Journal of Environmental Psychology 32 (2012) 19–29

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Psychology

journal homepage: www.elsevier.com/locate/jep

Decisions from experience reduce misconceptions about climate change

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A R T I C L E I N F O

Article history:
Available online 3 November 2011

Keywords:
Climate change
Decisions from description
Decisions from experience
Repeated feedback
STEM
Simulators

A B S T R A C T

Research has shown widespread misconceptions in public understanding of the dynamics of climate change: A majority of people incorrectly infer that carbon-dioxide (CO_2) concentrations can be controlled by stabilizing emissions at or above current rates (correlation heuristic), and while emissions continuously exceed absorptions (violation of mass balance). Such misconceptions are likely to delay actions that mitigate climate change. This paper tests a way to reduce these misconceptions through experience in a dynamic simulation. In a laboratory experiment, participants were randomly assigned to one of two conditions: *description*, where participants performed a CO_2 stabilization (CS) task that provided them with a CO_2 concentration trajectory over a 100 year period and asked them to sketch the corresponding CO_2 emissions and absorptions over the same period; and *experience*, where participants performed the same task in a dynamic climate change simulator (DCCS), followed by the CS task. In both conditions, half of the participants were science and technology (STEM) majors, and the other half were non-STEM. Results revealed a significant reduction in people's misconceptions in the *experience* condition compared to the *description* condition. Furthermore, STEMs demonstrated better performance than non-STEMs. These results highlight the potential for using experience-based simulation tools like DCCS to improve understanding about the dynamics of climate change.

1. Introduction

Despite strong scientific consensus about the causes and risks of climate change, the general public exhibits a complacent attitude towards actions benefiting Earth's climate (Bostrom, Morgan, Fischhoff, & Read, 1994; Leiserowitz, 2007; Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994; Weber, 2006). For example, based upon evidence from surveys of people's beliefs and policy preferences, a large majority would likely advocate *wait-and-see* preferences: They would like to delay significant actions to reduce greenhouse gas emissions until impacts have been more convincingly demonstrated (Kull, 2001; Leiserowitz, 2007; Sterman & Booth Sweeney, 2002, 2007). For example, 60% of participants in a U.S. survey chose either the option "until we are sure that global warming is really a problem, we should not take any steps that would have economic costs," or the option "its effects will be gradual, so we can deal with the problem gradually" (Kull, 2001). This wait-and-see preference is also seen among policymakers: "Slow the growth of greenhouse gas emissions (GHGs), and – as the science justifies – stop, and then reverse that growth" (G. W. Bush, 2/14/02; Jones, 2002). According to Jones (2002), George W. Bush believed that climate mitigation actions could be taken at a slow pace until science confirmed climate change as a real problem.

Furthermore, some scientists also seem to possess a stronger wait-and-see (inaction) view on climate change. For example, Fred Singer, professor emeritus of environmental sciences at the University of Virginia and an ex-member of the U.S. National Advisory Committee on Oceans and Atmosphere, recently commented: "Human activities are not influencing the global climate in a perceptible way. Climate will continue to change, as it always has in the past, warming and cooling on different time scales and for different reasons, regardless of any human action" (Singer, 2009, p. 1). Thus, Singer argues that human activity has no influence on climate change whatsoever, which would result in inaction rather than a slow wait-and-see action. Moreover, climate initiatives like the Kyoto Protocol and Clear Skies, which have pledged to mitigate the global warming problem, have also expressed support for wait-and-see preferences: The Kyoto Protocol's proposed reductions in emissions fall short of the proposed targets and Clear Skies' initiative promotes even further greenhouse gas emissions growth (Sterman & Booth Sweeney, 2002, 2007).

Wait-and-see preferences would work well in simple systems with short delays between the detection of a problem and the implementation of corrective actions. For example, one can afford to wait-and-see when boiling beans until steam builds up and the

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doi:10.1016/j.jenvp.2011.10.003

cooker whistles because there is a short delay between the whistle and removing the cooker from the flame. Unfortunately for a complex system like Earth's climate, there are much longer delays between the decision to mitigate emissions and the corresponding changes in atmospheric GHG concentrations (IPCC, 2007; Sterman, 2008; Sterman & Booth Sweeney, 2002, 2007). Prior research shows that people often ignore long feedback delays in complex systems (Sterman, 1989), and those who exhibit wait-and-see preferences might be acting under the implicit misconception of very short delays in Earth's climate system (Sterman, 2008; Sterman & Booth Sweeney, 2002, 2007). As there are long feedback delays, however, wait-and-see preferences become problematic. Because even if mitigation actions are taken, atmospheric CO_2 accumulation would continue to rise until emissions fell below the absorptions rate. Average atmospheric temperature would then peak, and consequences such as rising sea levels and thermal expansion would continue (Meehl et al., 2005; Wigley, 2005). Therefore, wait-and-see preferences are likely to cause abrupt, persistent, and costly regime changes on Earth in the future (Alley et al., 2003; Scheffer, Carpenter, Foley, Folkes, & Walker, 2001).

Prior research has shown that people's misconceptions about the climate system are related to their own deficient mental models[1]: The general public lacks training in climatology and has little understanding of climate processes (Bostrom et al., 1994; Kasemir et al., 2000; Kempton, 1997; Morgan, Fischhoff, Bostrom, & Atman, 2002; Palmgren, Morgan, de Bruin, & Keith, 2004; Read et al., 1994). In this paper, however, we argue that people's misconceptions are due to a more fundamental limitation of their mental models: A weak understanding of accumulation and mass balance concepts rather than to the particulars of climatology and the climate system. Cronin, Gonzalez, and Sterman (2009) have demonstrated that as the relationship between inflows and outflows become more complex, people tend to rely more on simple but erroneous heuristics. According to Cronin et al. (2009), people rely on the "correlation heuristic," whereby they wrongly infer that the system's accumulations are positively correlated to its inflows.

Through laboratory studies, Sterman (2008) and Sterman and Booth Sweeney (2007) have shown that people's wait-and-see preferences on climate are related to their reliance on the correlation heuristic. For climate, relying on the correlation heuristic means wrongly inferring that an accumulation (CO_2 concentration) follows the same path as the inflow (CO_2 emissions); hence, stabilizing emissions would rapidly stabilize the concentration, and emissions cuts would quickly reduce the concentration and damages from climate change. Consequently, people who rely on the heuristic would demonstrate wait-and-see preferences because they would significantly underestimate the delay between reductions in CO_2 emissions and in the CO_2 concentration. They would also underestimate the magnitude of emission reductions needed to stabilize the concentration. Furthermore, Sterman and Booth Sweeney (2007) have also shown that people's wait-and-see preferences are also related to the violation of mass balance, whereby people incorrectly infer that atmospheric CO_2 concentration can be stabilized even when emissions exceeds absorptions. Violating mass balance leads to wait-and-see preferences because people think the current state of the climate system, where emissions are double that of absorptions (IPCC, 2007), would not pose a problem to future stabilization.

Prior research has evaluated people's misconceptions and related wait-and-see preferences in terms of correlation heuristic reliance and mass balance violation in a one-shot paper-and-pencil climate stabilization (CS) task (Sterman, 2008; Sterman & Booth Sweeney, 2007). In the CS task, participants are asked to sketch CO_2 emissions and absorptions that would stabilize the CO_2 concentration to an attainable goal by the year 2100. In this problem, they are given the concentration's starting value in the year 2000, and its historic trends and emissions between the years 1850 and 2000. Sterman and Booth Sweeney (2007) report that about 70% of participants (about 60% of whom had backgrounds in science, technology, engineering, and management (STEM), and a majority of the rest in economics) sketched CO_2 emissions that were positively correlated with the CO_2 concentration. Moreover, 74% of participants violated mass balance in their responses either by failing to keep emissions greater than absorptions before the concentration stabilized in the year 2100; or failing to make emissions equal to absorptions when the concentration reached 2100.

Sterman (2008) and Sterman and Booth Sweeney (2007) made a qualitative claim that using simulation-based tools would likely help people correct their misconceptions about Earth's climate. Other researchers also suggest that experiencing the adverse consequences of climate change is likely to improve people's understandings of the climate system (Weber, 2006). However, the efficiency of simulation tools in reducing people's reliance on the correlation heuristic and the violation of mass balance has only been demonstrated in some initial attempts (Dutt & Gonzalez, 2009, in press; Moxnes & Saysel, 2009). Moxnes and Saysel (2009) used a simulated computer task where participants were required to stabilize the CO_2 concentration by making emissions decisions every 10 simulated years starting in the year 2010. After every 10 years elapsed, participants could see the changes in the concentration as a result of their decisions. Moxnes and Saysel (2009) demonstrated that better emission decisions are possible through providing repeated feedback about decision actions and outcomes to participants. Feedback empowers participants to try new hypotheses and also to understand the cause-and-effect relationships between their decisions and outcomes.

Building on these results, we developed a very simplified but interactive computer-based simulation of the climate system called the Dynamic Climate Change Simulator (DCCS), and used it to collect data on how participants control the atmospheric CO_2 accumulation to a goal under different conditions of feedback delays (Dutt & Gonzalez, 2009, in press). The two types of manipulated feedback delays employed in the DCCS were the natural delays in CO_2 absorptions, and the frequency with which multiannual emission policies are revised for a simulated climate system. We found that participants improved their control of the CO_2 concentration through experiences gained in DCCS, where these experiences might have enabled participants to revise their existing mental models. But again, the efficiency of simulation tools against more traditional descriptive methods has not been fully demonstrated.

2. Current research

Given people's widespread misconceptions about the climate system, research is critically needed that shows how their misperceptions can be overcome through experience in simulation tools. The main objective of this paper is to evaluate whether or not experiencing repeated outcome of decisions (i.e., feedback) in DCCS reduces participant's misconceptions about our climate.

DCCS provides repeated feedback on the changes in the CO_2 concentration each year as a result of CO_2 emission and absorption policies set by participants, allowing participants to observe the results of their decisions as they try to control the concentration to

[1] By "mental model" we mean a person's inferences or judgments about the networks of causes and effects that describe how a system operates which include the system's boundary (i.e., factors are considered endogenous or exogenous) and its time horizon. Therefore, in this paper, the term "mental model" refers to participants' inferences about shapes of CO_2 emissions and absorptions overtime.