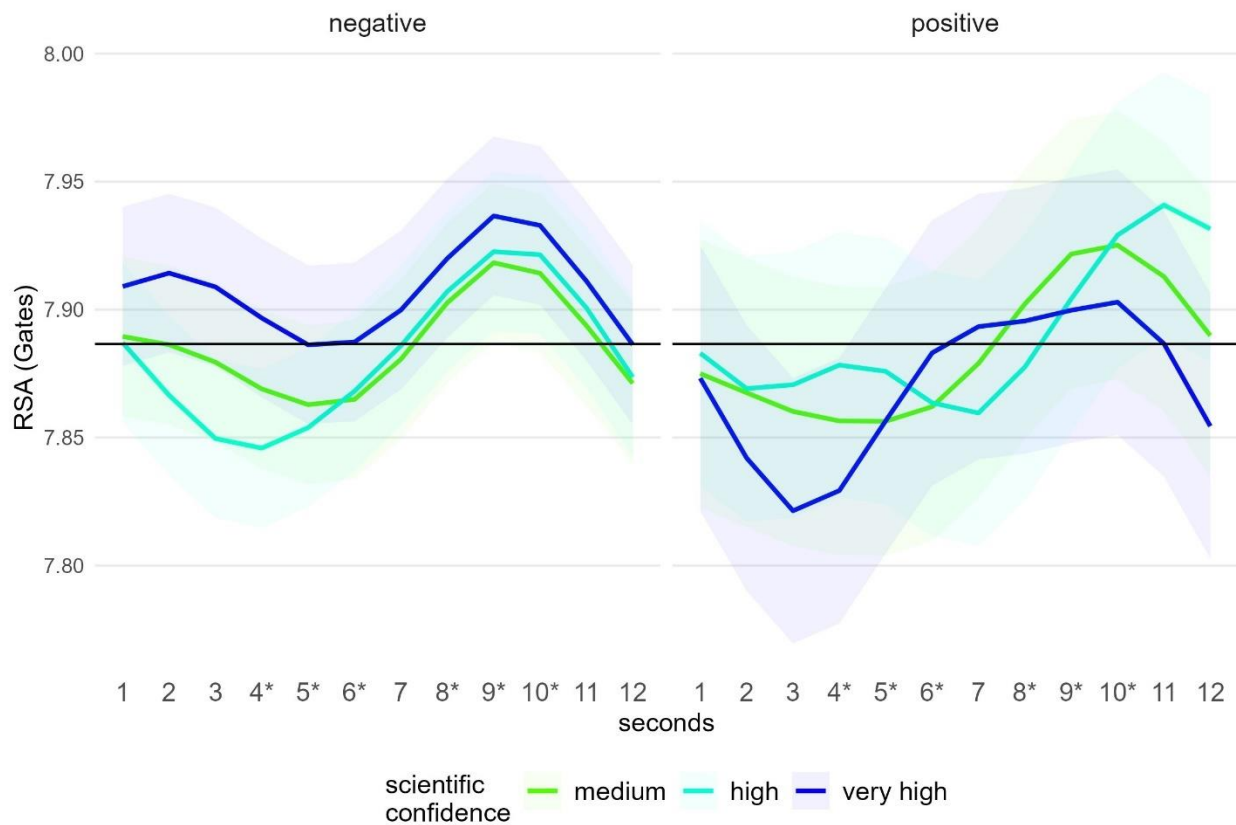
¹⁶ Random intercepts are used in the multilevel regression models to the same effect as clustering of standard errors by participant and stimulus.

Figure 4*Tonic Electrodermal Activity by Second and Stimulus Characteristics*

Note. Marginal means showing tonic EDA by trial second, stimulus valence, and stimulus confidence. Lines are plotted based on point predictions and shaded areas indicate 95% confidence intervals. The black line indicates the average tonic EDA across the epoch and stimulus characteristics. Tonic EDA was statistically significantly ($\alpha = .05$) lower than epoch average in the first second of the epoch, as indicated by the *.

Figure 5*Heart Rate by Second and Stimulus Characteristics*

Note. Marginal means showing heart rate in beats per minute (BPM) by trial second, stimulus valence, and stimulus confidence. Lines are plotted based on point predictions and shaded areas indicate 95% confidence intervals. The black line indicates the average BPM across the epoch and stimulus characteristics. When participants were exposed to climate change information, heart rate increased at first and then decreased, across all stimulus characteristics. Heart rate was statistically significantly ($\alpha = .05$) higher than the epoch average in the first three seconds of the epoch and lower than average in seconds six through eight, as indicated by the *.

Figure 6*Respiratory Sinus Arrhythmia by Second and Stimulus Characteristics*

Note. Marginal means showing respiratory sinus arrhythmia (RSA) calculated following Gates et al. (2015) by trial second, stimulus valence, and stimulus confidence. Lines are plotted based on point predictions and shaded areas indicate 95% confidence intervals. The black line indicates the average amount of RSA across the epoch and stimulus characteristics. RSA was statistically significantly ($\alpha = .05$) lower than the epoch average in seconds four through six and higher than average from second eight through ten, as indicated by the *.

Table 3*Physiological Signals While Viewing Climate Change Information*

<i>Fixed Effect Predictors</i>	<i>Outcomes</i>		<i>EDA (Tonic)</i>		<i>BPM</i>		<i>RSA (Gates)</i>	
	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>
(intercept)	7.66	<0.001	80.15	<0.001	7.89	<0.001		
trial seconds [1]	-0.07	0.019	0.90	0.007	0.00	0.656		
trial seconds [2]	-0.05	0.062	1.84	<0.001	-0.00	0.718		
trial seconds [3]	-0.04	0.183	1.27	<0.001	-0.01	0.102		
trial seconds [4]	-0.02	0.434	0.19	0.572	-0.02	0.005		
trial seconds [5]	-0.01	0.791	-0.48	0.150	-0.02	0.002		
trial seconds [6]	0.01	0.847	-1.11	0.001	-0.02	0.016		
trial seconds [7]	0.02	0.566	-1.48	<0.001	-0.00	0.692		
trial seconds [8]	0.03	0.384	-0.87	0.009	0.02	0.018		
trial seconds [9]	0.03	0.277	-0.47	0.159	0.03	<0.001		
trial seconds [10]	0.04	0.222	-0.16	0.623	0.03	<0.001		
trial seconds [11]	0.04	0.200	0.06	0.847	0.01	0.186		
valence [Positive]	0.04	0.603	0.75	0.064	-0.01	0.186		
confidence [high-medium]	0.04	0.712	0.36	0.461	-0.00	0.663		
confidence [very high-high]	-0.02	0.864	-1.48	0.003	0.03	0.008		
no. times viewed [2]	-0.01	0.457	0.52	0.003	-0.01	0.005		
valence : high confidence	-0.04	0.826	-1.20	0.225	0.01	0.588		
valence : very high confidence	0.09	0.644	2.10	0.033	-0.05	0.017		
EDA Tonic at Base (PMC)	0.77	<0.001						
EDA Tonic at Rest (GMC)	1.02	<0.001						
BPM at Base (PMC)			0.23	<0.001				
BPM at Rest (GMC)			1.01	<0.001				
RSA Gates at Base (PMC)					0.55	<0.001		
RSA Gates at Rest (GMC)					1.00	<0.001		
...	...	...	...	...	...	...	...	...
<i>Random Effects Clusters</i>								
ICC	0.02 _{P_ID}		0.07 _{P_ID}		0.02 _{P_ID}			
	0.04 _{stim}		0.01 _{stim}		0.00 _{stim}			
N	12 _{stim}		12 _{stim}		12 _{stim}			
	20 _{P_ID}		20 _{P_ID}		20 _{P_ID}			
Observations	5740		5740		5740			
Marginal R ²	0.989		0.796		0.865			
Conditional R ²	0.989		0.811		0.868			

Note. All interactions with trial seconds (fixed effects) were omitted from this table (indicated in the table with "..."); no interactions between stimulus characteristics and trial seconds were statistically significant. Valence was coded such that the higher value represents positive stimuli. Block was coded such that the higher value is the second time the image was viewed. ICC is the intraclass correlation coefficient, each corresponding to the percentage of variability in the estimation explained by one random intercept. P_ID refers to the unique participant identifier and stim refers to the unique stimulus identifier. GMC = grand-mean centered. PMC = person-mean centered. Statistically significant *p*-values ($\alpha = .05$) are in **bold**. As shown in Figures 4-6, tonic EDA increased after the first second post-stimulus presentation, BPM increased for three seconds, returned close to average for two seconds, then decreased for

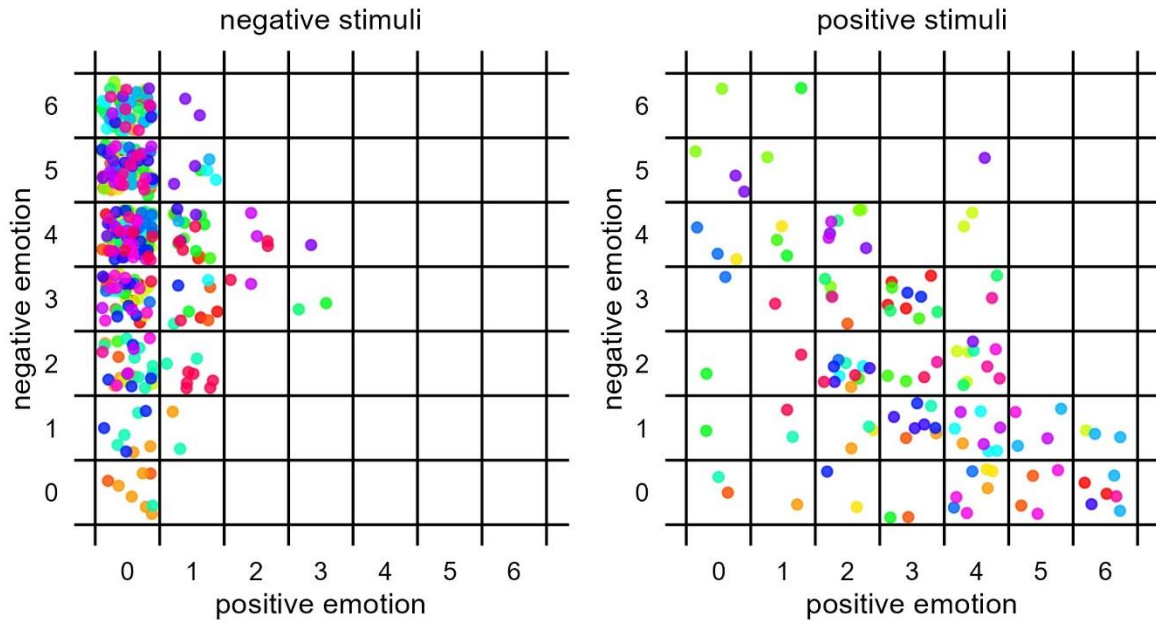
three seconds before returning to average, and RSA changed after BPM, decreasing from the average in seconds three through six, returned close to average for a second, then increased above the trial average in seconds eight through ten.

At the individual level, greater signals at rest predicted greater signals during the task. At the trial level, higher signals immediately before the start of the trial predicted higher signal during the trial. BPM increased the second time the stimuli were viewed, while RSA decreased. The positive stimulus with very high confidence elicited higher BPM and lower RSA than the positive stimulus with high confidence. Other than that single effect, valence and confidence did not significantly affect physiological responses.

Visually, tonic EDA showed an initial increase, with only the first second differing significantly from the trial average (i.e., the first second was lower than the trial average). BPM was higher than the trial average during the first three seconds, and lower than average during seconds six through eight, showing a non-linear trend. RSA also displayed non-linear activity; RSA was lower than the trial average following BPM increases (seconds four through six) and higher following BPM decreases (seconds eight through ten).

Self-reported Responses

On a scale from 0 to 6, the average amount of positive emotion was 0.86, less than the average amount of negative emotion, 3.50 (Table 1). The self-reported emotional responses to the climate change information are shown in Figure 7, split by negative stimuli ($n = 9$) and positive stimuli ($n = 3$).

Figure 7*Emotional Responses to Climate Change Information Stimuli*

Note. Emotional responses to climate change information plotted on the response grid for each valence category of stimulus. Each dot represents one response and each color represents one participant. Each participant made 24 total responses.

Emotion Responses. To probe emotion responses based on stimulus characteristics and individual differences, we examined hierarchical models of feelings in response to climate change information that followed the equation below (1). We report one model of positive emotion and one model of negative emotion (outcomes Y_{ij}), each with a random intercept representing the participant (μ_{0i}), a random intercept representing the stimulus (ν_{0j}).

$$Y_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 X_{ij} + \beta_3 X_{ij} + \beta_1 \beta_2 X_{ij} + \beta_1 \beta_3 X_{ij} + \beta_2 \beta_3 X_{ij} + \beta_1 \beta_2 \beta_3 X_{ij} + \mu_{0i} + \nu_{0j} + \epsilon_{ij} \quad (1)$$

The stimulus characteristics in Table 4 were modeled in the same way as in the models of physiological responses in Table 3. Three stimuli were coded as positive valence and nine as negative (β_1). There were nine slides categorized as negative and three as positive; each of the three confidence levels (medium, high, very high) was present on four of 12 slides and modeled

with repeated contrast coding (β_2). We also tested the effect of block to see if emotions changed during the second viewing of the information slides (β_3). People reported less positive emotion in the second block, compared to the first, but a corresponding increase in negative emotions was nominally smaller and not statistically significant.

Table 4*Stimulus Characteristics Predict Positive and Negative Emotion*

<i>Fixed Effect Predictors</i>	<i>Outcomes positive emotion negative emotion</i>			
	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>
intercept	1.54	<0.001	2.99	<0.001
valence [positive]	2.72	<0.001	-2.06	<0.001
confidence [high-medium] (2-1)	-0.15	0.226	0.77	0.092
confidence [very high-high] (3-2)	0.41	0.001	-0.46	0.312
no. times viewed [block] (2)	-0.28	0.002	0.16	0.150
valence × confidence 2-1	-0.15	0.544	0.46	0.616
valence × confidence 3-2	1.12	<0.001	-1.82	0.046
valence × block	-0.31	0.084	0.26	0.237
confidence 2-1 × block	-0.30	0.174	-0.12	0.636
confidence 3-2 × block	-0.21	0.344	0.14	0.592
valence × confidence 2-1 × block	-0.70	0.112	0.05	0.925
valence × confidence 3-2 × block	-0.48	0.273	0.02	0.975
<i>Random Effects Clusters</i>				
ICC	0.06 _{P_ID}		0.36 _{P_ID}	
	<0.01 _{stim}		0.14 _{stim}	
N	20 _{P_ID}		20 _{P_ID}	
	12 _{stim}		12 _{stim}	
Observations	480		480	
Marginal R ² (predictors)	0.652		0.328	
Conditional R ² (predictors and clusters)	0.676		0.661	

Note. Valence was coded such that the higher value represents positive stimuli. Confidence 1 is medium, 2 is high, and 3 is very high. Block was coded such that the higher value is the second time the image was viewed. ICC is the intraclass correlation coefficient, each corresponding to the percentage of variability in the estimation explained by one random intercept. P_ID refers to the unique participant identifier and stim refers to the unique stimulus identifier. All interactions that were included in the models are included in the table. Statistically significant *p*-values ($\alpha = .05$) are in **bold**.

Compared to negative information slides, positive information slides were associated with more positive emotion ($b = 2.72$) and less negative emotion ($b = -2.06$). Very high confidence was associated with more positive emotion than high confidence ($b = 0.41$). There was also an interaction between valence category and confidence level such that for positive valence category stimuli, very high confidence was associated with more positive emotion than

high confidence. Confidence did not appear to have statistically significant main effects on negative emotion. However, there was an interaction between valence category and confidence level such that for positive valence category stimuli, very high confidence was associated with less negative emotion than high confidence.

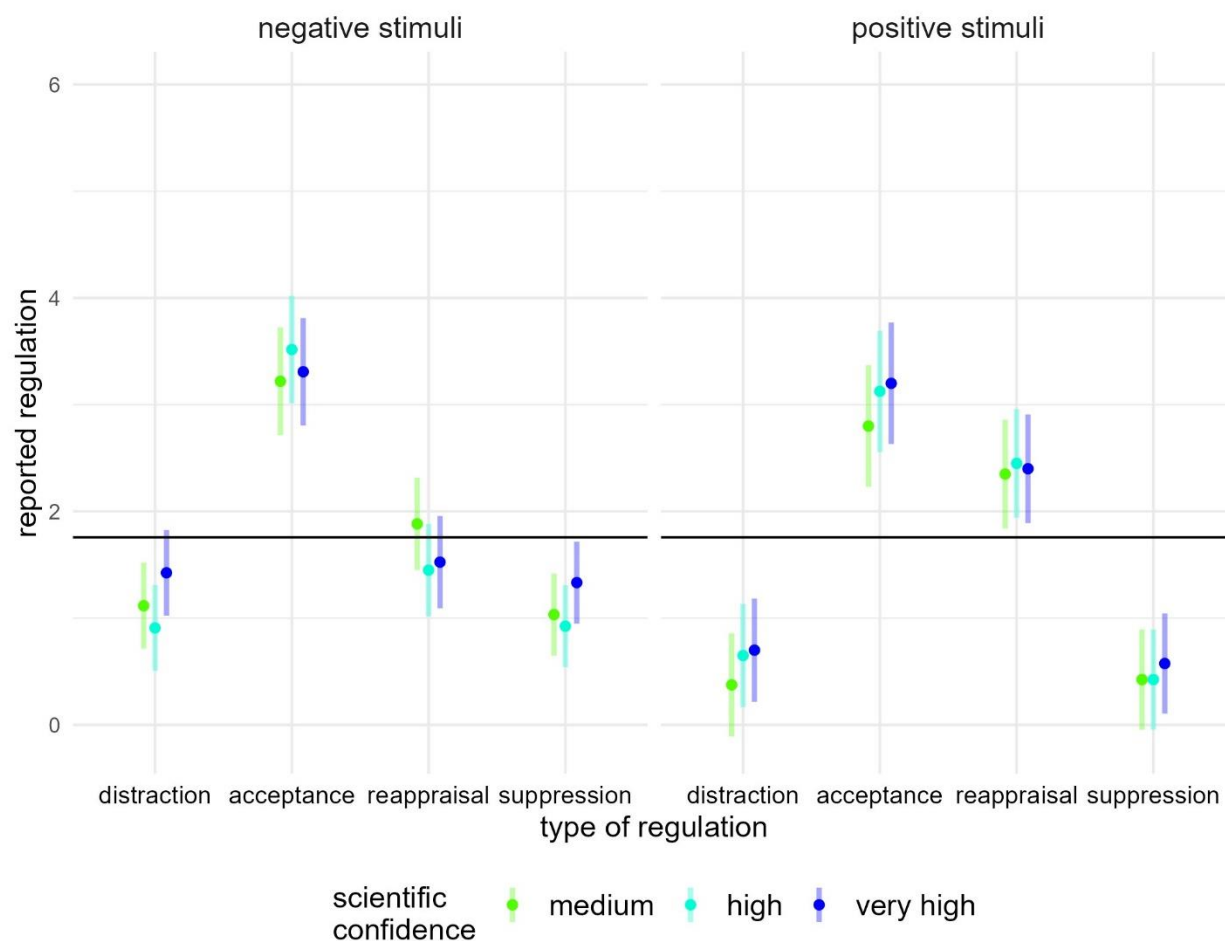
About 6% of the variability in positive emotional responses and about 36% of the variability in negative emotional responses could be statistically attributed to individual differences, based on the magnitude of the intraclass correlation coefficient in each model. Compared to the variability associated with individuals, and after accounting for stimulus characteristics (valence and confidence), less variability in both positive (<1%) and negative (14%) emotion was attributable to the stimuli.

Emotion Regulation Strategies. We measured four specific types of emotion regulation at the end of each trial: distraction, mindful acceptance, cognitive reappraisal, and expressive suppression. Table 3 shows the average emotion regulation by type and stimulus. To compare the types of emotion regulation, we examined a sum-to-zero contrast-coded fixed effect predictor, with expressive suppression as the reference level¹⁷. In the model, we also included stimulus characteristics (i.e., valence and confidence) and their interactions with emotion regulation. Finally, we included a random intercept for participant to account for individual differences¹⁸ and a random slope for emotion regulation type by participant to account for individual differences in emotion regulation use. Pairwise contrasts were used to compare each emotion regulation strategy to the others, based on the *t*-distribution and Satterthwaite methods for the degrees of freedom in the lmerTest package (Kuznetsova et al., 2017).

¹⁷ In this contrast coding, the regression estimate for the reference (i.e., estimated conditional difference from the grand mean) is the negative of the sum of the other estimates.

¹⁸ Including a random intercept for stimulus in models that also included stimulus characteristics resulted in singular model fit and therefore only the random intercept for participant was included in the reported results. Conclusions were consistent across model variations.

Mindful acceptance was used the most, more than distraction ($b = 2.33$, 95%CI [1.68, 2.99], $t(19.66) = 7.43$, $p < .001$), expressive suppression ($b = 2.41$, 95%CI [1.81, 3.01], $t(19.80) = 8.42$, $p < .001$), and cognitive reappraisal ($b = 1.19$, 95%CI [0.48, 1.89], $t(19.56) = 3.50$, $p = .002$). Cognitive reappraisal was used more than both distraction ($b = 1.15$, 95%CI [0.67, 1.63], $t(20.26) = 4.99$, $p < .001$) and expressive suppression ($b = 1.22$, 95%CI [0.72, 1.73], $t(20.14) = 5.07$, $p < .001$). There was not a statistically significant difference in the amount of reported distraction and expressive suppression ($b = 0.08$, 95%CI [-0.14, 0.29], $t(26.24) = 0.72$, $p = .477$). Notably, more cognitive reappraisal was reported for positive information and more distraction and expressive suppression for negative information (Figure 8).

Figure 8*Emotion Regulation by Type and Stimulus Characteristics*

Note. Marginal means of regulation reported during the task, predicted by type of emotion regulation and stimulus characteristics. Dots indicate point predictions and error bars indicate 95% confidence intervals for the point estimate, conditioned on the other variables in the model. The black line indicates the average amount of regulation reported across all types and stimulus characteristics.

Discussion

The main point of Study 1 was to provide validation of our climate change information stimuli. We were interested in the effect of climate change information on autonomic nervous system activity and subjective feelings, as well as how people regulate their emotions. The results provide preliminary evidence in a small sample that climate change information does

affect autonomic nervous system activity and bring about subjective feelings, and people do regulate their emotions. The evidence is consistent with the conceptual framework; specifically, it seems reasonable to assume that climate change information can initiate affective processes of emotion generation and regulation.

There are multiple branches of the autonomic nervous system and in this study, we found that multiple measures of autonomic nervous system activity were affected by climate change information. There were electrodermal responses, though they were less frequent and prominent than expected. Heart rate increased and then decreased in the twelve seconds of the trial, which we interpret as converging evidence for a sympathetic response, plus subsequent parasympathetic activation. RSA decreased after initial increases in heart rate, then began to increase as heart rate decreased, consistent with the hypothesis that RSA indexes parasympathetic control over heart rate. It is important to note that the temporal precision provided by this RSA calculation (Gates et al., 2015) is relatively novel, and that we did not examine second-by-second dynamics between heart rate and RSA (Fisher et al., 2016).

Strengths, Limitations, and Future Directions

One major strength of this study is that we collected data in person and included physiological measurements. However, we do not know from this study how physiological responses to climate change information are similar to or different than physiological responses to other types of semantic and visual stimuli. Information stimuli about other affective situations, such as biodiversity, violence, or war, might be comparable to response to climate change information.

Furthermore, we did not artificially manipulate scientific confidence. The scientific confidence level of the information is tied to the specific statements that we selected and each image was used for only one information slide (i.e., confidence is confounded with the words and the picture for each information slide). Although we selected statements that had different

confidence levels and found that physiological activity might be influenced by scientific confidence, it is possible that the variability in physiological signals explained by scientific confidence is driven by other aspects of the information (e.g., there is high scientific confidence that climate change causes natural disasters, medium confidence that climate change is responsible for human deaths, and very high confidence that climate change is bad for mental health). We also created only one information slide with positive valence for each confidence level. As such, future research would be needed to make strong causal claims about the physiological effects of scientific confidence in climate change information, and particularly how confidence could interact with valence.

In that future work on physiological responses, model comparisons could be informed by the results of this study. For example, visually, there were small increases in electrodermal activity throughout the seconds of the trial for some climate change information stimuli, but other stimuli appeared to elicit initial electrodermal activity that later decreased. Since our models only tested deviation in signal from the mean of the trial, we do not know whether a linear trend or a parabolic curve would be a better fit for the data. Multiple models for heart rate and RSA could similarly be compared.

Future work would benefit from larger samples. In addition, this sample was relatively homogenous in belief in climate change and does not necessarily reflect the target population (adults in the United States). People who believe in climate change (i.e., have greater perceptions of climate change) likely experience emotions related to climate change differently (Leiserowitz et al., 2021a; van Valkengoed et al., 2021). Climate change belief is an important component of the conceptual framework that was not a factor in this study. Considering the importance of people who do not believe in climate change in societal patterns and trends, this is a critical limitation. Examining a range of beliefs may be imperative to understand

associations between emotion regulation and climate change solutions – solutions that were also not addressed with this small sample.

Finally, it may be the case that mindful acceptance is more similar to passive viewing than to emotion regulation in the task that we designed. In Study 1, we found evidence that climate change information can elicit physiological changes in the body and bring about emotional experiences that people can regulate. In Study 2, we move away from bodily responses and further probe emotion, emotion regulation, and climate change solutions in people who believe and do not believe in climate change.

Study 2

Introduction

Climate change beliefs are also called perceptions (e.g., Heath & Gifford, 2006). Climate change perceptions are complex cognitions, which are more similar to beliefs, worldviews, or scientific conclusions than sensory percepts or experience (Hornsey et al., 2016; Thagard & Findlay, 2010). For more than a decade, we have known that perceptions of climate change risk and support for climate change solutions are associated with psychological and cultural factors (Leiserowitz, 2006). Perceptions of climate change were fundamental when psychologists recognized that addressing climate change was one of the most urgent tasks facing people on Earth and assembled a task force more than a decade ago (American Psychological Association, 2011). Recently, five distinct climate change perceptions were distinguished: reality, human causation, negative consequences, spatial occurrence, and temporal occurrence (van Valkengoed et al., 2021).

Climate change perceptions are central to understanding climate change emotions through appraisal theories. Appraisal theories describe the generation of emotion as dependent upon appraisals that determine the “significance of the environment for well-being” (Moors et al., 2013, p. 120). Extant belief in climate change will influence how situations are appraised as

either relevant or irrelevant for wellbeing and modulate subsequent emotional experiences. There is substantial evidence that climate change perceptions are associated with emotions related to climate change (e.g., Leiserowitz, 2006; Marczak, Wierzbą, Kossowski, et al., 2023; Marczak, Wierzbą, Zaremba, et al., 2023). For example, negative emotions driven by appraisals of irritation or contempt for the science of anthropogenic climate change could have negative implications for climate change solutions. Between 2008 and 2020, a small but meaningful portion of people in the United States (less than 10%) reported being dismissive of climate change (Leiserowitz et al., 2021a). On the other hand, negative emotions driven by threat perceptions, such as guilt, anxiety, or anger, have the potential to spur helpful action.

Given accumulating evidence for the potential of emotions to improve climate change solutions, one approach might be to increase climate change-related emotions. However, as mentioned above, more emotion may not always drive climate change solutions. Unlike constructive hope and doubt, false hope (e.g., wishful thinking) and fatalistic doubt (e.g., it's too late) show negative associations with climate change mitigation outcomes (Marlon et al., 2019). One way to facilitate more adaptive, constructive emotions is through emotion regulation – the optimization of emotional responses (Gross, 2015). Yet, it is unclear how and to what extent people spontaneously optimize their emotions in response to climate change.

People can use emotion regulation to increase or decrease their own positive or negative emotion. For example, cognitive reappraisal could involve reframing situations as more positive (or less negative) than initially perceived (McRae et al., 2012). In addition to the effects of real-time emotion regulation when exposed to climate change information, it is also important to consider the type(s) of emotion regulation implemented. There are numerous ways that people can regulate emotions other than cognitive reappraisal (Gross, 2015; McRae & Gross, 2020). Different types of emotion regulation could be preferred by the portion of people who are dismissive of climate change, compared, for example, to those who are concerned or alarmed.

Emotion regulation has the potential to motivate (or inhibit) climate change solutions. Climate change could be considered a specific type of threat and one way to think about climate change solutions is as threat mitigation behavior. However, people who are dismissive of climate change may perceive the threat to be climate solutions, rather than climate change itself (Leiserowitz et al., 2021b). Wenzel et al. (2023) found that, although emotion regulation patterns may be difficult to manipulate, when people successfully down-regulate negative emotion, they also engage in less threat mitigation behavior; on the other hand, successfully reappraising barriers to action was associated with more engagement in threat mitigation behavior. Even less is known about the potential for emotion regulation to drive climate change policy support or financial decision making, which are also important climate change solutions.

Current Research

We know that climate change beliefs are associated with climate emotions and climate solutions, but we don't know whether climate change beliefs are associated with emotion regulation, or whether emotion regulation can drive climate change solutions. There were two primary objectives of Study 2. One objective was to obtain evidence about emotion regulation strategy use in response to climate change information in people in the United States who believe and do not believe in climate change. The second objective was to test climate solutions as the outcome of belief and emotion processes.

If we find that emotion regulation strategies in response to climate change information are associated with climate change solutions, and if these patterns vary as a function of belief in climate change, then emotion regulation strategies would be plausible targets for cognitive and behavioral interventions. Furthermore, these patterns would be consistent with the conceptual framework motivating this dissertation.

Method

Statement of Transparency

Participants in Study 2 completed the study procedures between 06 April 2023 and 18 April 2023. Hypotheses, analysis plans, and exclusion criteria were not preregistered. Informed consent was provided after viewing the consent form online before taking part in any research procedures. Information was presented and responses solicited using a task built in the PsychoPy Builder interface (Peirce et al., 2019) and administered online as a PsychoJS experiment (Bridges et al., 2020). Data and materials for this study are publicly available at osf.io/9jda4. More data are available than were analyzed for this report.

Design

We recruited participants from two populations, those who believe in climate change and those who do not believe in climate change. We used the same climate change information task as in Study 1, with stimuli of differing valence and scientific confidence and self-report measures of emotion and emotion regulation. Belief, emotion, and emotion regulation were conceptualized as predictors of four climate change solution outcome measures: two surveys of policy support, one of pro-environmental behavior, and one real donation.

Participants

We employed Prolific (Prolific, Oxford, UK) services to recruit 300 adults in the United States (US) in 2023. Participants were paid approximately USD\$8.00 per hour¹⁹. Recruitment took place in two phases and each phase used two different prescreening criteria. One group of

¹⁹ In the first phase, the study was advertised at a rate of \$3.34 for a 25-minute study. The procedures took longer than anticipated, so after the first phase of data collection, the compensation rate was adjusted such that the median participant payment was at least \$8.00 per hour. That change is the only difference between the phases; in the second phase, the study was advertised at a rate of \$4.75 for a 35-minute study. The bonus was in addition to the advertised rate per hour. Prolific charged a 33% service fee and the task was hosted by the Pavlovia online platform at a cost of \$0.29 per participant.

participants were eligible if they responded “yes” and another group of participants were eligible if they responded “no” to a prescreening question in the demographic surveys on Prolific, “Do you believe in climate change?”. Recruitment for each study was balanced by Prolific to obtain approximately equal numbers of men and women. The sampling method and sample size were determined primarily by the available funds, task duration, and the intention to recruit generalizable samples of people who believe and do not believe in climate change.

Data are available from $N = 296$ participants²⁰ age 18 to 75 ($M = 45$, $SD = 14.55$), from rural ($n = 71$), suburban ($n = 165$), and urban areas ($n = 56$). Participants in this sample reported a range of political ideologies ($M = 3.18$, $SD = 2.05$) on a Likert-style scale from zero (extremely liberal) to six (extremely conservative).

In two open-ended prompts, we asked participants to provide a word or phrase that best describes their gender and race and/or ethnicity. After handling responses the same as in Study 1, most participants reported one binary gender, either woman ($n = 140$) or man ($n = 146$); other categories were bisexual ($n = 3$) and nonbinary ($n = 6$)²¹. Participants reported race and/or ethnicity as Hispanic or Latino ($n = 10$), White alone non-Hispanic ($n = 229$), Black or African American alone non-Hispanic ($n = 19$), American Indian or Alaska Native alone non-Hispanic ($n = 3$), Asian alone non-Hispanic ($n = 17$), Native Hawaiian and Other Pacific Islander alone non-Hispanic ($n = 0$), some other race alone non-Hispanic ($n = 0$), and multiracial non-Hispanic ($n = 10$)²². Human ($n = 6$) and American ($n = 1$) were not counted in any category. Note that Arab

²⁰ Three participants did not report demographic information.

²¹ One of the women specified “born with vagina”, one woman specified transgender, one woman specified “cis woman”, one woman used the term “lady” instead of woman, and 39 women used the term “female” instead of woman. One man specified “cis male” and 62 men used the term “male” instead of man.

²² Without collapsing by the census categories, participants reported African American ($n = 6$), American ($n = 1$), Arab American ($n = 1$), Asian ($n = 11$), Asian American ($n = 1$), Asian/Korean ($n = 1$), Biracial ($n = 2$, one specified Afro Caribbean American / White European American), Black ($n = 9$), Black American ($n = 2$), Black/Brown ($n = 2$), Caucasian ($n = 18$), Euro ($n = 1$), European ($n = 2$), European American ($n =$

American ($n = 1$) was included in White alone non-Hispanic, Spanish was considered Hispanic, and White/Asian ($n = 2$) or White and Asian ($n = 1$) were counted in the multiracial non-Hispanic category.

Materials

Perceptions of Climate Change. The climate change perceptions scale was administered pre-post task. It is a 15-item self-report measure with 7-point Likert-style response options, all labelled with words, ranging from “Strongly disagree” to “Strongly agree” with “Neither agree nor disagree” scored as four. The measure assesses five distinguishable dimensions of climate change perceptions, each of which contains three items. One subscale is reality the belief in the occurrence of climate change ($\alpha_{pre} = .97$, $\alpha_{post} = .99$), another is the belief that climate change is anthropogenic, human causation ($\alpha_{pre} = .99$, $\alpha_{post} = .99$), and a third is the belief that climate change will have negative consequences ($\alpha_{pre} = .95$, $\alpha_{post} = .96$). The last two perceptions probe whether people believe climate change will affect their geographic region ($\alpha_{pre} = .97$, $\alpha_{post} = .98$) and how temporally proximal the impacts of climate change are perceived ($\alpha_{pre} = .91$, $\alpha_{post} = .94$). Before the second administration of this measure, we asked participants if they thought their beliefs had changed since the beginning of the study (four response options: definitely/probably no/yes).

Discrete Climate Change Emotions. The inventory of climate emotions (Marczak, Wierzbka, Zaremba, et al., 2023) is a 32-item self-report measure with 5-point Likert-style response options, all labelled with words, ranging from “Strongly disagree” to “Strongly agree”

2), European Caucasian ($n = 2$), European/White ($n = 1$), Fair Skinned ($n = 1$), Hispanic ($n = 6$), Human ($n = 6$), Indian ($n = 2$), Lao Asian ($n = 1$), Latino ($n = 1$), Mixed ($n = 5$, one specified Black/White), Southeast Asian ($n = 1$), White ($n = 191$), White not Hispanic ($n = 1$), White/Caucasian ($n = 1$), White American ($n = 1$), White and Asian ($n = 1$), White Bread ($n = 2$), White European ($n = 1$), White Hispanic ($n = 1$), White Native American ($n = 1$), White of Cuban Descent ($n = 1$), White, Cherokee ($n = 1$), White, French Canadian ($n = 1$), White/Asian ($n = 2$), White/Caucasian ($n = 2$), White/Hispanic ($n = 1$), White/Native American ($n = 1$), and White/Spanish ($n = 1$).

with “Neither agree nor disagree” scored as three and “Somewhat” as the modifier for options two and four. The measure was designed to comprehensively assess the emotions related to climate change that people feel, and has been tested in multiple languages and countries in Europe (Poland, Norway, Ireland: Marczak, Wierzbka, Kossowski, et al., 2023). Eight discrete emotions were measured in the current study: contempt ($\alpha = .93$), anxiety ($\alpha = .92$), guilt ($\alpha = .95$), anger ($\alpha = .94$), loneliness ($\alpha = .79$), powerlessness ($\alpha = .77$), sorrow ($\alpha = .95$), and enthusiasm ($\alpha = .89$).

Climate Change Information Stimuli. The same climate change information stimuli were used as in Study 1. Each information slide was presented only once for a total of 12 trials.

Emotion and Emotion Regulation. The same emotion and regulation responses to climate change information stimuli were obtained as in Study 1.

Climate Emotion Regulation Follow-up. After the task, we asked participants to write one or two sentences about how they regulated their emotions with an open-ended prompt (not analyzed here). We also asked participants to report how much they attempted to regulate their emotions during the task (“How much did you try to control your emotions while viewing the information slides?”) and how successful they were (“How successful were you at controlling your emotions while viewing the information slides?”). Responses options were on a 7-point Likert-style scale from “Not at all” to “Extremely” with “Slightly” and “Quite a bit” as anchors on the third and fifth points, respectively.

Pro-environmental Policy Support (Version 1). This measure of policy support is one score ($\alpha = .95$), the average of ten policies (compiled in van Valkengoed et al., 2021). The items have 7-point Likert style response options from “Strongly oppose” to “Strongly support” with “Neither support nor oppose” at the midpoint. Five items probed mitigation policies and five adaptation policies.

Pro-environmental Policy Support (Version 2). This measure of policy support is one score ($\alpha = .96$), the average of eight policies (Swim & Geiger, 2021), with two items on 100-point scales for each policy (i.e., “I would support this policy” and “I would sign a petition supporting this policy”). The scale was labelled with numbers from 0 to 100 by tens and six-point Likert style labels were presented above the numbers from “Strongly disagree” to “Strongly agree”. Four policies targeted businesses and four individuals, with two targeting supply and two targeting demand. For each pair, one described an incentive and one a disincentive.

Pro-environmental Behavior. This surrogate outcome for behavior is one score ($\alpha = .69$), the average of ten items (compiled in van Valkengoed et al., 2021) with 5-point Likert style responses (“Never”, “Sometimes”, “About half the time”, “Most of the time”, “Always”).

Pro-environmental Donation. Multiple weeks after recruitment was completed, we messaged all the participants with an opportunity to receive \$1.00 as a bonus payment. When claiming the bonus, we allowed them the opportunity to donate some or all of the bonus (in \$0.10 increments) to a pro-environmental organization, the Clean Air Task Force.

Power and Sensitivity Analysis

The primary target outcomes were climate change solutions, such as climate policy support. We wanted to ensure that there were enough participants to detect a relatively small correlation between one of the metrics obtained in the task and a policy support measure. We conducted tests to determine the minimum correlation coefficient r which would be detectable with 80% and 95% power in both populations separately, based on potential sample sizes from 200 to 400. For 100 people per group, the minimum detectable correlation with 80% power was $r = .28$ and with 95% power, $r = .35$. For 150 people per group, the minimum correlations were $r = .23$ and $r = .29$, respectively and for 200 people, $r = .20$ and $r = .25$. After these tests, we confirmed our aim was to recruit at least 300 people total. In the whole sample combined, there was 80% power to detect correlations of $r \geq .16$.

Procedure

Participants signed up for the study via Prolific, consented and completed survey questions via Qualtrics, and completed the climate information task via Pavlovia. Specifically, after consent, participants completed self-report measures. Then, participants completed the climate change information task. After the task, participants completed additional self-report measures and were compensated for their time. Weeks after completing the study, participants were re-contacted via Prolific and offered a bonus payment contingent upon completion of a single survey. In addition to a Prolific identifier, the survey contained only one item which asked the participant if they would like to donate some or all of the bonus payment to a pro-environmental organization, the Clear Air Task Force. Participants were informed that they would receive a receipt for the total donations after the study was complete.

Results

Climate change perceptions did not significantly change from baseline to post-task, so the scores were averaged for each participant across the time points. Participants who believed in climate change differed from those who did not believe in climate change on their climate change perceptions and discrete emotions related to climate change (Table 5). Although people who reported belief in climate change also reported more perceptions of climate change, compared to people who reported disbelief, it is noteworthy that there is variability between people and between perceptions, regardless of belief. Contempt for climate change was the only emotion reported in greater amounts by people who did not believe in climate change.

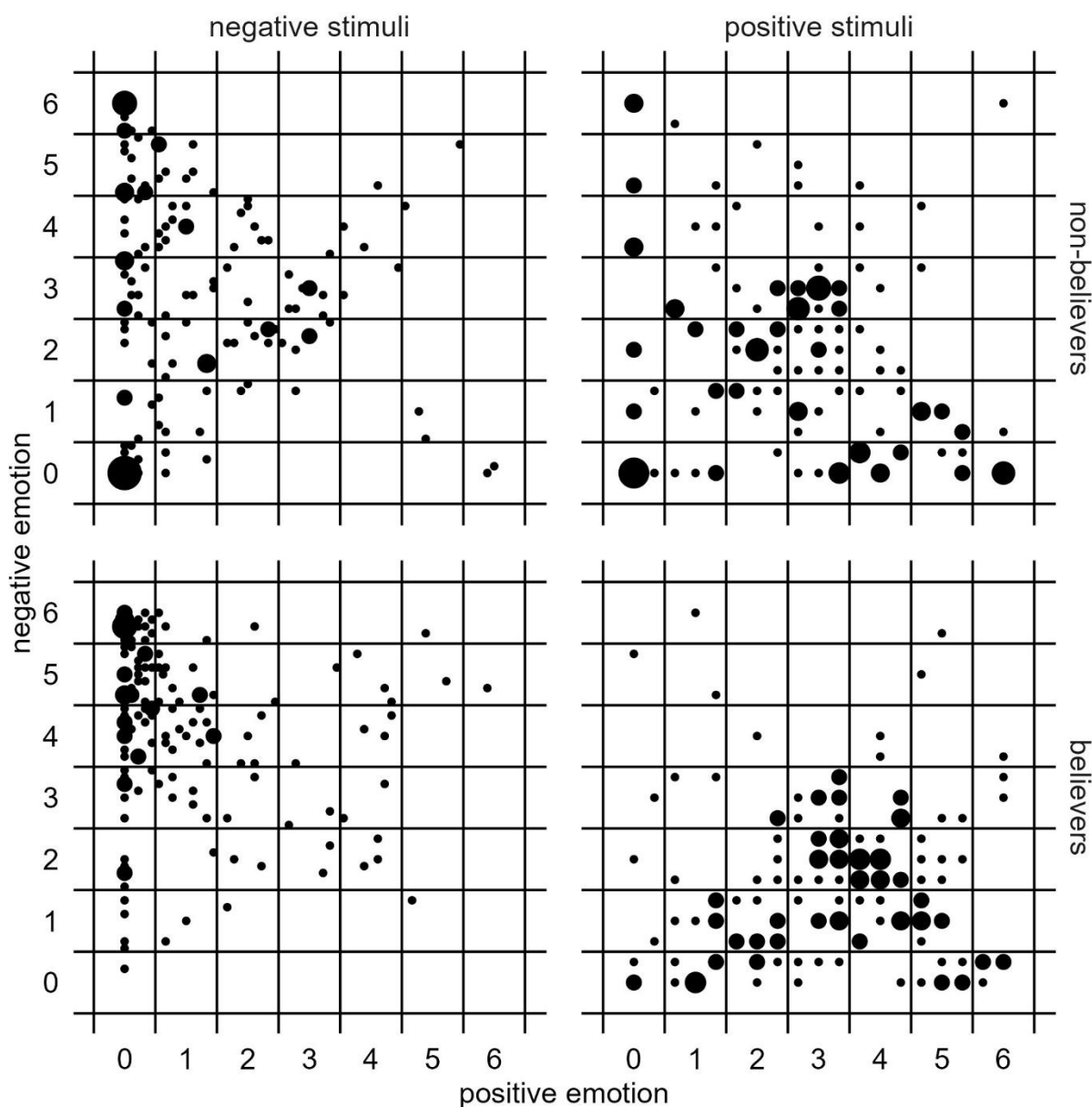
Table 5*Climate Change Perceptions and Discrete Emotions by Belief Group*

	non-believers	believers
	<i>mean (SD)</i>	<i>mean (SD)</i>
reality	1.90 (1.72)	5.54 (0.84)
human causation	1.49 (1.57)	5.10 (1.17)
negative consequences	2.15 (1.59)	5.22 (0.98)
spatial proximity	1.96 (1.62)	4.89 (1.17)
temporal proximity	2.55 (1.46)	4.70 (1.37)
contempt	4.89 (1.29)	1.57 (1.41)
anxiety	1.12 (1.39)	3.95 (1.31)
guilt	0.65 (1.03)	3.03 (1.51)
anger	1.52 (1.44)	4.57 (1.54)
loneliness	1.10 (1.06)	1.92 (1.38)
powerlessness	1.79 (1.38)	3.34 (1.21)
sorrow	1.54 (1.54)	4.60 (1.32)
enthusiasm	1.79 (1.30)	3.77 (1.20)

Note. Response options ranged from 0 to 6. Believers reported greater perceptions of climate change and more of every discrete emotion, except contempt.

Belief and Emotion Responses

To validate the information task in this sample, we tested whether there were differences in positive emotions or negative emotions based on climate change belief group (Figure 9) with two hierarchical models using simple sum-to-zero contrast coding for belief group and stimulus valence, and confidence levels compared to the one lower, with cross-classified random intercepts for participant and stimulus. There was a statistically significant main effect of belief on greater negative emotional responses, but not positive emotional responses, controlling for all interactions between belief and stimulus characteristics (Table 6). There was an interaction between belief and information valence such that the effect of valence on emotion was stronger for people who believe in climate change (positive stimuli led to more positive emotion and negative to more negative emotion).

Figure 9*Emotion Responses by Stimulus Valence and Belief Group*

Note. The plot shows average emotional responses for each individual. The size of each dot represents the number of individuals with the same average response. The left panels average across the nine negative stimuli and the right panels average across the three positive stimuli. The top panels are the group who did not believe in climate change and the bottom panels are the group who did believe in climate change.

Table 6*Belief and Stimulus Characteristics Predict Emotional Responses*

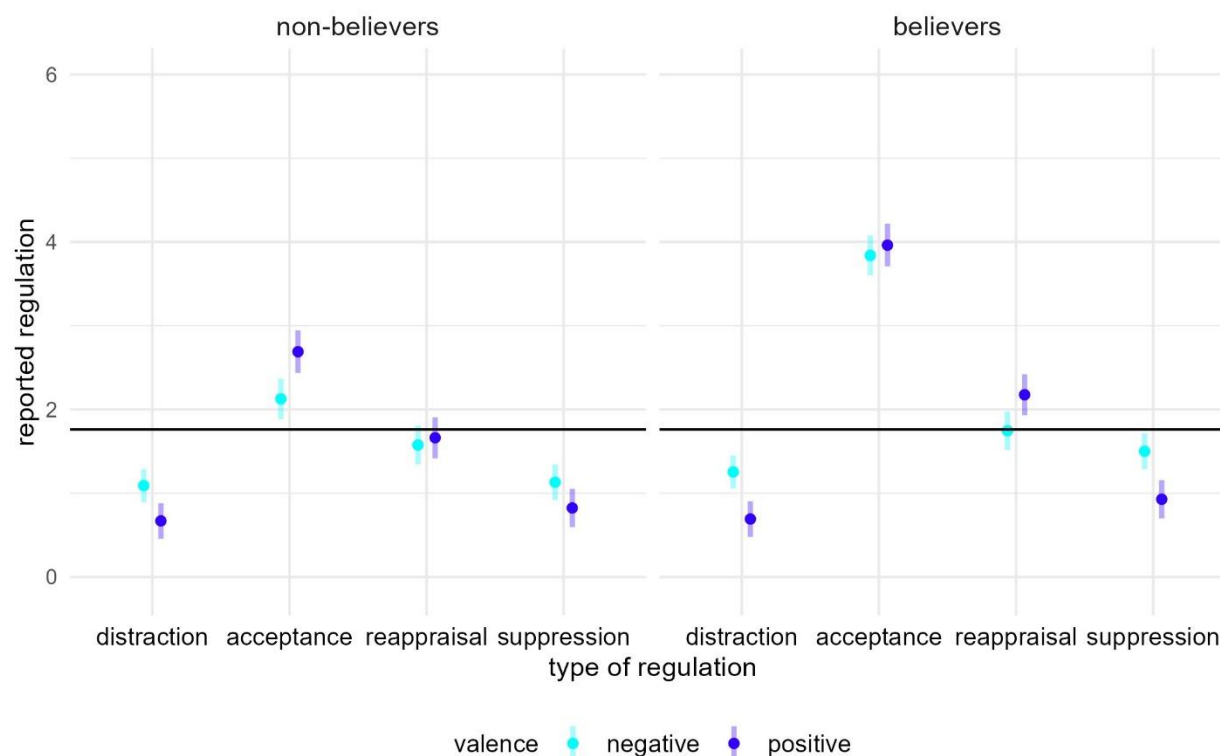
<i>Fixed Effect Predictors</i>	<i>Outcomes positive emotion negative emotion</i>			
	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>
intercept	2.00	<0.001	2.61	<0.001
belief	0.25	0.079	0.48	0.004
confidence [high-medium][2-1]	-0.21	0.113	0.34	0.270
confidence [very high-high][3-2]	0.34	0.023	-0.10	0.738
valence [positive]	1.80	<0.001	-1.72	<0.001
belief × confidence 2-1	-0.61	<0.001	0.27	0.048
belief × confidence 3-2	0.95	<0.001	-0.29	0.028
belief × valence	0.81	<0.001	-1.47	<0.001
confidence 2-1 × valence	-0.22	0.371	-0.09	0.885
confidence 3-2 × valence	0.65	0.026	-0.48	0.431
belief × confidence 2-1 × valence	-1.16	<0.001	0.29	0.276
belief × confidence 3-2 × valence	1.91	<0.001	-0.84	0.002
<i>Random Effects Clusters</i>				
ICC	0.33	P_ID	0.46	P_ID
	0.17	stim	0.03	stim
N	296	P_ID	296	P_ID
	12	stim	12	stim
Observations	3551		3551	
Marginal R ² (predictors)	0.179		0.185	
Conditional R ² (predictors and clusters)	0.513		0.582	

Note. Belief was coded such that the higher value represents the group who expressed belief in climate change. Valence was coded such that the higher value represents positive stimuli. Confidence 1 is medium, 2 is high, and 3 is very high. ICC is the intraclass correlation coefficient, here corresponding to the percentage of variability in the estimation explained by the random intercept. P_ID refers to the unique participant identifier and stim refers to the unique stimulus identifier. Statistically significant *p*-values ($\alpha = .05$) are in **bold**.

Belief and Emotion Regulation Strategies

Next, we examined whether people who believed in climate change regulated differently than people who did not believe in climate change. Type of regulation was included as a sum-to-zero contrast coded fixed effect and a random slope by participant. The rest of the model remained the same. There was a statistically significant interaction between belief and regulation type ($F(3, 321.5) = 14.37, p < .001$). Averaged across stimulus characteristics,

pairwise contrasts were used to determine whether use of each regulation strategy differed based on belief in climate change. Based on the *t*-distribution and Satterthwaite methods for the degrees of freedom in the lmerTest package (Kuznetsova et al., 2017), there was only one statistically significant difference based on belief group. Believers reported more mindful acceptance than nonbelievers. Marginal mean estimates for the model are depicted in Figure 10.

Figure 10*Emotion Regulation by Belief, Type, and Stimulus Valence*

Note. Marginal means of regulation reported during the task, predicted by type of regulation, stimulus valence, and belief. Dots indicate point predictions and error bars indicate 95% confidence intervals for the point estimate, conditioned on the other variables in the model. The black line indicates the average amount of regulation reported across all types, stimulus characteristics, and belief. In both groups, mindful acceptance was used the most, followed by cognitive reappraisal.

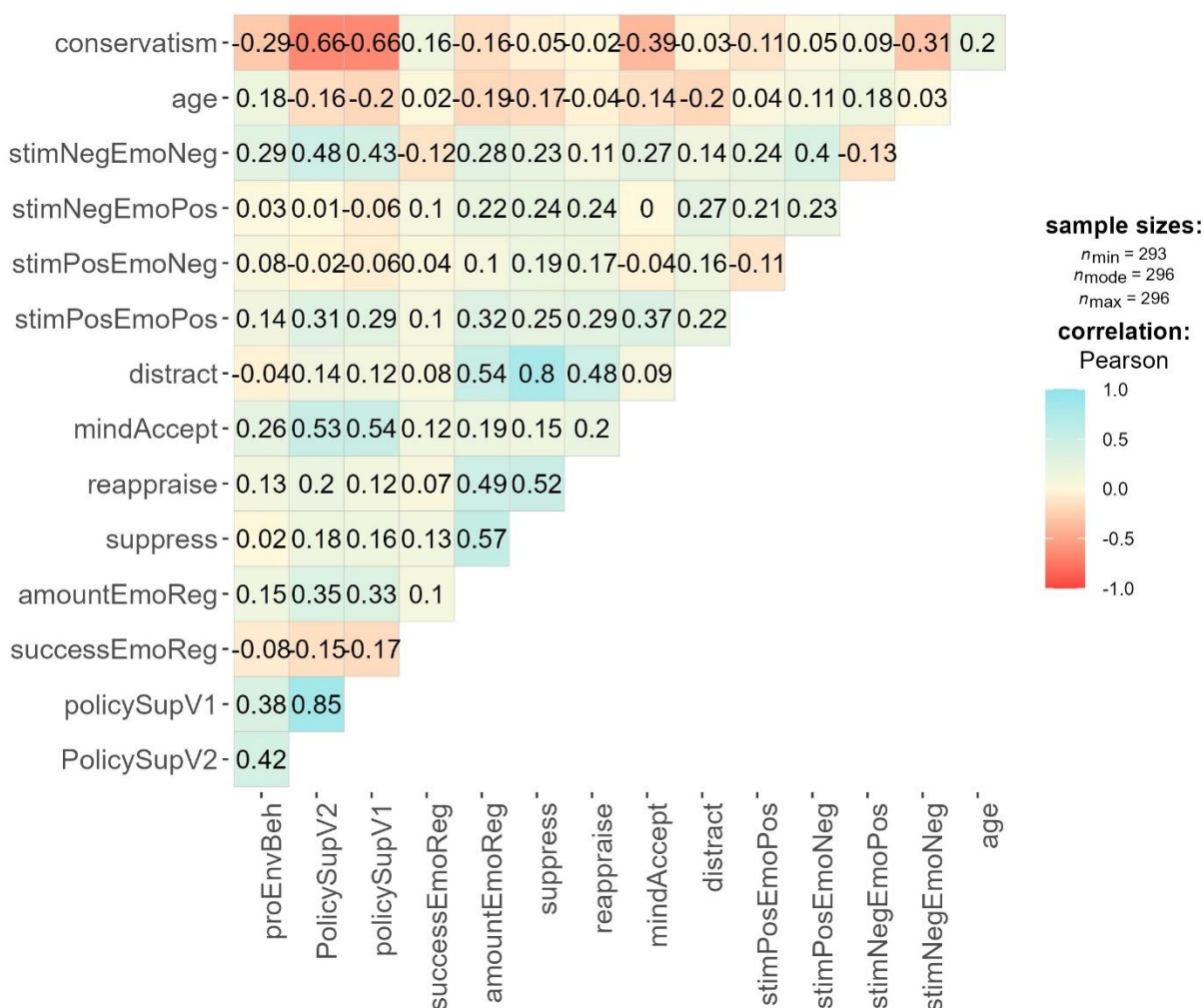
Solutions

After examining emotional responses and regulation in the climate information task, and testing differences based on belief group, the last set of analyses focused on climate change solutions. We averaged responses on all 12 trials for six different metrics: positive emotion, negative emotion, distraction, mindful acceptance, cognitive reappraisal, and expressive suppression. Averaging these scores removed the clustering by participant and allowed for individual differences to be explored using single-level correlations and non-hierarchical regression models. To confirm that the task metrics were reducible to a single score across

trials, we conducted a confirmatory factor analysis with each trial score loading on a latent factor. The model had adequate fit, based on the RMSEA (.063, 90%CI [.060, .065]), SRMR (.075), CFI (.837), and TLI (.832). However, two of the positive stimuli had standardized factor loadings below .4 for negative emotion and all positive stimuli had factor loadings below .4 for positive emotion, one of which was not statistically significant. A multi-group model based on belief groups was not a better fit.

We then fit a model with separate latent factors for emotional responses based on the stimulus valence (negative, $n = 9$; positive, $n = 3$), negative emotion to negative stimuli, positive emotion to negative stimuli, negative emotion to positive stimuli, and positive emotion to positive stimuli. The model had good fit, based on the RMSEA (.059, 90%CI [.057, .062]), SRMR (.058), CFI (.855), and TLI (.849). No standardized factor loadings were below .4 and a multi-group model was not a better fit. Measurement invariance was observed for the configural model and the factor loadings; non-invariance was observed when factor intercepts were constrained to be equal across the belief groups.

We averaged the responses by participant and by latent variable, then examined zero-order correlations between political ideology, age, task metrics, subjective amount and success of emotion regulation in general, and solutions measures. In general, there were positive zero-order correlations between the use of each type of regulation and climate change policy support (Figure 11). Mindful acceptance, cognitive reappraisal, and the overall amount of emotion regulation self-reported after the task were positively correlated with pro-environmental behavior and climate change policy support. The only emotion-related variable that had any statistically significant negative zero-order correlation with any climate solution measure was the subjective success of emotion regulation.

Figure 11*Zero-order Correlations Between Emotion, Emotion Regulation, and Climate Solutions*

Note. Between-persons zero-order correlations $|r| \geq .12$ are statistically significant at $\alpha = .05$ with no adjustment for multiple tests. stimNegEmoNeg = mean negative emotion in response to negative stimuli, stimNegEmoPos = mean positive emotion in response to negative stimuli, stimPosEmoNeg = mean negative emotion in response to positive stimuli, stimPosEmoPos = mean positive emotion in response to positive stimuli, distract = mean distraction, mindAccept = mean mindful acceptance, reappraise = mean cognitive reappraisal, suppress = mean suppression, amountEmoReg = reported amount of emotion regulation, successEmoReg = reported success of emotion regulation, policySupV1 = climate change policy support, version one, policySupV2 = climate change policy support, version two, proEnvBeh = self-reported pro-environmental scale average.

After examining zero-order correlations between three climate solutions and task metrics, we tested whether there were differences in the climate solutions outcomes based on

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belief in climate change, emotion, and regulation using regression models (belief group was simple contrast-coded with the positive value assigned to the group that believed in climate change). All interaction terms were included in each model. The policy version two variable was scaled down from 0-100 by a factor of 10. The donation was scaled up from increments of \$0.10 by a factor of 10 and a log-transformed Poisson distribution was used in the model. The two policy measures were administered in counterbalanced order (before and after the climate information task). Counterbalanced order and all interactions between order and other variables were not statistically significant predictors of the policy support solutions (Table 7).

Table 7*Emotion and Regulation Predict Climate Change Solutions*

<i>Fixed Effect Predictors</i>	<i>Outcomes</i>	policy support v1		policy support v2		pro-env behavior		donation	
		<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>IRR</i>	<i>p</i>
(Intercept)		3.18	<0.001	4.74	<0.001	3.10	<0.001	1.62	<0.001
belief		1.32	<0.001	2.76	<0.001	0.37	<0.001	2.57	<0.001
negative emotion negative stim		0.14	0.002	0.48	<0.001	0.09	0.002	1.25	<0.001
positive emotion negative stim		0.02	0.718	0.17	0.235	0.03	0.336	0.92	0.093
negative emotion positive stim		-0.09	0.057	-0.14	0.295	0.02	0.550	0.99	0.897
positive emotion positive stim		-0.02	0.599	-0.09	0.466	-0.01	0.667	1.09	0.033
distraction		0.15	0.093	0.05	0.851	-0.05	0.306	0.85	0.031
mindful acceptance		0.10	0.017	0.33	0.005	0.02	0.453	1.06	0.115
cognitive reappraisal		0.01	0.827	0.31	0.033	0.07	0.029	1.10	0.051
suppression		-0.10	0.301	-0.06	0.823	-0.05	0.314	1.01	0.841
order		0.15	0.057	0.37	0.092				
belief × negative emotion negative stim		0.05	0.422	0.35	0.050	0.00	0.982	0.64	<0.001
belief × positive emotion negative stim		0.02	0.761	0.24	0.197	-0.05	0.403	1.35	0.002
belief × negative emotion positive stim		-0.04	0.569	0.07	0.735	0.11	0.091	1.22	0.040
belief × positive emotion positive stim		-0.19	0.002	-0.49	0.004	-0.06	0.259	0.92	0.326
belief × distraction		-0.03	0.769	-0.47	0.142	0.02	0.880	0.67	0.009
belief × mindful acceptance		-0.05	0.446	-0.03	0.842	-0.03	0.609	0.74	<0.001
belief × cognitive reappraisal		-0.02	0.763	0.12	0.517	0.08	0.193	0.62	<0.001
belief × suppression		0.03	0.761	0.30	0.336	0.00	0.972	1.20	0.202
belief × order		-0.03	0.885	0.88	0.099				
negative emotion negative stim × order		-0.01	0.908	0.18	0.299				
positive emotion negative stim × order		-0.08	0.203	-0.09	0.631				
negative emotion positive stim × order		0.13	0.064	-0.03	0.887				
positive emotion positive stim × order		0.08	0.164	0.13	0.412				
distraction × order		-0.13	0.258	-0.04	0.896				
mindful acceptance × order		0.01	0.919	-0.12	0.465				
cognitive reappraisal × order		-0.03	0.688	-0.20	0.295				
suppression × order		0.11	0.347	-0.04	0.907				
Observations		296		296		296		243	
R ² / R ² adjusted or pseudo R ²		0.681 / 0.649		0.677 / 0.645		0.224 / 0.177		0.639	

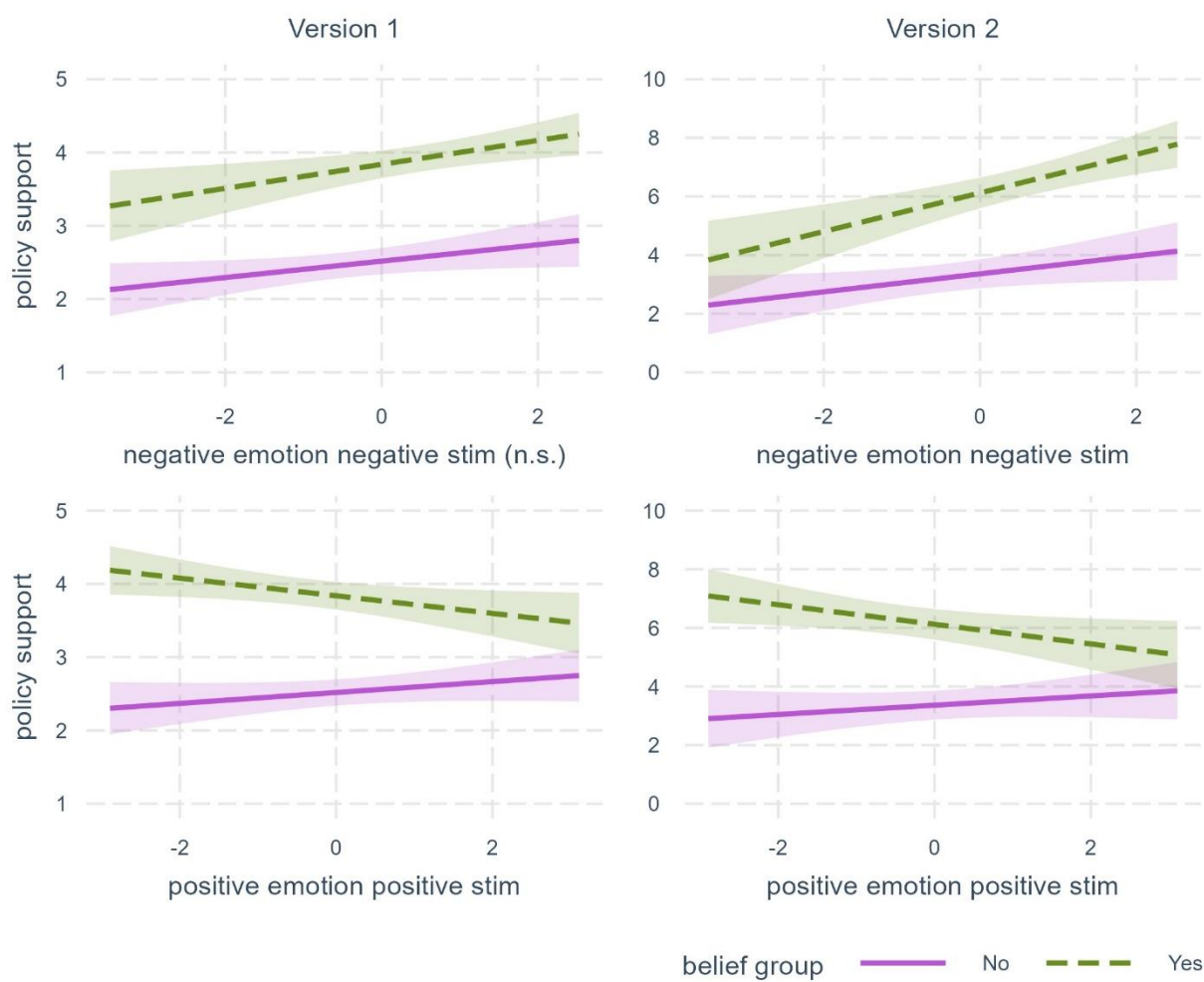
Note. Policy support and pro-environmental (pro-env) behavior were self-report measures. Donation was out of USD\$1.00, scaled in ten-cent increments, and fit to a generalized linear model with a Poisson distribution and a log link. A zero incidence rate ratio (IRR) indicates no association; for single effects (not interactions), IRRs above zero indicate more donations and IRRs below zero indicate fewer donations. Interactions are visualized in Figures 12 and 13.

Belief was coded such that the higher value represents the group who expressed belief in climate change. Order was coded such that the high value represents the group who saw version 2 of the policy support measures before the information task. All emotion and regulation metrics were grand mean-centered. Statistically significant p -values ($\alpha = .05$) are in **bold**. Figures 12 and 13 depict interactions between belief and emotion-related metrics.

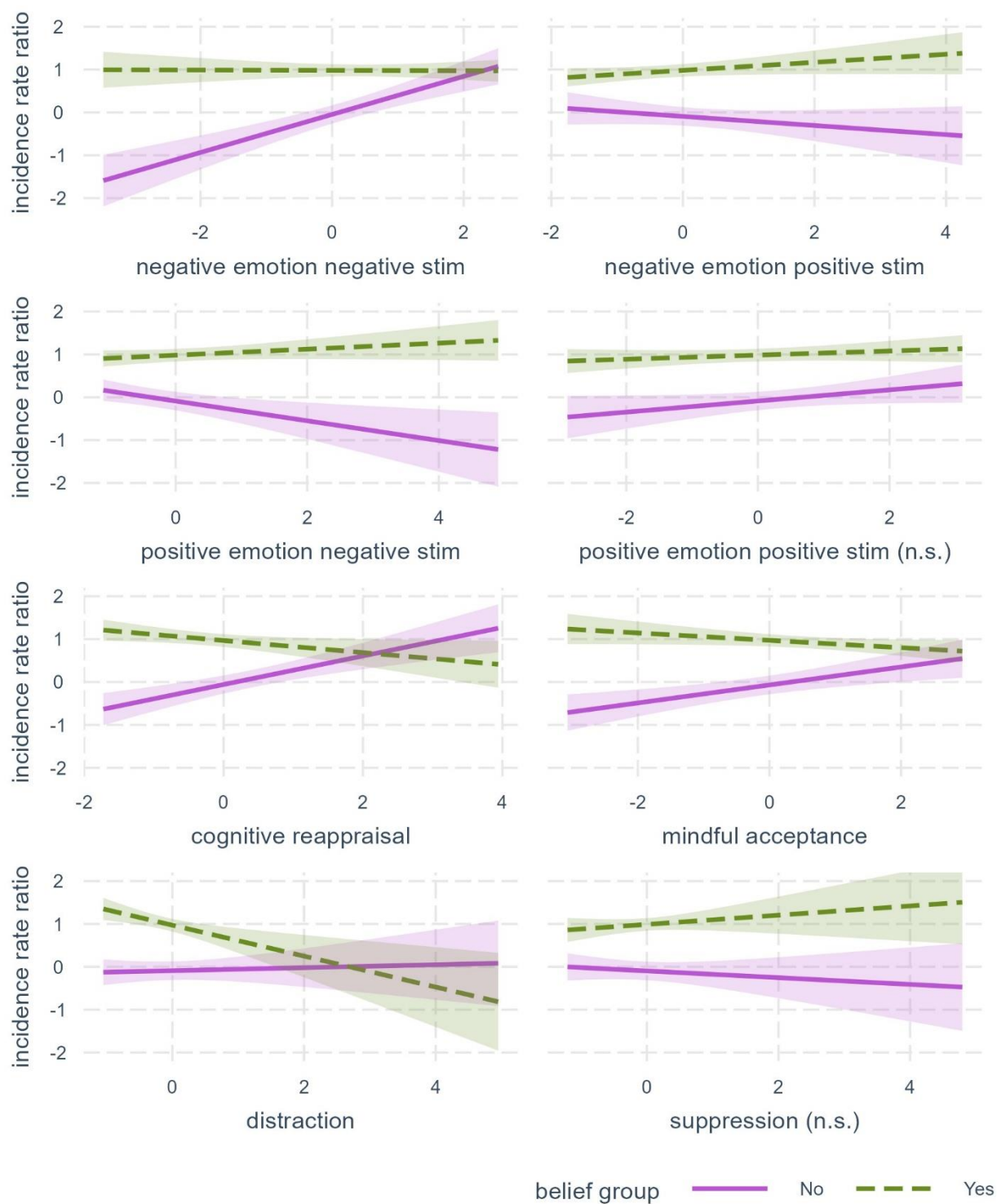
Belief in climate change was associated with more climate change solutions, but some emotion-related metrics were also important. Negative emotion in response to negative stimuli predicted more solutions, but the association was qualified by an interaction with belief for policy version two (slightly greater positive association for believers, Figure 12) and for donations (no association for believers, Figure 13). Positive emotion in response to negative stimuli and negative emotion to positive stimuli did not have main associations with solutions. The rest of the associations were inconsistent across the solutions measures.

Positive emotion in response to positive stimuli was associated with more policy support for non-believers, but less policy support for believers. Mindful acceptance was associated with more policy support (both measures) and cognitive reappraisal was associated with more policy support on version two and more self-reported pro-environmental behavior. Positive emotion in response to positive stimuli had a positive association with donations and distraction had a negative association with donations; all other emotion-related metrics had associations with donations that varied by belief.

Interestingly, as shown in Figure 13, negative emotion in response to negative stimuli was associated with greater donations, but only for non-believers. On the other hand, the “mismatched” emotions (negative emotion to positive stimuli and positive emotion to negative stimuli) were associated with fewer donations for non-believers and more donations for believers. Conversely, distraction, mindful acceptance, and cognitive reappraisal were associated with fewer donations for believers; mindful acceptance and cognitive reappraisal were associated with more donations for non-believers.

Figure 12*Interactions Between Emotion Responses and Climate Change Belief Predict Policy Support*

Note. Predicted policy support values are lines with a 95% CI in shadow. All predictors are grand mean-centered. The interaction between negative emotion for negative stimuli and belief was not a statistically significant predictor of policy support; all other interactions were statistically significant, as shown in Table 7.

Figure 13*Interactions Between Each Task Metric and Climate Change Belief Predict Donations*

Note. Predicted donation values are lines with a shadow that approximates a 95% CI (± 1.96 SE). Predicted donation values are shown on a log scale and all predictors are grand mean-centered. The interaction between suppression and belief was not a statistically significant predictor of donations; all other interactions were statistically significant, as shown in Table 7.

Discussion

The main goal of Study 2 was to gather evidence on the associations between climate change belief, emotion and regulation in response to climate change information, and climate change solutions. Emotion and regulation were associated with belief and climate change solutions, therefore the evidence continued to support the conceptual framework. Climate change solutions extend the investigation from Study 1, in a larger sample with a range of beliefs in climate change.

People who believed in climate change reported experiencing more emotion in response to climate change information, supporting the premise of the framework (and conceptually replicating other findings) that pre-existing belief can drive emotional experience. Associations between belief and regulation were also present, but was inconsistent across the characteristics of the information stimuli. Only mindful acceptance was used more across all stimuli for those people who believed in climate change, compared to those people who did not believe in climate change. However, across belief groups, and consistent with Study 1, people reported using mindful acceptance the most, followed by cognitive reappraisal.

Emotion regulation like cognitive reappraisal can be driven by hedonic or instrumental goals. Hedonistic optimization results in longer or more intense periods of feeling more positive or less negative. Regulation with mindful acceptance does not center hedonic goals. This study applied an instrumental perspective to consider how emotion and its regulation could lead to climate change solutions. We found consistent positive associations between negative emotional experience and all our measures of climate change solutions, although negative emotion to negative stimuli was associated with donations for non-believers, whereas negative

emotion to positive stimuli was associated with more donations for believers and fewer for non-believers. The associations between positive emotions and solutions were more complicated.

Regarding the regulatory strategies, mindful acceptance and cognitive reappraisal both had positive associations with some climate change solutions, whereas distraction predicted reduced donations. However, distraction, mindful acceptance, and cognitive reappraisal all interacted with belief to predict reduced donations for people who believed in climate change. These effects support the premise of the conceptual framework that emotion regulation can lead to climate change solutions. Suppression was the least-used regulatory strategy and as such, there could be insufficient variation in the use of suppression to reveal associations with climate change solutions. Future work would also be needed to determine how to consistently improve climate change solutions with emotion regulation.

Thinking about all the solutions measures together, we found that uninstructed use of mindful acceptance and cognitive reappraisal were associated with more climate change policy support and/or pro-environmental behavior across belief groups, but also predicted reduced donations to a pro-environmental organization for people who believe in climate change. The reasons for the patterns are unclear, but some research has suggested that emotion regulation can decrease the motivation to act to solve a problem (Ford & Feinberg, 2020) and other research has pointed to the emotional changes from emotion regulation as a reason for the motivational downgrade in the case of climate change (Wenzel, Rowland, et al., 2023).

Strengths, Limitations, and Future Directions

Even before beginning enrollment, in line with national samples (e.g., Leiserowitz et al., 2021b), there were noticeably fewer people who reported disbelief in climate change on the Prolific recruitment platform (around 1,200), compared to people who reported belief (around

25,000)²³. Somewhat surprisingly, there were no major issues recruiting people who did not believe in climate change to participate in a study about climate change. A strength of Study 2 is that we included and oversampled the small portion of the population who do not believe in climate change. To improve climate change solutions by manipulating emotion responses or the way that people regulate those responses, these results suggest that the optimal approach will differ based on belief. For example, for people who do not believe in climate change, less positive and more negative emotion might lead to more donations, but effects could depend on the valence of the information. For people who believe in climate change, less regulation of emotional responses may promote donation.

One limitation of this study is that our behavioral assessments could be considered psychologically *in vitro*. Self-reported pro-environmental behavior is not an ideal surrogate outcome for a person's impact on climate change adaptation and mitigation (Lange & Dewitte, 2019). The self-report scale of pro-environmental behavior that we used did not distinguish between purchase decisions for vehicles or appliances, daily transportation or plastic use decisions, or voting behavior, nor did it measure actual behavior that would be driven by emotion and regulatory processes. However, we did measure one real behavior in the form of a donation. Belief in climate change predicted more donations overall, yet for those people who believed in climate change, distraction, mindful acceptance, and cognitive reappraisal all predicted less donations. One limitation of the donation metric was that a portion of the sample (53 of 296) did not respond to the follow-up survey.

Another limitation is that this naturalistic study did not test the ability of scientific researchers, politicians, activists, or anyone else to leverage emotion or emotion regulation to

²³ These numbers also include an explicit screen for people in the United States and implicitly screen out people who did not answer the question about climate change belief. There were around 1,500 people who had responded to the climate change belief question with the only other option, "don't know".

drive climate change solutions. We did, however, validate the tool (i.e., the climate information task) with the most current, scientific consensus-based information about climate change and gathered data on how people responded emotionally to that information and how they regulated those emotions. These studies lay the foundation for studies of emotion regulation and mindful acceptance that could influence climate change solutions, including mechanistic tests. For example, regulation can change emotional experience, but both regulation and emotional experience could have different effects on solutions, depending on how the experience feels and how one wants to feel.

Regardless of the mechanism, the context is another important direction for future work. We know there is not one universally best way to balance hedonic and instrumental goals. For example, when people are in immediate physical danger due to climate change risk, or have experienced a natural disaster, mental health in the present could be considered more important than long term climate change solutions. In that case, there may be a priority to downregulate excessive negative climate change emotions. On the other end of the spectrum, people who are relatively protected from climate change, or have the resources to implement climate change solutions, might benefit from mindfully accepting – or perhaps even increasing – negative emotions. However, beliefs or perceptions and the valence of the climate change information are likely important considerations.

Study 2 provided support for the associations between belief, emotion and emotion regulation, and climate change solutions as proposed in the conceptual framework. There were clear positive associations between belief, emotion, emotion regulation, and some climate solution outcomes. We did not test a causal path from belief to increased negative emotion to climate change solutions. However, the associations between regulation and climate change solutions were dependent on the type of regulation and belief in climate change. The proposed Study 3 addresses the limitation of Study 2 to draw causal inferences about the effect of

regulatory processes. Specifically, we consider how moment-by-moment decision making to mitigate climate change risk could be influenced by emotion regulation and mindful acceptance.

Study 3

Introduction

One of the challenges to understanding how emotion regulation could affect climate change solutions is distinguishing non-causal associations between emotion regulation and climate change solutions from causal effects of emotion regulation. Positive associations between cognitive reappraisal and self-reported pro-environmental behavior were reported in previous literature (Panno et al., 2015) and in Study 2. However, there is also correlational evidence in the literature (Wenzel, Rowland, et al., 2023) that down-regulating negative emotion could be negatively associated with climate change solutions. Although these findings may seem contradictory at first glance, there could be a logical explanation.

A common idea in evolutionary and affective science is that emotion can drive adaptive behavior. Specific to the climate change situation, there is a large body of literature suggesting positive associations between negative emotion and climate change solutions (Leiserowitz, 2006; Marczak, Wierzbka, Zaremba, et al., 2023; van Valkengoed & Steg, 2019). This evidence supports the notion that when emotion regulation is used to down-regulate negativity, it could inhibit the motivational aspects of negative emotion. However, there are numerous factors that could influence the effectiveness and adaptivity of emotion regulation strategies (McRae & Gross, 2020). In addition, people may generally use more emotion regulation when they experience more negative emotion related to climate change.

One critical step is to separate the tendency for any one person to use emotion regulation (i.e., individual differences) from the effects of regulation when it occurs. People who perceive climate change as more important may be more likely to experience, and therefore regulate emotion related to climate change. If those same people engage in more pro-

environmental behavior, that could explain positive associations between individual differences in emotion regulation use and climate change solutions.

The effects of regulation when it occurs may be different for different people, but there may be consistencies across people, which we can refer to as within-person effects. For example, negative emotion could be experienced by people who believe in and perceive the threat of climate change. However, if those people then down-regulate that negative emotion before engaging in pro-environmental behavior or other adaptive processes, emotion regulation could inhibit climate change solutions.

Lastly, for both non-causal associations and causal effects, we must consider that emotion can be regulated in many ways. In emotion regulation research, strategies have often been classified as healthy and unhealthy according to whether they affect the antecedents of emotional experience, or the experience itself (Gross & John, 2003; John & Gross, 2004). Antecedent strategies include cognitive reappraisal and distraction, which target stages of the emotion generative cycle before the response itself. Expressive suppression is a response-focused strategy, affecting the experience of emotion. Mindful acceptance could affect both antecedent stages and the experience of emotion.

As described in the conceptual framework, there are critical process differences between the regulatory processes of mindful acceptance and cognitive reappraisal. In line with current research (Wenzel, Blanke, et al., 2023), we posit that intentional awareness and acceptance of emotion (i.e., mindful acceptance) differs from intentional emotion change through regulation implementation (e.g., cognitive reappraisal). Mindful acceptance is similar to emotion regulation in that it can affect the emotion generation cycle yet is unique in that there is no primary goal of emotional change to activate the second level of the emotion regulation process and as such, no emotion regulation strategy to be selected. However, the effects of dissimilar regulatory processes may nonetheless overlap.

Some research on climate change solutions has conceptualized mindfulness as a trait or disposition that varies between individuals. Self-reported measures of dispositional mindfulness have been associated with self-reported pro-environmental behavior (Amel et al., 2009; Barbaro & Pickett, 2016; Brown & Kasser, 2005) and practitioners of Buddhist meditation also reported more pro-environmental behavior, compared to non-practitioners (Panno et al., 2018). A systematic review was conducted to assess mindfulness as a way to facilitate sustainable consumption and the authors concluded that early work supports the potential but highlighted the need for increased study and mechanistic focus (Fischer et al., 2017). One way that mindfulness could lead to sustainable consumption and other climate change solutions is by helping people to approach climate change information and their emotional responses to that information with mindful acceptance. Mindful acceptance can be measured as a dispositional regulatory process, but occurs in the moment, during emotional experience.

Rather than being guided by a goal to accept emotional experience exactly as it emerges and fades away, the goal of cognitive reappraisal is to reinterpret an emotion-eliciting situation or reframe the relation between the individual and the event. Cognitive reappraisal is conceptualized to specifically target the appraisal stage (Valuation) of emotion generation through cognitive change. Cognitive reappraisal, like mindfulness, has been considered as an individual difference as well as a process. In previous work, self-reported measures of habitual cognitive reappraisal were associated with self-reported pro-environmental behavior (Panno et al., 2015, 2020). However, recent work has suggested that successful cognitive reappraisal (i.e., down-regulation of negative emotion) could pose problems when action is required (e.g., Ford et al., 2019).

To think about dispositional patterns of cognitive reappraisal, some research has considered the target of cognitive reappraisal using a coping framework. When coping with the climate change situation, there are distinctions between techniques that focus on emotion,

techniques that focus on meaning, and techniques that focus on the problem (Ojala, 2012; Wullenkord & Ojala, 2023). Although emotion-focused coping could involve distraction or avoidance of information about climate change, it could also involve cognitive reappraisal to de-emphasize the seriousness of the climate change problem. Meaning-focused coping with climate change is designed to reframe the climate change situation to promote feelings of hope or optimism. Problem-focused coping involves thinking about action to deal with climate change, as an action channel for negative emotion.

Among older high-schoolers in Sweden, problem-focused coping and meaning-focused coping had positive associations with pro-environmental behavior, while emotion-focused coping had a negative association (Wullenkord & Ojala, 2023). Although the data were cross-sectional, problem-focused coping appeared to mediate the association between meaning-focused coping and pro-environmental behavior, supporting the notion that problem-focused coping can channel negative emotion toward action (Wullenkord & Ojala, 2023). However, in an experimental design, neither emotion-focused or problem-focused cognitive reappraisal had a statistically significant effect on climate change threat-mitigation (i.e., conservation) intentions or behavior, yet the success of problem-focused reappraisal was associated with more (and for emotion-focused reappraisal, less) conservation intentions and behavior (Wenzel, Rowland, et al., 2023).

Although mindful acceptance and cognitive reappraisal are associated with climate change solutions, it is unclear whether the effects are causal, or which outcomes might be affected. One way to understand climate change solutions is through the decisions people make when they think about the risk of climate disaster. We know that in basic cognitive testing, cognitive reappraisal reduced risk aversion (measured by an increased number of balloon pumps in unexploded balloons) in the Balloon Analogue Risk Task (Heilman et al., 2010). Emotion regulation can also affect decision making through long term financial thinking.

Reappraisals of long term thinking about financial decisions resulted in not only neurological and physiological differences, but also reduced loss aversion (which is similar to risk aversion) compared to thinking about single financial decisions (Sokol-Hessner et al., 2009, 2013).

However, decision making about climate change differs from both of these studies in three critical ways. First, climate change occurs over a longer period. Second, the risks of climate change are largely uncertain. Third, decision making to mitigate climate change risk requires more than individual decision making; climate change is a collective problem with collective risk. Study 3 focuses on the last point – collective risk.

Climate Change: A Collective Social Dilemma

That climate change is a collective problem creates a social dilemma, when maximizing short term individual outcomes yields a collectively worse outcome later. In many social dilemmas, despite barriers to cooperation, people often contribute to the public good (Zelmer, 2003). Social dilemmas often involve conditional cooperation, a phenomenon in which people contribute in proportion to their beliefs about others' behavior (Chaudhuri, 2011; Fischbacher et al., 2001). Cognitive reappraisal to remain calm has the potential to reduce negative emotion and reduce punishment behavior in public goods scenarios (Gee et al., 2017), but emotion regulation has not been studied in a climate change public goods scenario.

The climate change scenario has specifically been studied in groups of six who play public goods games based on the tragedy of the commons to simulate anthropogenic climate change (Milinski et al., 2006). Some studies have introduced the risk of climate change disaster and aptly labelled the scenario a “collective risk social dilemma” (Jacquet et al., 2013; Milinski et al., 2008; Tavoni et al., 2011). In these studies, players could donate a small amount of money to a public fund that, if not lost to insufficient contributions or simulated climate disaster, would be used for climate change solutions (either disseminate climate change information, purchase CO2 emissions certificates, or plant trees).

In the first study without a disaster component, people were more motivated to mitigate climate risk when their decisions were made public to the group (Milinski et al., 2006). When the risk of climate disaster scenario was simulated by putting the public funds at risk of loss if the collective goal was not met (90% compared to 50% or 10% risk of loss, and 50% compared to 10% risk), participants were substantially more likely to contribute to the common pool at higher risk (Milinski et al., 2008). Both studies found more altruistic behavior at the beginning of the climate public goods games, with declines in cooperation over rounds (Milinski et al., 2006, 2008).

A third study (Tavoni et al., 2011) kept the risk consistent at 50% and removed autonomy from participant decisions in the first three rounds of the game to introduce a controlled simulation of inherited wealth (i.e., automatic donations from some participants and automatic non-donations from other participants); unequal conditions reduced donations and led to fewer groups reaching the collective goal, but communication increased success. A fourth study demonstrated temporal discounting with a consistently high risk of 90% if the collective goal was not met, finding that delaying the rewards from the public fund (seven weeks compared to one day, and decades compared to seven weeks and one day) reduced the amount of investment in the public fund and the ability of the groups to meet the collective goal (Jacquet et al., 2013).

In sum, when the financial risk of climate disaster increases in controlled laboratory experiments, people can act collectively to mitigate the risk, but groups do not always achieve collective goals. In addition, there are signs that people display conditional cooperation and temporal discounting in the collective risk social dilemma. Emotion regulation has been shown to affect decision making in basic cognitive testing (Heilman et al., 2010) and in public goods games (Gee et al., 2017) but we don't know how emotion regulation could affect decision making in collective risk social dilemma scenarios that simulate climate change. However, we

hypothesize that if regulation reduces negative emotion, it will also reduce donations to mitigate the risk of climate change.

Current Research

We know that of the four regulatory processes assessed in Studies 1 and 2, mindful acceptance and cognitive reappraisal were used the most. Individual differences in both measures had at least one positive association with climate change policy support, yet both regulation processes also predicted reduced donations for those people who believed in climate change. The focus of Study 3 was to understand how these two regulatory processes could influence climate change solutions. We focused on regulation instructions that targeted negative emotions. We tested two different cognitive reappraisal tactics, using instructions to increase and decrease negative emotions. We focused on people who express belief in climate change, for whom regulatory strategies predicted fewer donations to a pro-environmental organization. To disentangle causal effects from patterns related to individual differences, we manipulated use of mindful acceptance and cognitive reappraisal and observed effects on moment-by-moment pro-environmental decision making.

Decision making was assessed with a gamified version of the climate information task. Participants donated from bonus funds with a simulated partner to reduce the risk of losing funds to a “climate disaster”. In addition to an active “notice” control condition, we also included a condition in which participants changed partners and the new partner was a free-rider, who barely donated in the game. Based on other social dilemma scenarios, we expected that a free-riding partner would reduce the donations from the participant. However, we also thought that participants might instead compensate for the reduced partner donations by increasing their own donations. Neither effect would have provided conclusive evidence about the validity of the simulated scenario in the real world, but increased donations in the presence of a free rider (i.e.,

no conditional cooperation) might point to one way that this task differs from other social dilemma scenarios.

Based on previous literature on emotion regulation and mindful acceptance, we had directional hypotheses about the effects of each strategy on emotional responses. Relative to an active viewing control instruction, cognitive reappraisal with the intention to increase negative emotion should increase negative emotion, cognitive reappraisal with the intention to decrease negative emotion should decrease negative emotion, and mindful acceptance should decrease negative emotion.

Based on previous literature on emotion regulation and risk aversion (Heilman et al., 2010), we hypothesized that when cognitive reappraisal decreases negative emotion, it would also decrease the amount donated to mitigate the risk of climate change. Conversely, when cognitive reappraisal increases negative emotion, that would increase the amount donated to mitigate the risk of climate change. However, cognitive reappraisal has also had null effects, as reported in recent research on conservation behavior that could mitigate the climate change threat (Wenzel, Rowland, et al., 2023).

The same logic about goals could support other results, however, if the participants in the sample had goals to mitigate the threat of climate change. In that case, cognitive reappraisal to decrease negative emotion could be like problem-focused coping, which was associated with increased pro-environmental behavior (Wullenkord & Ojala, 2023). Finally, although the evidence is sparse, recent work has mentioned the potential for negative emotions to be overwhelming or paralyzing and lead to inaction on climate change (Clayton, 2020; Doherty & Clayton, 2011). If cognitive reappraisal increases negative emotion and decreases donations, or decreases negative emotion and increases donations, we could interpret that as effects of cognitive reappraisal on paralyzing consequences of negative emotion. In sum, although we expect regulation that reduces negative emotion to also reduce donations to mitigate climate

change risk, there are theoretical bases for no effects of regulation processes on emotional responses and decision making, or effects other than those hypothesized.

Method

Statement of Transparency

Participants in Study 2 completed the study procedures between 23 May 2024 and 24 May 2024. We preregistered this study by uploading the dissertation proposal document to osf.io/2dwb6 before data collection. Informed consent was provided after viewing the consent form online before taking part in any research procedures. Information was presented and responses solicited using a task built in the PsychoPy Builder interface (Peirce et al., 2019) and administered online as a PsychoJS experiment (Bridges et al., 2020).

De-identified data and materials for this study are publicly available at osf.io/9v7cz/. Before recruiting the sample, we recruited six pilot participants to complete all procedures and checked the responses to the open-ended compliance check question. Four of the six pilot participants were clearly able to summarize the instructions. We decided to use an intent-to-treat analysis plan with the data provided by the participants (i.e., we will assume that participants completed the task in good faith, even if they were unable to summarize the regulation instructions) for confirmatory hypothesis testing to avoid potential confounds between ability to follow regulation instructions and outcome variables. We recruited four additional pilot participants to test the final procedures before recruiting the sample.

Design

We used eight negative valence climate change information stimuli. Each stimulus included a statement of fact and its associated level of scientific confidence (one within-subjects factor with three levels), either medium ($n = 2$), high ($n = 3$), or very high ($n = 3$). Each of the eight slides was presented to each participant one time at baseline and one time after random assignment (one within-subjects factor with two levels) to one of five experimental conditions.

Participants were randomly assigned to think about negative emotion, think about negative emotion and play with a simulated free-riding partner, reappraise to increase negative emotion, reappraise to decrease negative emotion, or mindfully accept negative emotion (one between-subjects factor with five levels). Therefore, we used a 3 x 2 x 5 mixed factorial experimental design. To test the effect of regulation instructions on emotional responses and decision making, the responses at baseline were used as fixed-effect predictors.

Participants

We recruited 405 adult participants in the United States who believed in climate change using Prolific recruitment services. The target sample size was maximized within our financial constraints and the final study design. Participants were paid a base rate of USD\$4.00 for a study estimated to take 30 minutes. Participants were given a bonus of \$1.60, and the option to donate from that bonus to a pro-environmental organization. The study used three prescreening criteria; participants were residing in and participating from the United States²⁴, had at least a 95% approval rate for Prolific submissions, and responded “yes” to the prescreening question in the voluntary demographic surveys on Prolific: “Do you believe in climate change?”.

Data from $n = 2$ participants were excluded because there were duplicate entries that indicated each participant was randomly assigned to an experimental condition more than once and data from $n = 16$ participants were excluded because they had reported participating in the study previously. Participants may have reported participating previously due to inattention, so this exclusion could be considered an attention check²⁵. Climate change perceptions (i.e., perceptions of negative consequences, human causation, and temporal proximity), age, and political ideology were not statistically different between the participants who said they did

²⁴ On Prolific, the United States is specified as the 50 states of the United States, plus Washington, DC.

²⁵ One of the participants whose data was excluded sent a message on Prolific that they accidentally reported previous participation.

versus did not participate previously. There were not statistically different numbers of participants excluded for previous participation between the experimental conditions.

After exclusions, participants ($N = 387$) were aged between 18 and 72 years, with an average age of 40 ($median = 35$, $SD = 11.81$). Participants in this sample reported mostly liberal political ideologies ($M = 1.97$, $SD = 1.58$) on a Likert-style scale from 0 (extremely liberal) to 6 (extremely conservative). Participants reported high levels of climate change perceptions on a scale from 0 to 6; specifically, they reported more perceptions of negative consequences ($M = 5.18$, $SD = 0.95$) of climate change than perceptions of human causation ($M = 4.99$, $SD = 1.07$) and greater perceptions of both negative consequences and human causation than perceptions of temporal proximity ($M = 4.45$, $SD = 1.39$).

In two open-ended prompts, we asked participants to provide a word or phrase that best describes their gender and race and/or ethnicity. After handling responses as described in the two previous studies, most participants reported one binary gender, either woman ($n = 189$) or man ($n = 194$); other categories were nonbinary ($n = 2$), nonbinary/agender ($n = 1$), and nonbinary/femme ($n = 1$)²⁶. Participants reported race and/or ethnicity as Hispanic or Latino ($n = 38$), White alone non-Hispanic ($n = 209$), Black or African American alone non-Hispanic ($n = 62$), American Indian or Alaska Native alone non-Hispanic ($n = 1$), Asian alone non-Hispanic ($n = 51$), Native Hawaiian and Other Pacific Islander alone non-Hispanic ($n = 1$), some other race alone non-Hispanic ($n = 3$), and multiracial non-Hispanic ($n = 22$)²⁷. One participant wrote

²⁶ Two of the women and one of the men specified cisgender, 16 women used the term “female” instead of woman, and 33 men used the term “male” instead of man.

²⁷ Without collapsing by the census categories, participants reported African ($n = 1$), African American ($n = 14$), African American/Black ($n = 1$), American Indian ($n = 1$), Anglo-Saxon ($n = 1$), Asian ($n = 37$), Asian American ($n = 2$), Asian, Chinese ($n = 1$), Asian/Pacific Islander ($n = 1$), Biracial ($n = 4$), Black ($n = 38$), Black African ($n = 1$), Black African American ($n = 1$), Black/African American ($n = 1$), Black American ($n = 4$), Black and Latino ($n = 1$), Black, Latino ($n = 1$), Canadian ($n = 1$), Caucasian ($n = 20$), Caucasian/Hispanic ($n = 1$), Caucasian or White ($n = 1$), Caucasian/White ($n = 1$), decline to answer ($n = 1$), East Asian ($n = 2$), Ethiopian ($n = 1$), European ($n = 2$), European American ($n = 1$), Filipino ($n = 1$),

“decline to answer”. Note that Middle Eastern was counted in White alone non-Hispanic and “Liberal” ($n = 1$) was not counted as a race and/or ethnicity.

Materials

Perceptions of Climate Change. Questions from the same climate change perceptions scale as described in Study 2 were administered after the task. One subscale was the belief that climate change is anthropogenic, human causation ($\alpha = .93$), the second was the belief that climate change will have negative consequences ($\alpha = .85$). The last perception was about the temporal proximity of climate change impacts ($\alpha = .90$).

Climate Change Information Stimuli. We selected eight of the nine negative climate change information stimuli used in Studies 1 and 2. No positive information stimuli were shown.

Emotion and Emotion Regulation. The same emotional responses to climate change information stimuli were solicited as in Studies 1 and 2.

Regulation Instructions. For the full text of the regulation instructions, see Appendix B. An active control condition instructed participants to notice negative emotion. The same “notice” instructions for the active control group were used in a condition that manipulated an external factor; to test one aspect of the simulated collective risk social dilemma, participants were told that they were to play the game with a different simulated partner (the new partner’s pattern of behavior, unbeknownst to the participant reading the instructions, simulated a free rider). A third

Filipino/Mexican American ($n = 1$), Hispanic ($n = 20$), Hispanic Latinx ($n = 1$), Hispanic/Latino ($n = 2$), Indian ($n = 1$), Latina ($n = 1$), Liberal ($n = 1$), Mexican ($n = 3$), Mexican American ($n = 1$), Mexican American (Latina) ($n = 1$), Middle Eastern ($n = 2$), Mixed ($n = 10$), Mixed (Black/White) ($n = 1$), Mixed (Caribbean) ($n = 1$), Mixed Race ($n = 2$), “Mostly white, part black. Not sure if I identify as white or mixed, but I look more white.” ($n = 1$), Multiracial ($n = 3$), Non-Hispanic ($n = 1$), Non-Hispanic White ($n = 1$), Other ($n = 1$), Romani ($n = 1$), South Asian ($n = 4$), South Asian/Indian ($n = 1$), Southeast Asian ($n = 1$), Syrian American ($n = 1$), Vietnamese ($n = 1$), White ($n = 171$), White/Caucasian ($n = 2$), White Caucasian ($n = 1$), White American of Polish Heritage ($n = 1$), White Latina ($n = 2$), White Latino ($n = 1$), White Non-Hispanic ($n = 1$), White, Latine ($n = 1$), White/American ($n = 1$), White/Hispanic ($n = 1$), and “7 generations all US born euromutt” ($n = 1$).

group was instructed to change their emotions by using cognitive reappraisal to increase negative emotion and a fourth, to decrease negative emotion with reappraisal. The last condition instructed participants to mindfully accept negative emotion.

Compliance Check. After the regulation instructions, we asked the participants in an open-ended prompt to summarize the regulation instructions. The prompt was *“Please write one or more sentences describing what you will do while viewing the information slides for a second time. First, in one complete sentence, please summarize the instructions. Then, if you choose to, you can describe your plans in greater detail.”*

Post-task Pro-environmental Donation. After the task, participants had an opportunity to donate any amount of the total \$1.60 bonus payment in \$0.10 increments to a pro-environmental organization. The researchers will manually adjust the bonus payment for each participant based on their responses and send a receipt of the total donations by all participants via message at the conclusion of the study.

Climate Change Mitigation Motivation. Two questions were designed to assess motivation to mitigate climate change in this study. Participants were first asked to report their motivation to mitigate climate change in general (*“How much do you try to mitigate climate change in your everyday life?”*). After responding, on the next page they were asked how the study could have influenced motivation (*“After viewing the information in this study, how much will you try to mitigate climate change in the future?”*). Likert-style response options were 0, “Not at all”, to 2, “Slightly”, to 4, “Quite a bit”, to 6, “Extremely”.

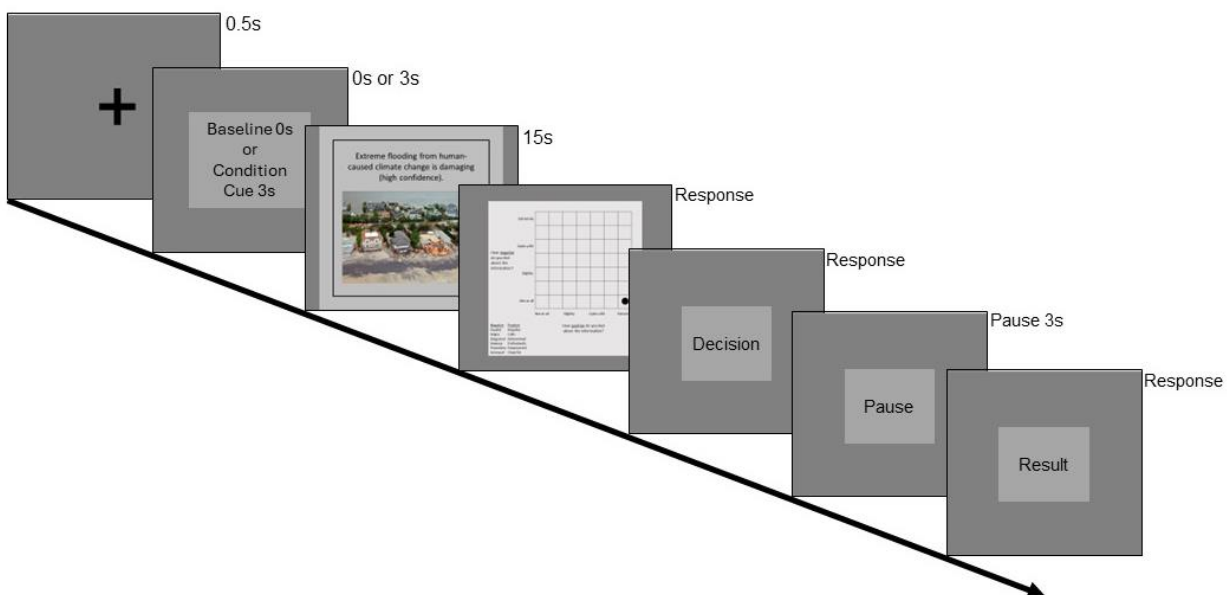
Pro-environmental Policy Support. This measure of policy support was the same as version two in Study 2, but we averaged the questions about support and willingness to sign a petition separately. Each score, support ($\alpha = .80$), and willingness to sign a petition ($\alpha = .90$), were the average of eight policies (Swim & Geiger, 2021). There were two items on 100-point scales for each policy (i.e., “I would support this policy” and “I would sign a petition supporting

this policy”). The scale was labelled with numbers from 0 to 100 by tens and six-point Likert style labels were presented above the numbers from “Strongly disagree” to “Strongly agree”. Four policies targeted businesses and four individuals, with two targeting supply and two targeting demand. For each pair, one described an incentive and one a disincentive.

Risk Preferences. We administered a five-item titrating risk preferences measure from the Preference Survey Module (Falk et al., 2023). The instructions were “*You can choose between a sure payment of a particular amount of money, or a draw, where you would have an equal chance of getting \$300 or getting \$0. We will present to you five different situations. Even though the money is hypothetical, please remember to choose as if the money you could get was real.*” The first item was “*What would you prefer: a draw with a 50 percent chance of receiving \$300, and the same 50 percent chance of receiving \$0, or the amount of \$160 as a sure payment?*”. Items two through five had a different amount for the sure payment, but the same gamble. and were based on the decision made in the previous item. Each participant was assigned one number out of 32 possible options. Higher scores indicated greater preferences for risks and lower scores indicated reduced risk preferences or greater risk aversion.

Procedure

Participants signed up for the study via Prolific, consented and completed follow-up survey questions via Qualtrics, and completed the gamified climate information task via Pavlovia. We experimentally tested effects of three regulation strategies on emotional responses to climate change information and decision making in a two-person collective risk social dilemma with a simulated partner. After consent, participants received baseline instructions to view the climate change information stimuli, report emotion response, and make decisions to mitigate climate change risk (Figure 14). They received regulation instructions based on randomized condition before viewing the information a second time.

Figure 14*Trial Diagram for the Gamified Climate Change Information Task*

Note. Each frame represents one screen of each trial in the modified climate information task. Each of the trials of the task will begin with a fixation; test trials will have a condition cue to think about, change, or accept negative emotion. The information slide will be presented for 15 seconds, then the participant will report their emotional experience on the grid. Immediately after indicating the emotional response, participants decided how much, if any, of their money for that trial to donate to reduce the risk of climate disaster. After deciding, there was a pause. Then, participants were shown the result (“Disaster! Gamble lost.” or “No disaster. Gamble kept.”). Other information on the Result screen for each trial included the participants’ donation, the participants’ gamble, the simulated partners’ donation, the total risk, and the cumulative total bonus.

Gamified Climate Change Information Task. After the participants were familiarized with the regulatory strategies, they received information about the climate change information task, including a description of the trial sequence (Figure 14) and the financial decisions that will be made with a simulated partner. Specifically, before beginning the task, all participants received the following instructions. *“You will receive a bonus of up to 160 cents (one dollar and sixty cents) for completing the next portion of the study. You will view information sixteen times and each time, you will be given 10 cents from your total possible bonus. Each time, however, there is a 90% chance that you will lose those 10 cents to a simulated climate disaster. You and a simulated partner, who also gets 10 cents on each viewing, can both donate some of your*

money to reduce the risk of climate disaster. Every 1 cent donated will reduce the risk by 10 percentage points. After you make a decision, you will see how much your partner donated, and whether climate disaster occurred. If there was no climate disaster, all the money that you did not donate will be part of the total bonus that you will receive.”

On every trial, participants made a donation decision (how much to donate and how much to gamble) using a vertical slider. The slider prompt was *“Please click the scale on the left and move the slider to indicate how many cents out of ten you want to donate to reduce the risk of climate disaster on this trial. Each cent donated reduces the risk by ten percentage points.”*

The donations from the participant and their partner both reduced the risk (therefore, the actual risk could be reduced below 0%, but the display had a minimum of 0%). The task was programmed such that on average, at baseline for all conditions, the simulated partners donated three-tenths of the trial bonus to reduce the risk of loss by 30 percentage points. On each trial, the exact partner donation decision was determined by the first value after shuffling the possible donation amounts out of 10 cents ([2,2,3,3,3,3,4]). After the baseline phase, in which participants viewed each information slide one time, participants were randomly assigned to one of five between-subjects conditions and completed the same task again with an additional cue (see Figure 14).

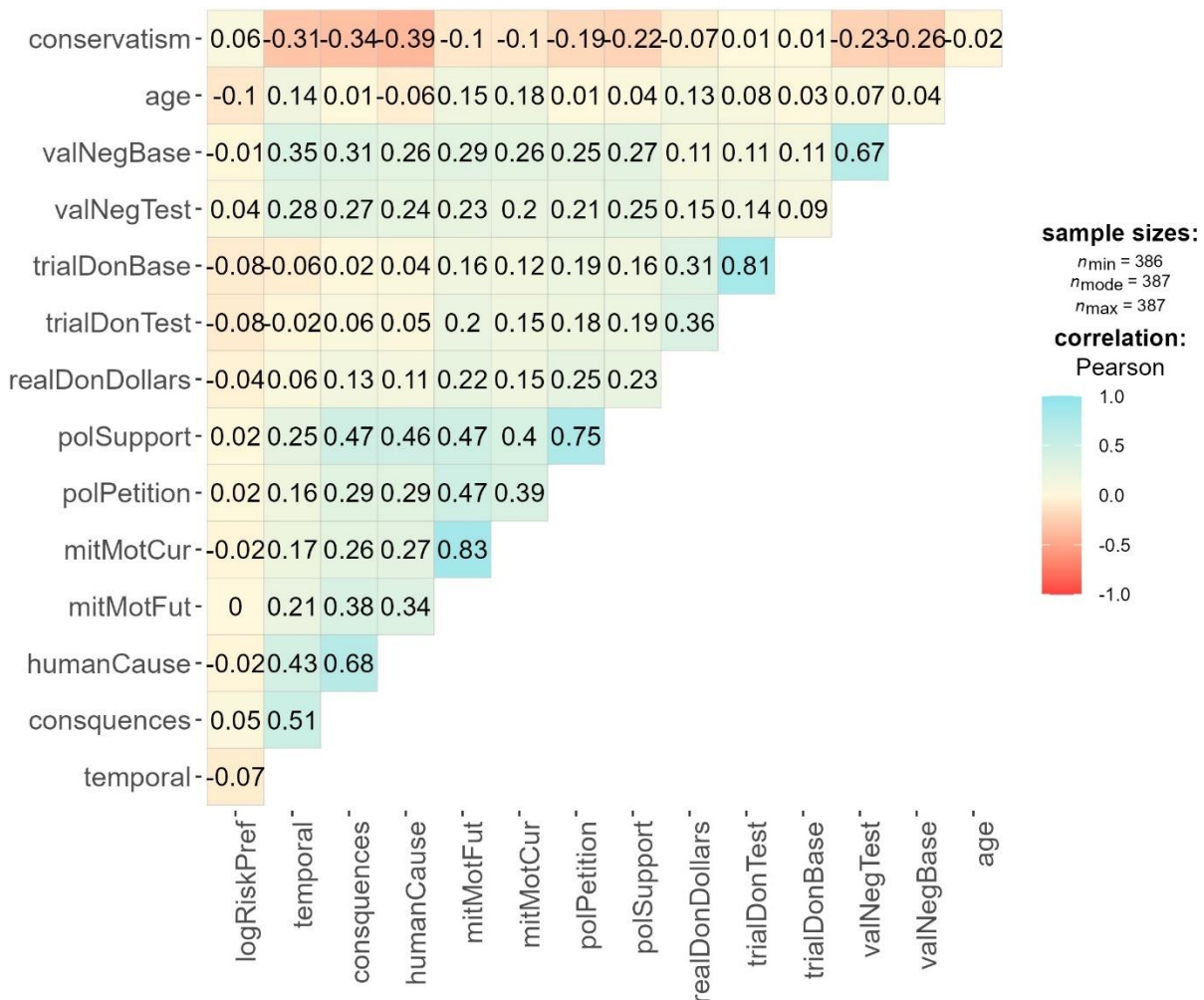
Follow-up. After the task, participants were all awarded the same total \$1.60 bonus and had the opportunity to donate any part of the bonus to a pro-environmental organization; they were told that they would receive a receipt via message with the total amount donated by all participants after the study is complete. Participants completed self-report measures of support for climate change policies, climate change mitigation motivation, and climate change perceptions. Then, participants reported risk preferences and had the opportunity to report any problems they experienced during the study in an open-ended response, before providing

demographic information. They saw a debriefing form and were redirected to Prolific for submission approval and compensation.

Results

No exclusions were made for confirmatory hypothesis testing based on how well participants summarized their instructions in the compliance check, or whether the instructions led to changes in emotional responses.

Participants reported relatively high climate change perceptions, nominally similar to those who believed in climate change in Study 2. Three dimensions were measured in Study 3, human causation ($M = 4.99$, $SD = 1.07$), negative consequences ($M = 5.18$, $SD = 0.95$), and temporal proximity ($M = 4.45$, $SD = 1.39$). There were statistically significant zero-order correlations between each of the climate change perceptions with negative emotion and mitigation motivation, but inconsistent associations between perceptions and real donations, and not statistically significant associations between perceptions and risk preferences or decision making in the gamified information task (Figure 15).

Figure 15*Zero-order Correlations Between Climate Change Perceptions, Solutions, and Emotions*

Note. Between-persons zero-order correlations $|r| \geq .10$ are statistically significant at $\alpha = .05$ with no adjustment for multiple tests. valNegBase = mean negative emotion at baseline, valNegTest = mean negative emotion after regulation instructions, trialDonBase = mean donations to mitigate risk at baseline, trialDonTest = mean donations to mitigate risk after regulation instructions, polSupport = average climate change policy support, polPetition = average willingness to sign petitions for climate change policies, mitMotCur = climate change mitigation motivation in general, mitMotFut = climate change mitigation motivation after the study, humanCause = perception of climate change as anthropogenic, consequences = perception of negative consequences of climate change, temporal = perception of temporal proximity of climate change effects, logRiskPref = log transformed risk preferences using the 5-item titrating measure and scored as one of the 32 possible final decisions.

After examining zero-order correlations between participants, we fit models with three primary outcomes, specified maximally in accordance with a randomized controlled treatment

design. We fit two sets of models with trial-level outcomes; the key predictor²⁸ was regulation condition, treatment coded such that each of the levels compared one of the four experimental conditions to the active viewing control condition. The effects of the experimental manipulations on negative emotion in the test block were conditioned on negative emotion at baseline. The effects of the experimental manipulations on trial donations in the test block were conditioned on trial donations and negative emotion at baseline. The effects of the experimental manipulations on person-level final donations were conditioned on trial donations and negative emotion for each participant at baseline

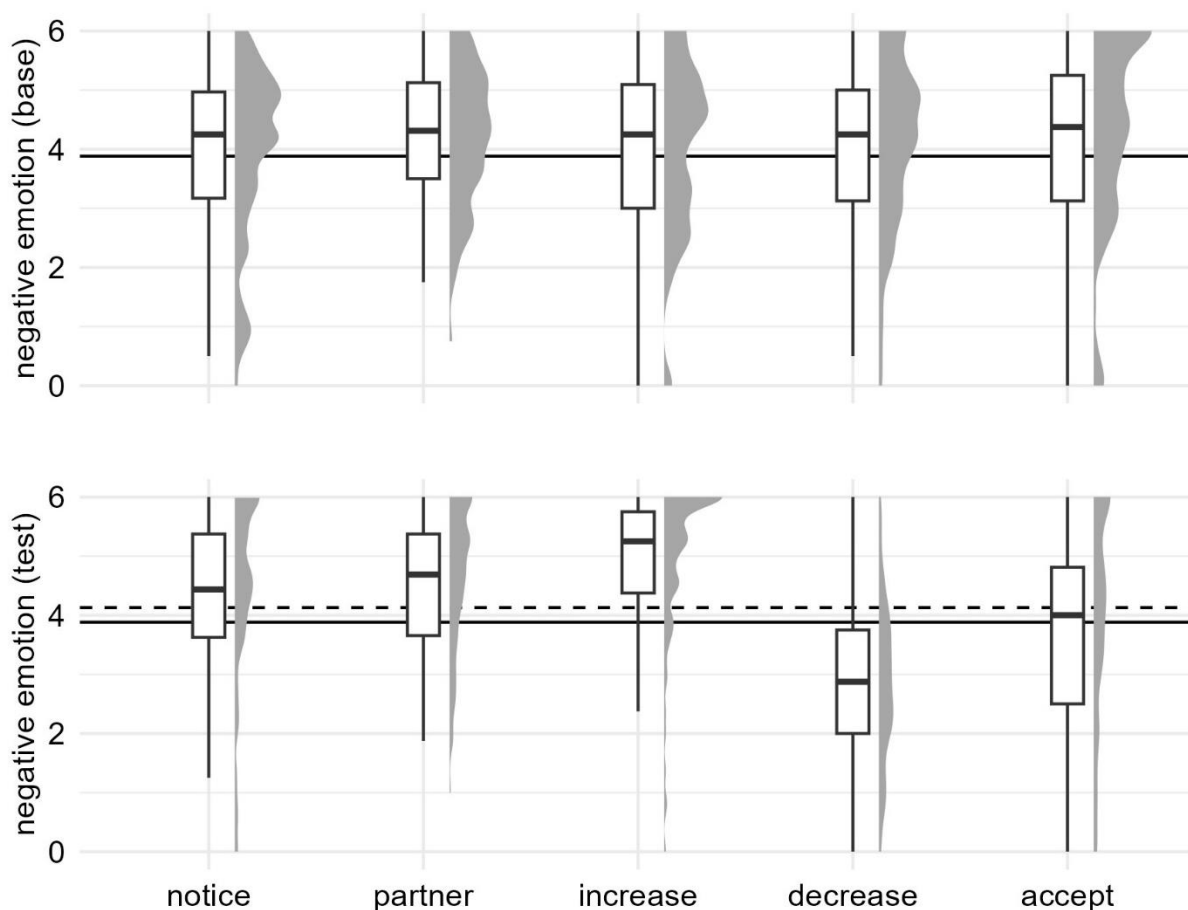
Scientific confidence was included as a fixed effect covariate and a random slope in models with trial-level negative emotion, and a fixed effect covariate in models with trial-level donations, contrast-coded with a sum to zero deviation²⁹ contrast. Models included random intercepts for participants and stimuli. Both negative emotion and trial donations at baseline were grand mean-centered and person mean-centered for each participant for trial-level outcomes (two separate terms accounted for between-persons and within-persons variability in the baseline scores) and grand mean-centered for the person-level outcome (when the outcome was only measured once for each participant, one term accounted for the between-persons only).

²⁸ In an earlier analysis plan, the key predictors were specified as the interaction of block and regulation condition. Results were generally consistent, regardless of decisions in the analytic approach.

²⁹ The two-condition contrast was set such that the regression coefficient estimates the difference between the two levels. The three-condition contrast was set such that the regression coefficients estimate twice the distance from the grand mean. The label “deviation” is used consistently with Barr (2021). Barr (2021) states that all sum-to-zero contrast coding is also labelled as effects coding. Without specifying specific contrast values, effects coding has also been labelled sum coding (e.g., Brehm & Alday, 2022).

Negative Emotions

We tested the statistical significance of experimental effects in a linear mixed model with negative emotion as the outcome (Figure 16, Table 8). We had a directional hypothesis about each regulation instruction on negative emotion, relative to the active viewing “notice” condition. As hypothesized, down-regulating negative emotion with reappraisal decreased negative emotion and up-regulating negative emotion with reappraisal increased negative emotion, relative to the active viewing “notice” condition. Also as hypothesized, mindful acceptance decreased negative emotion, but less than downregulation via cognitive reappraisal. Participants who were partnered with a free rider did not report more (or less) negative emotion than the active control.

Figure 16*Negative Emotion in Response to Climate Change Information*

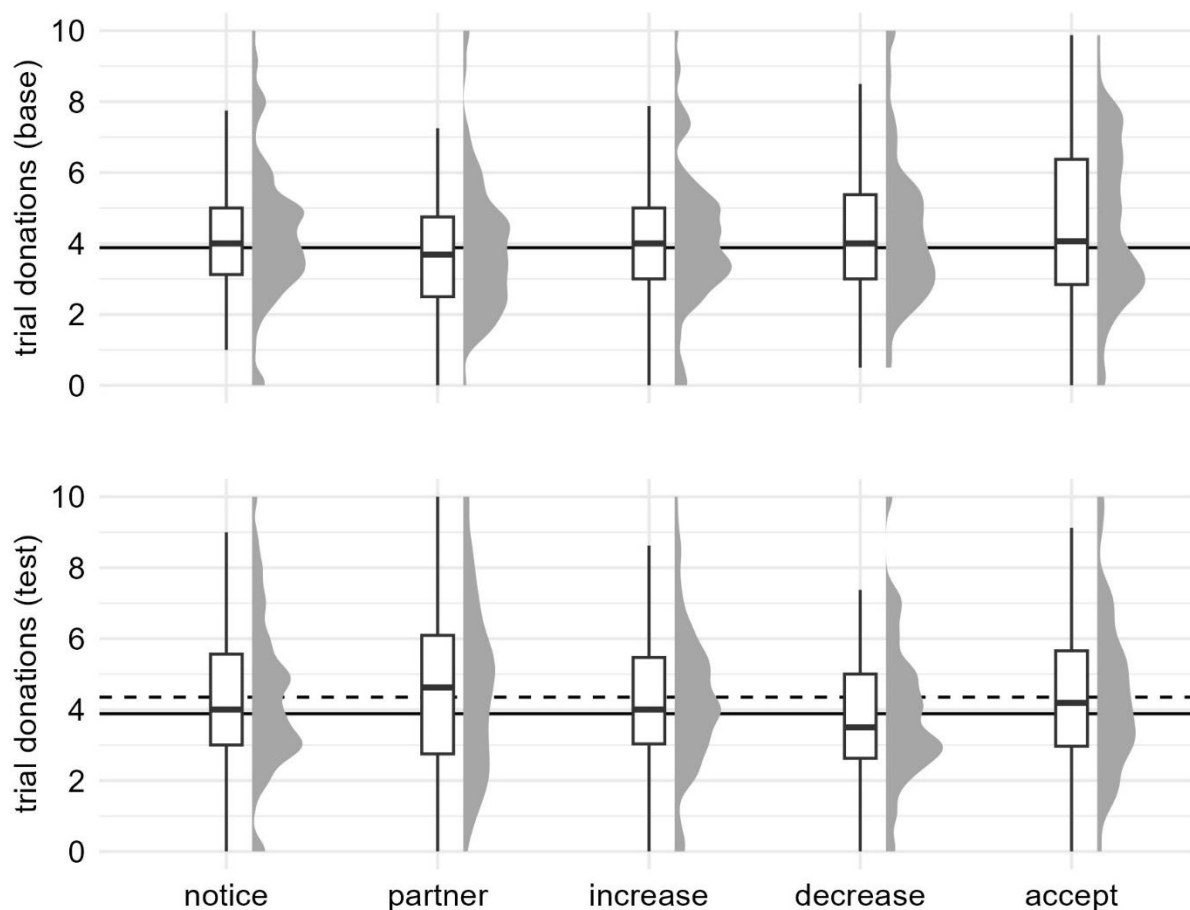
Note. Trial-level data were averaged for each individual before visualization. The top row displays negative emotion from the baseline block, before randomization to experimental conditions, and the bottom row displays negative emotion from the test block. The solid black line represents the mean for the “notice” control group at baseline and the dashed black line represents the mean for the same group at test. Compared to the “notice” control condition, and holding constant baseline emotions (grand-mean centered at the individual and person-mean centered at the stimulus levels) and stimulus confidence, and accounting for clustering at the individual, the stimulus, and in the effect of confidence by individual, increasing (“increase”) and decreasing (“decrease”) negative emotion with cognitive reappraisal was effective and mindful acceptance (“accept”) reduced negative emotion.

Trial Donations

To interpret the experimental effects on trial-level donations to mitigate the risk, we planned to test the statistical significance of experimental effects in a generalized linear mixed model, using a Poisson distribution with a log link. However, it was unclear whether a

nonnormal distribution would be the best approximation of the trial donation measure, so we fit a model with a Gaussian outcome distribution and report that model (Figure 17, Table 8).

Contrary to the directional hypothesis, participants who were assigned to notice negative emotion and play with a free rider donated more to mitigate climate change risk than those assigned to notice negative emotion and play with the more cooperative partner. Only one directional hypothesis about cognitive reappraisal regulation instructions on donations to mitigate risk was supported by the data. Relative to the active viewing “notice” condition, down-regulating negative emotion with reappraisal decreased donations, but up-regulating negative emotion with reappraisal did not increase donations. Our hypothesis for mindful acceptance was only partially supported because although mindful acceptance decreased negative emotion, it did not reduce donations.

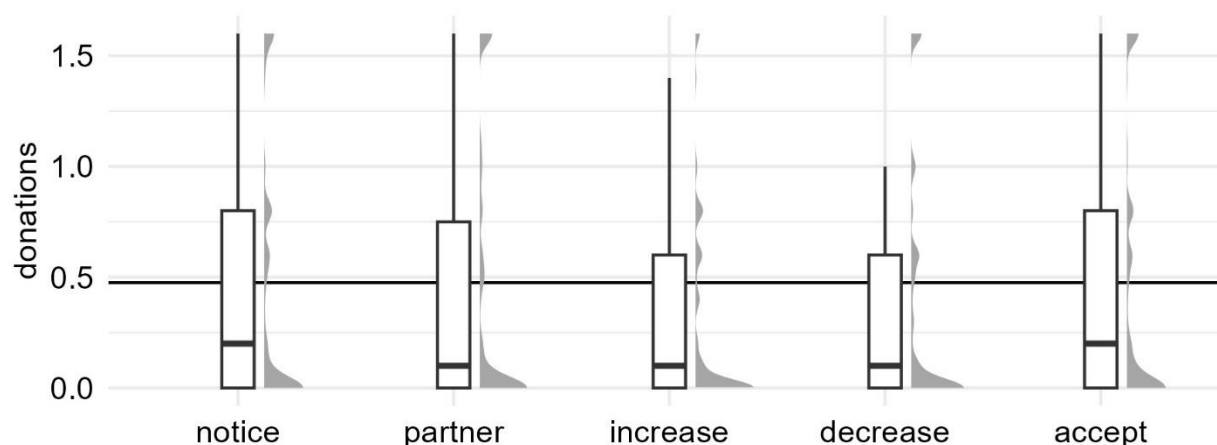
Figure 17*Donations to Mitigate Climate Change Risk in the Gamified Information Task*

Note. Trial-level data were averaged for each individual before visualization. The top row displays trial donations from the baseline block, before randomization to experimental conditions, and the bottom row displays trial donations from the test block. The solid black line represents the mean for the “notice” control group at baseline and the dashed black line represents the mean for the same group at test. Compared to the “notice” control condition, and holding constant baseline donations (grand-mean centered at the individual and person-mean centered at the stimulus levels), and accounting for clustering at the individual, the stimulus, and the confidence level, decreasing negative emotion with cognitive reappraisal (“decrease”) reduced donations and playing with a free-rider (“partner”) increased donations.

Post-Task Donations

The third outcome was the amount of the \$1.60 bonus donated to a pro-environmental organization after the task. We interpreted the statistical significance of experimental effects in a generalized linear model with the amount of donation in 10-cent units from 0 to 16, using a

Poisson distribution with a log link. Holding condition constant, and consistent with our hypothesis, we found that negative emotion and trial donation decisions at baseline predicted increased donations. In parallel to our *a priori* hypotheses about the effect of regulatory instructions on trial-level donations to mitigate risk, we expected that reducing negative emotion via regulation would also reduce real donations. That hypothesis was supported by the data, but the mechanism was called into question because we found a similar decrease in real donations after using reappraise to increase and decrease negative emotions (Table 8).

Figure 18*Post-Task Donations to a Pro-environmental Organization*

Note. Boxplots show the distribution of post-task donations from USD\$1.60 in dollars by condition. The solid black line represents the mean for the “notice” control condition. When donations were modeled as outcomes in ten-cent units with a generalized linear model using a Poisson distribution and a log link, predicted by each condition compared to the “notice” control condition and holding constant negative emotion and donation in the baseline block, both increasing (“increase”) and decreasing (“decrease”) negative emotion with reappraisal led to reduced donations to a pro-environmental organization.

Policy Support and Willingness to Sign Petitions

In exploratory models, we found that negative emotions and donations at baseline also predicted climate change mitigation policy support and willingness to sign petitions for those policies. Unlike the real, post-task donation measure, however, there were no statistically significant experimental effects on either policy solution (Table 8).

Table 8*Experimental Effects on Negative Emotion and Climate Change Solutions*

<i>Outcomes</i>	negative emotions		trial donations			post-task donations			policy support		policy petition	
<i>Fixed Effect Predictors</i>	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>IRR</i>	<i>PR=0</i>	<i>PR<0</i>	<i>PR>0</i>	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>
intercept	4.21	<.001	4.30	<.001	4.46	0.00	0.00	1.00	72.08	<.001	60.75	<.001
negative emotion base GMC	0.75	<.001	0.02	.632	1.07	0.01	0.00	**0.99	2.89	<.001	4.12	<.001
negative emotion base PMC	0.21	<.001	0.01	.447								
partner change (free rider)	0.09	.572	0.61	.002	0.91	**0.83	0.15	0.02	-0.88	.722	-4.05	.275
reappraisal negative up	0.59	<.001	0.05	.780	0.75	0.01	**0.99	0.00	-0.66	.787	-0.96	.792
reappraisal negative down	-1.37	<.001	-0.56	.005	0.76	0.03	**0.97	0.01	-4.08	.104	-3.19	.397
mindful acceptance	-0.58	<.001	-0.12	.522	0.87	**0.64	0.35	0.01	-0.26	.915	1.39	.700
medium confidence	-0.20	.500	-0.16	.128								
high confidence	-0.22	.394	-0.06	.505								
trial donation base GMC			0.88	<.001	1.18	0.00	0.00	1.00	1.07	.006	1.86	.002
trial donation base PMC			0.09	<.001								
<i>Random Effects Clusters</i>												
σ^2	0.82		1.21									
T00	0.92 P_ID		1.38 P_ID									
	0.07 stim		0.01 stim									
T11	0.10 P_ID X confH											
	0.08 P_ID X confVH											
ρ_{01}	-0.15 P_ID X confH											
	-0.20 P_ID X confVH											
ICC	.51 P_ID *		.53 P_ID									
	.04 stim *		.02 stim									
N	387 P_ID		387 P_ID									
	8 stim		8 stim									
Observations	3088		3092		387				387		387	
Marginal R ²	0.474		0.558									
Conditional R ²	0.762		0.794									
Pseudo R ²					0.487							
R ²									0.097		0.097	
Adjusted R ²									0.082		0.083	

Note. The table displays one model per column, each with a different outcome. Base refers to baseline measurements, before randomization to experimental condition. GMC is grand mean-centered, such that each person's score is relative to the sample-level average and PMC is person mean-centered, such that each trial's score is relative to the person-level average. *ICC components do not account for the random slope of stimulus confidence by participant. P_ID refers to the participant, stim refers to the stimulus, confH refers to high confidence, and confVH refers to very high confidence. For the model predicting post-task donations, the mindful acceptance condition was not a statistically significant predictor, but it was "trending" ($p = .064$),

so we instead report posterior probabilities for each experimental effect (*PRs*). *PR* = 0 is interpreted as the probability that the experimental condition led to the same donations as the control condition, *PR* < 0 is interpreted as the probability that the experimental condition led to less donations than the control condition, and *PR* > 0 is interpreted as the probability that the experimental condition led to more donations than the control condition. ** indicates the most probable interpretation.

Discussion

In this study, we experimentally manipulated the way that people regulate responses to climate change information. Emotion regulation functioned as hypothesized in the context of climate change information; people were able to increase and decrease negative emotions using cognitive reappraisal, and mindful acceptance decreased negative emotion. The experimental effects on emotional responses were consistent with research that has found both mindful acceptance and cognitive reappraisal to effectively modulate emotions (e.g., Kober et al., 2019; Webb et al., 2012). We can conclude that emotion regulation can be used for climate change situations as with other situations that precipitate emotion generation.

We found that downregulating negative emotions with cognitive reappraisal also reduced trial-level donations to reduce the risk of climate change, consistent with a previous study of emotion-focused emotion regulation and risk aversion in basic cognitive testing (Heilman et al., 2010). Mindful acceptance decreased negative emotion, but not as much as reappraisal, and mindful acceptance did not affect the trial-level donations to mitigate climate risk (although one statistical interpretation could be that there was a “trend” toward statistical significance, around a 35% probability that mindful acceptance leads to reduced donations). Cognitive reappraisal was effective in up-regulating negative emotion, but cognitive reappraisal that increased negative emotion did not affect trial-level donations to mitigate climate change risk.

Playing the game with a simulated free rider did not affect negative emotions, but it did affect the trial-level donation decisions. Contrary to our hypothesis, however, playing with a free rider increased, rather than decreased, donations. This result suggests that the simulated

partner might have been perceived differently than a real partner in a social dilemma. Rather than conditional cooperation, we found that participants made up for the lower contributions of a simulated free rider by donating more themselves. However, we cannot conclude more about the reason for this pattern without additional research.

We also used a second measure to assess donations to mitigate the risk of climate change. After the task, we told participants that they would receive the whole bonus, no matter how much they lost or donated previously, and that they could donate some of that bonus to a pro-environmental organization. Interestingly, we found that negative emotions at baseline predicted increased post-task donations, but both cognitive reappraisals to increase negative emotions and cognitive reappraisals to decrease negative emotions decreased post-task donations (Table 8). Although not statistically significant, the direction of both other experimental effects (i.e., mindful acceptance and a free-riding partner) were also negative, relative to the control. There were also no statistically significant experimental effects on climate change policy support, willingness to sign petitions, or self-reported climate change mitigation motivation.

In sum, in Study 3, we experimentally tested mindful acceptance and cognitive reappraisal in climate change situations. We used a simulated social dilemma to assess decision making and tested the effect of the simulated partner behavior. We found that climate change-related emotional responses are malleable and that when cognitive reappraisal is used to downregulate negative emotion, that process can also reduce donations to mitigate climate change risk. In this small-scale simulation of climate change risk, there was evidence that a simulated partner changed the way that participants made financial decisions, without affecting emotional responses. We did not find conditional cooperation, but instead found that participants compensated for free-riding partners by donating more under conditions of risk. That was the only evidence of a regulatory strategy or external condition that would be good for climate change solutions.

Strengths, Limitations, and Future Directions

One strength of this study is that we provided minimal training on how to use cognitive reappraisal and mindful acceptance, which suggests that even with short-term implementation, these instructions could have utility. However, that is also a limitation of the manipulation. Since both cognitive reappraisal and mindful acceptance are strategies that can be developed over time and may be difficult to enact, longitudinal work could test the potential for sustained change in individuals based on practice working with emotions. Training in emotion regulation or mindful acceptance could have different effects than brief instructions without training.

Our focus on negative emotion is also a strength and a weakness of Study 3. On the one hand, there is substantial evidence that negative emotion can motivate people to deal with threat. The interpretation of our results was more straightforward than if we had also used positive stimuli and considered emotion in multiple dimensions. Future research could explore how regulatory strategy use could change responses to climate change information in multiple dimensions. Our results suggest that manipulating negative emotion may not be an effective driver of climate change solutions; positive emotions could be a more sustainable and hedonically desirable way to promote solutions.

Although this controlled experiment was helpful to assess causal effects of the experimental manipulations, the gamified climate change information task in Study 3 was brief and small-scale. Climate change is large-scale and long-term; therefore, the ecological validity of the task is questionable. The ecological validity was improved by the presence of a partner and a collective risk of climate change, but the partner was simulated and the temporal dimension of climate change risk in this game was dramatically different from actual climate change risk. If regulatory instructions were to be embedded with climate change information that people encounter outside of this study, it is unclear whether our results would be able to predict their feelings or their decision making. However, future research could test decisions and

behavior that occur in daily life and over long periods, to better understand how people deal with the long-term and large-scale nature of climate change.

In addition, it is possible that participants did not take the trial donations seriously, even though we told them that the money was real. Unlike the public goods games in behavioral economics that inspired the gamified task (Jacquet et al., 2013; Milinski et al., 2008), our task was conducted online and did not involve real people working together. The gamified information task in Study 3 should be considered novel and may or may not generalize to other collective risk social dilemmas. We would have considered correlations between risk preference scores and trial donations as validation of the simulation, but we did not observe a correlation. However, the risk preferences measure may not tap into specific cognitive processes such as loss aversion, learning parameters, or other functions that can be estimated with computational models (Ahn et al., 2017), which are cognitive factors that could be associated with decisions in the simulation.

Now that we know that there are effects of regulation instructions on emotion and effects of reappraisal and simulated partner behavior on donations to mitigate climate change risk, there are many future directions. One straightforward next step would be to conduct the same study procedures with a real, live partner who can choose whether to cooperate or not. Other modifications to the gamified procedures could involve more than two people or greater stakes. As future research proceeds, it will be imperative to consider not only how emotion and emotion regulation occurs within individuals, but in the context of larger systems.

General Discussion

This set of three studies was intended to improve understanding of how U.S. adults respond to climate change information. Climate change information is ubiquitous in the modern world and, although the information can vary greatly, is an essential pillar necessary to understand the phenomenon of climate change. As described in the conceptual framework,

climate change information is the situation responsible for initiating emotion generative processes and there are causes and consequences of regulating those processes. The current studies used climate change information from one working group of the Intergovernmental Panel on Climate Change (Climate Change 2022: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022).

We combined scientific statements with related images to create information stimuli, then measured how participants in our lab exhibited physiological responses to those stimuli. We saw autonomic nervous system activity that indicated emotional responses when people encountered information about climate change. Participants also reported subjective emotional experiences and said that they tried to control their emotions. The results of Study 1 suggested that the conceptual framework was plausible.

Most of the participants in Study 1 believed in climate change and we thought that people who did not believe in climate change might have different emotions and try to regulate them in different ways. In Study 2, we recruited a relatively large sample of believers and non-believers online. We found evidence that the emotional responses and regulation differed based on belief in climate change. As expected, we found strong associations between climate change belief and climate change solutions. We also found evidence, although inconsistent, of positive associations between emotion responses to climate change information, regulatory strategy use, and climate change solutions.

However, despite those positive associations, we also found evidence that regulation predicted fewer donations to a pro-environmental organization for people who believed in climate change. Importantly, there are more people who believe in climate change than those who do not, and those who believe in climate change are likely responsible for enacting climate

change solutions. It is exactly those people for whom regulatory strategies could improve hedonic experience while inhibiting threat mitigation decisions.

Study 3 probed causal effects of regulatory strategy use on donations to mitigate climate change risk in people who believe in human-caused climate change. In that small-scale, controlled experiment, causal evidence supported the idea that downregulation of negative emotion could inhibit decisions to mitigate climate change risk, but also hinted that upregulating negative emotion could also have detrimental effects. If the dissemination of climate change information is accompanied by instructions to use cognitive reappraisal to down- or upregulate negative emotion, we might expect that the information would be less effective at promoting decisions to mitigate the risk of climate change. Mindful acceptance did not drive more adaptive decision making, but neither did it have a detrimental effect, while simultaneously improving hedonic experience.

All three studies support the utility of the conceptual framework. Although we did not set up falsifiable tests of specific premises, our results pave the way for that work. By formalizing aspects of the conceptual framework into theoretical models, future research can continue to advance systematically. This future research can build on our contributions of theory, methods, and data in this interdisciplinary field. Specifically, a major theoretical contribution is a conceptual framework that centers climate change information, describes how emotion generative and regulatory processes could connect to climate change solutions, and distinguishes between emotion regulation and mindful acceptance. Our methodological contributions include climate change information stimuli, and our data include a battery of physiological responses to climate change information, as well as measures of subjective experience, regulation use, and outcomes that represent climate change solutions.

Climate Change and Other Environmental Issues

This dissertation frames climate change in a specific way – as a problem or challenge to be addressed with psychological research on cognition, emotion, and behavior. However, we do not talk about other environmental problems; climate change is only one of many massively complex, “wicked” (Lönngren & Van Poeck, 2021) environmental problems that are necessary to address for the continued existence and well-being of the human species on Earth. The phenomenon labelled climate change cannot be isolated from a multitude of other, entwined, environmental issues, such as decreasing biodiversity and increasing pollution. Climate change, and other environmental problems, are collective problems. These problems will not be solved with only one approach, such as the problem-focused approach taken in this dissertation.

One way to contextualize the current approach alongside other potential approaches to environmental problems is with the idea of environmental discourses – how people talk about environmental problems (Dryzek, 2022). Since the first edition in 1997, Dryzek (2022) has argued for a transition from an industrial society to an ecological society and organized environmental wicked problems in a taxonomy, which I think is useful to describe how the current work fits in a broader conversation. First, this dissertation is not survivalist; there is no claim that sustainable economic growth is impossible, nor that hard limits require authoritarian governance. Second, this dissertation is not Promethean; there is no claim that market systems, untouched by societal reform, will lead to a sustainable society in the long term. Third, there are no combinations of imaginative and reformist solutions or discussions of sustainable development, ecological modernization, green politics, or ecological democracy. This is a social science examination focused on human cognition and emotion. Human responses to climate change can be targeted with a prosaic, yet reformist discourse – environmental problem-solving.

Strengths, Limitations and Future Directions

One strength of this work is the focus on individuals and problem-solving. However, when considering the scope of environmental discourses, that is also a limitation. The climate change problem will not be solved with laboratory experiments about how people feel and manage feelings when they see climate change information.

We also focused on negative emotion more than positive emotion. In Studies 1 and 2, we included some positively-valenced climate change information stimuli and examined positive emotion, but we used fewer positive than negative stimuli. In the first models, it seemed like positive emotion had more to do with the characteristics of the pictures used in the stimuli or the statements about climate change, rather than the scientific confidence in the statements. In Study 2, we found differences in the associations between emotion and solutions based on belief, particularly positive and negative emotion with policy support. In Study 3, we focused on negative emotion. This could be a strength in that it simplified interpretation of the work. However, our focus on negative emotion is also a limitation and the regulation of positive emotions is a clear direction for future work. Positive and negative emotion could have different effects on solutions, depending not only on belief, but also whether the climate change information had a positive or negative valence, and the type of solution.

In addition to not examining how people regulate positive emotion, these studies focused on a subset of possible ways that people could regulate emotion. For example, in Studies 1 and 2, distraction and expressive suppression were used less frequently than mindful acceptance and cognitive reappraisal and we did not examine either of them in Study 3. Even within the stage-specific emotion regulation strategies, there are numerous ways that people can manage emotion. Future studies could examine other ways to regulate emotion in climate change situations.

Another limitation about emotion regulation is that the conceptual framework distinguished mindful acceptance from other emotion regulation strategies by the lack of a goal to change emotional experience. However, we did not test that claim in these studies. It is possible that people use mindful acceptance with a goal to change emotion, despite the theoretical difference. Future studies could address that open question by gathering evidence of people's motivation to use mindful acceptance when encountering climate change information in everyday life.

Furthermore, there are a number of open questions for future research about the metacognitive processes that underlie mindfulness-based regulation and traditional emotion regulation. Although people have classified aspects of mindfulness (i.e., mindfulness-based skills) as stage-specific emotion regulation strategies (Raugh & Strauss, 2023), it is possible that mindfulness-based skills affect higher-order cognitive processes and subsequently affect emotion generation through different mechanisms than any stage-specific emotion regulation strategy. One possible conceptualization of mindfulness could be that metacognitive aspects of mindfulness-based skills (e.g., goals related to emotional experience) could drive distinguishable mechanistic processes, despite the apparent similarities between aspects of mindfulness and emotion regulation in both processes and consequences. A conceptualization of metacognition and meta-affect in task engagement (Thomas et al., 2022) could be a starting point for integrating mindfulness and emotion regulation with cognition and affect.

One limitation about the climate change information stimuli is that the confidence of the statements was not artificially manipulated (and is therefore confounded with the statement and the image); each statement from the IPCC had a real level of scientific confidence. When we tested the effect of scientific confidence, the patterns are not linear. For example, for negative emotional responses; the high confidence information stimuli seemed to elicit greater negative emotion than the medium confidence information and the very high confidence information.

Future studies could consider using deception to assess whether different levels of scientific confidence attached to the same information affect emotion and emotion regulation. However, especially considering the preponderance of misinformation about climate change (e.g., see Treen et al., 2020), it would be critical to carefully consider whether the scientific value of the research question(s) could offset the potential harms of deception.

Finally, these studies sampled from the population of U.S. adults. While this is a strength considering the sample size, our results cannot be automatically generalized to other populations around the world. This is a critical limitation and direction for future work because climate change is a global problem, and the solution will necessitate collective global action. When future work considers geographic and other demographic factors, it will be important to consider the tradeoff between poverty reduction and environmental degradation in developing countries, as well as the disproportionate ability of a small portion of the Earth's population with the most wealth to effect climate change in positive or negative ways. Importantly, in addition to economic disparities in the ability of people to deal with the consequences climate change for themselves, there are unequal consequences of climate change across geographic regions and demographic factors such as race/ethnicity (e.g., Berberian et al., 2022; Samson et al., 2011). The reasons for disparities in the consequences of climate change are critical not just to improve the human condition in the short term, but also to ensure that efforts to enact climate change solutions are optimized for any given target population.

Conclusion

These studies provide preliminary support for the utility of the conceptual framework and set the stage for future work on emotion regulation and climate change situations.

In Study 1, we found that the body responds to climate change information. In Study 2, we found that climate change belief is associated with more emotion, as well as more mindful acceptance. We also found mixed associations between emotion regulation in response to

climate change information and the measures of climate change solutions. In Study 3, we tested causal effects of emotion regulation on decision making under the risk of climate disaster in people who believe in anthropogenic climate change and found support for the idea that when emotion regulation reduces negative emotion, it can also reduce donations to mitigate climate change risk. The conceptual framework, methods developed, and results from these studies provide a foundation for future research translating climate change information into climate change solutions through emotion-based processes.

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Appendix A: Climate Change Information Stimuli

Climate change caused by humans leads to heat waves that kill people (medium confidence).



Human-caused climate change leads to extreme weather and droughts (high confidence).



Human-caused climate change has negative effects on mental health (very high confidence).



Climate change caused by humans leads to more tropical cyclones and damages (medium confidence).



Human-caused climate change increases intense, destructive fires (high confidence).



Climate change caused by humans leads to mass deaths in hundreds of species (very high confidence).



Human-caused climate change affects global patterns of water flow (medium confidence).



Extreme flooding from human-caused climate change is damaging (high confidence).



Human-caused climate change has negative effects on physical health (very high confidence).



Adapting to human-caused climate change can stabilize food systems (medium confidence).



In certain places, human-caused climate change can increase tourism (high confidence).



Progress in adapting to human-caused climate change has benefits (very high confidence).



Appendix B: Study 3 Manipulation Instructions

In Study 3, participants were randomly assigned to one of the five conditions described below. They received the instructions after viewing the information slide stimuli once; initial instructions did not specify how to think about, change, or accept the way that they feel. Each bullet is one screen and the first two screens were the same for all participants.

- **INSTRUCTIONS**

Climate change information is negative, or unpleasant, for most people.

- You may feel bad about climate change for many reasons.

In the next part of the task, please continue playing the game with this in mind.

Active Viewing Control

- We would also like you to notice your negative feelings while you view the same information again.
- Specifically, please note that you can attend to your negative feelings about the situation.
- While viewing the climate change information again, please notice your negative emotions about the situation.
- On every trial, you will see the word **notice** as a reminder to notice any negative emotions about the situation

Change Partner

- We would also like you to notice your negative feelings while you view the same information again.
- Additionally, please note that in the next round, you will play the game with a different simulated partner.
- Your partner will be programmed with a new pattern of behavior because different people think, feel, and act differently in situations like these.
- While viewing the climate change information again, please notice your negative emotions and the donations from your new partner.
- On every trial, you will see the word **notice** as a reminder to notice any negative emotions about the situation

Reappraise Negative Up

- We would also like you to change your negative feelings to feel worse while you view the same information again.
- Specifically, please note that there are ways to increase your negative feelings by rethinking the situation.
- Try to rethink the climate change situation to make it feel worse.
- While viewing the climate change information again, you could think about how climate change is annoying to talk about, how it seems like a bigger or unsolvable problem, or any other way of rethinking that makes you feel worse about the situation.
- On every trial, you will see the word **increase** as a reminder to rethink the situation to increase negative emotions

Reappraise Negative Down

CLIMATE CHANGE INFORMATION, REGULATION & SOLUTIONS

- We would also like you to change your negative feelings to feel better while you view the same information again.
- Specifically, please note that there are ways to decrease your negative feelings by rethinking the situation.
- Try to rethink the climate change situation to make it feel better.
- While viewing the climate change information again, you could think about how climate change is interesting to talk about, how it seems like a smaller or solvable problem, or any other way of rethinking that makes you feel better about the situation.
- On every trial, you will see the word **decrease** as a reminder to rethink the situation to decrease negative emotions

Mindful Acceptance

- We would also like you to notice and accept your negative feelings while you view the same information again.
- Specifically, please note that there are ways to allow your negative emotions to come and go by mindfully accepting the feelings.
- Try to pay attention mindfully, with awareness of the breath.
- While viewing the climate change information again, you could mindfully attend to your breath, accept the situation, or use mindful acceptance to remain open to your experience. Allow softness around feelings; let them come and go.
- On every trial, you will see the word **accept** as a reminder to notice and softly accept negative emotions as they come and go