The Effect of Systems Thinking on Pro-Environmental Behavior

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ABSTRACT

Systems thinking is a way of conceptualizing reality and making decisions that emphasizes relationships and interdependencies. This mindset has been identified by several sustainability psychologists as a possible means of promoting pro-environmental behavior. However, no study to date has demonstrated a causal link between learning systems thinking and actual pro-environmental behavior. The present research sought to experimentally test this relationship, and to test whether systems thinking in one domain spills into another. Participants learned about an environmental (wastewater treatment) or non-environmental (physical pain) phenomenon, described in either a systems-oriented or non-systems-oriented manner through a three-minute educational video. They then completed a pro-environmental behavior decision-making task that had real-world environmental and personal consequences (the amount of money donated to a carbon offset fund and wait time, respectively). There was a marginally significant increase in pro-environmental behavior for participants in the two environmental conditions, but no significant effect was found of system learning, nor a significant interaction between the two. These findings suggest that future studies should explore other methods of teaching systems thinking.

Keywords

Keywords: systems thinking, decision making, sustainability, pro-environmental behavior

1. INTRODUCTION

Global climate change is one of the most critical issues humans face today, posing a serious long-term threat to the planet and its inhabitants. While the earth's climate can fluctuate naturally, the current warming trend is proceeding at a rate that is unprecedented (Ramaswamy, Schwarzkopf, Randel, Santer, Soden, & Stenchikov, 2006) and, according to widespread consensus among scientists, is largely caused by human activity (Doran & Zimmerman, 2009). As such, it is essential that human behavior become more sustainable, in order to mitigate the effects of climate change.

However, despite the massive threat posed by humans' impact on the climate, many still don't engage in pro-environmental behavior. There are a number of reasons for this widespread failure to take action in the face of climate change, including the complicated nature and scale of the global climate and the way in which modern technology conceals critical resource usage. These characteristics make it difficult to realize the extent of the growing environmental destruction and its relation to human life (Frantz & Mayer, 2009). Additionally, there are many structural factors that inhibit one's ability to engage in pro-environmental behavior, such as lack of access to public transportation or absence of renewable energy from their public utilities. These barriers must be addressed through collective action and political behavior, such as advocating for structural level changes through supporting carbon offset funds or voting for pro-environmental policy. However, similar to individual action, one must realize the magnitude of the threat and its impact on one's life to be motivated to take collective action. Many researchers believe that through promoting systems thinking—a trans-disciplinary construct that is believed to help individuals better comprehend and mitigate complex social-ecological dilemmas (Bosch, King, Herbohn, Russell, & Smith, 2007)—the threat of climate change will become more apparent and lead to increases in environmentally responsible behavior, in both the realm of individual and collective behavior.

1.1 Systems Thinking

A system is any group of interacting, interrelated, or interdependent parts that form a complex and unified whole (Kim D., n.d.). For example—the global climate is a system comprised of a complex network of feedback loops from the atmosphere, sun, land, ocean, and the inhabitants of the planet. A systems thinking mindset thus allows one to attend to and process such system-related information more broadly and recognize complex causal relationships and patterns of change.

A move towards holism and away from reductionism

A nuanced and expanded understanding of causality

A recognition that systems are in constant—but patterned—flux

An understanding of the self embedded within the system (Thibodeau, Frantz, & Berretta, 2017).

It has been theorized that someone who engages in systems thinking will be more likely to perceive the broader context of their actions. For example, someone high in systems thinking may realize that their decision about whether to drive or bike is a part of a wider system that affects the global climate through an expanded chain of causality and that the global climate, in turn, affects their own life. Realizing that they are embedded within this system, they may opt to bike to work more often than someone low in systems thinking.

Several researchers have demonstrated a relationship between systems thinking and pro-environmental attitudes and behaviors. In one study, Lezak and Thibodeau (2016) investigated the relationship between systems thinking and attitudes towards climate change. They found that participants high in systems thinking—as measured by the Systems Thinking Scale (Davis & Stroink, 2016; Thibodeau, Frantz, & Stroink, 2016)—tended to more strongly support policy interventions aimed at reducing greenhouse gas emissions and ascribe a higher monetary value to various ecosystems than those low in systems thinking. In another study examining the relationship between systems thinking and the new ecological paradigm (a measure of endorsement of a "pro-ecological" world view), Davis and Stroink (2016) found a significant positive relationship between systems thinking and self-reported pro-environmental behaviors, such as recycling and turning off lights. Systems thinking has also been found to support decision making outside of environmental behavior, with one correlational study finding that those who utilize systems thinking—especially focusing on the holism aspect of systems thinking—performed better in a business simulation game that required complex decision making (Maani & Maharaj, 2004).

While some systems thinking researchers consider systems thinking to be a relatively stable mindset (e.g. Forrester, 2007; Meadows, 1999; Maani & Maharaj, 2004), there is research that supports the contrary—a systems thinking mindset can be learned or induced, and may not even require extensive training to do so. In Thibodeau, Winneg, Frantz, and Flusberg's (2015) study, they found that people who were exposed to more systemic metaphors when thinking about a social problem—for example, thinking about crime as a virus as opposed to a beast—demonstrated higher levels of holistic and relational reasoning than people who were not exposed to metaphors that prime a systems thinking mindset. Another paper (Alessi, 2000) outlined how to utilize "systems modeling" as a tool for enhancing students' systems thinking skills. They proposed that students will learn about concepts related to systems thinking and modeling (such as behavior over time graphs, causal loop diagrams, stocks, and flows) by building and interacting with their own models of systems. Another study found significant changes in students' understanding of interconnectivity, cause-effect relations, feedback processes, and dynamic processes after taking a semester-long course on systems thinking (Hung, 2008). Several books have even been written to teach systems thinking, such as "The Systems Thinking Playbook for Climate Change" (Sweeney, Meadows, & Mehers, 2011) and "Leverage Points: Places to Intervene in a System" (Meadows, 1999).

However, while a demonstrated relationship has been found between a systems thinking mindset and self-reported pro-environmental behavior, as well as evidence that such a mindset can be learned, past research has yet to demonstrate a causal relationship between systems thinking and actual pro-environmental behavior. Previous studies have largely been correlational in nature and have relied on self-report measures of environmentally responsible behavior. The few studies that have attempted to demonstrate causality or measure actual environmentally responsible behavior have been contradictory. A study by Frantz and Suh (2017) found that among people who did not believe in climate change, exposure to the "earth is a home" metaphor—which has been suggested to increase state systems thinking (Thibodeau et al., 2015)—increased willingness to donate to a theoretical climate change fund. However, a conceptual replication by Frantz and Webster (2018) failed to replicate this effect.

Additionally, researchers of systems thinking have not yet explored the possibility of a domain spillover effect. For instance, prior studies on the relationship between systems thinking and pro-environmental behavior have not explored if those who engage in systems thinking about environmental issues also tend to think about social issues in a more systemic way. Conversely, numerous cross-cultural psychological studies have suggested that members of collectivist cultures are more prone to think systemically about social systems (Maddux & Yuki, 2006; Maddux, Lau, Chiu, Hong, & Yuki, 2007; Nisbett, Peng, Choi, & Norenzayan, 2001), but there is little evidence to support that this spills over into an environmental domain.

1.2 Aims of current study

The current research seeks to expand on previous findings by (a) determining whether a systems thinking learning task can increase performance on a pro-environmental behavior task, and (b) if systems thinking must be taught in an explicitly environmental context (as opposed to a non-environmental context) for improved pro-environmental behavior. Participants learned about an environmental (wastewater treatment) or non-environmental (physical pain) phenomenon, described in either a systems-oriented or non-systems-oriented manner through a three-minute educational video. They then completed a pro-environmental behavior decision-making task that addresses both individual and collective aspects of pro-environmental behavior and had real-world environmental and personal consequences (the amount of money donated to a carbon offset fund and participants' wait time, respectively). I predicted that learning about systems thinking and learning about an environmental phenomenon would each independently increase participants' number of pro-environmental behavior choices—exposure to environmental learning by itself has been found to promote pro-environmental behavior (Arendt & Matthes, 2016). As such the participants in the environmental system condition would score the highest in pro-environmental behavior, followed (equally) by the non-environmental system and environmental-system conditions, with the non-environmental non-system condition scoring the lowest.

2. METHODS

2.1 Participants

Based on a power analysis calculated using a similar study that yielded an effect size of approximately 0.5 (Cohen's d), 400 participants were recruited through Amazon's Mechanical Turk and paid $5.50. All participants signed a consent document and were informed that they could quit the study at any time without loss of compensation. I used Turk's exclusion capabilities to ensure that participants lived in the US and were 18 years old or older.

This sample included a roughly equal number of males (56.7%) and females. The average age of participants was 37.14 (SD = 10.10) and 77.8% identified as white. Most (86.3%) had completed at least some college. The political orientation of participants was skewed liberal, with 51.8%, 34.5% and 13.7% identifying as liberal, conservative, and moderate, respectively.

2.2 Materials and procedure

2.2.1 Manipulation stimuli creation.

Four educational videos were created and piloted for a 2 (system) x 2 (domain) between-subjects design (results of the pilot study are described below). All videos were in the style of a Powerpoint presentation containing text and images, had no audio, and were three minutes in length. For the two system condition videos, participants were told they were learning about "systems". For the two non-system conditions, participants were told they were learning about "processes". Participants learned about "systems" or "processes" in these videos by examining an example phenomenon. In the two environmental domain conditions, participants learned through the example of the wastewater treatment system. In the two non-environmental domain conditions, participants learned through the example of the pain system (drawing from the biopsychosocial model of pain). Wastewater treatment was chosen for the environmental domain because it's a phenomenon that has an impact on the health of the environment (pollution from runoff), is connected to people's daily lives, and can be broken down into easily understandable elements. Additionally, I wanted an environmental phenomenon other than climate change, as the measurement of pro-environmental behavior used in the study is deals with CO2 emissions, so learning about climate change would be too directly related. Pain was chosen for the non-environmental because it's a phenomenon that has an impact on the health of the body, is connected to people's daily lives, and can also be broken down into understandable elements.

To teach systems thinking, the two system videos were designed to emphasize all key aspects of systems thinking laid out by Thibodeau, Frantz, and Berretta (2017). This was achieved by explaining the elements of the system, their interconnections, and their contribution to the overall function of the system; drawing from work in systems thinking pedagogy (both evidence-based and theoretical) laid out by previous researchers (Meadows, 2011; Ben-Zvi Assaraf & Orion, 2010; Kim, 1999). Additionally, the images used in the system videos emphasized systemic features by displaying interconnections and relationships with arrows between elements of the system. Conversely, the two non-system videos were designed to avoid mentions of the key aspects of systems thinking and described the elements of the process in a disconnected way. The images in these videos were laid out in an isolated way to visualize this disconnect. Aside from these differences between the conditions, content and flow of the videos were controlled to be as identical as possible, with either identical or similar text and identical slide timings. For example, the text in each video at 0:30 were as follows;

> *Environmental system: "The wastewater treatment system is made up of many different elements; human sources of wastewater, wastewater treatment plants, and the natural environment. All of these elements are interconnected and work together holistically for the function of maintaining our clean water cycle."*
>
> *Environmental non-system: "The wastewater treatment process is made up of many different elements; human sources of wastewater, wastewater treatment plants, and the natural environment. All of these elements are important for the function of maintaining our clean water cycle."*
>
> *Non-environmental system: "The pain system is made up of many different elements; biological elements, psychological elements, and social elements. All of these elements are interconnected and work together holistically to create the perception of pain in the body, functioning to protect your well being."*
>
> *Non-environmental non-system: "The pain process is made up of many different elements; biological elements, psychological elements, and social elements. All of these elements are important for the function of protecting your wellbeing."*

Stills of all slides from all four manipulation videos with full text can be found in *Appendix A*.

2.2.2 Measurement creation

An adapted online version of the Pro-Environmental Behavior Task (PEBT) designed by Lange, Steinke, and Dewitte (2018) was created and piloted to assess participants' actual pro-environmental behavior through an online survey (pilot results are described below). In the PEBT, the participant makes choices between two fictional transportation options for a virtual "trip"—one of which will represent an environmentally friendly transportation choice (the "SEST") and one of which will represent an environmentally unfriendly choice (the "DIFT"). The researchers who designed the original PEBT chose fictional transportation options for the task based on pilot data using bikes and cars as the options that suggested that some participants always chose the bicycle option because they did not have access to a car in everyday life. The original PEBT was found to be positively correlated to self-report measures of environmental attitudes, environmental concern, environmental identity, ecological behavior, and biospheric value orientation while being negatively related to egoistic value orientations—suggesting psychometric quality and utility of the measure.

The original PEBT involves an actual set of lights being turned on in the lab for the environmental consequence when the participant chose the DIFT; for the purpose of this study, this was adapted into a deduction from a carbon offset fund set up for each participant at the start of the study, to enable the use of an online sample and because contributions to a carbon offset fund act as both an individual and collective behavior. Participants are acting individually in their trip choices, but also contributing to structural level change through carbon offsets. Each trial on the PEBT consists of a transportation choice display and a waiting period, whose length is contingent on participants' responses to the choice display. Taking the SEST generally results in longer trip times (waiting periods), whereas taking the DIFT will result in a shorter trip but also a deduction of a few cents from a carbon offset fund donation of $4.25 that is granted to each participant at the start of the survey. When asked which of these means of transportation they would like to use for the upcoming trip, participants receive explicit instructions about the travel times associated with the two options. They are also informed about the amount deducted carbon offset fund, should they chose the DIFT. After the transportation selection, the participants proceed to a waiting screen which is displayed according to the times that were given on the choice display. Thus there is a real personal cost for choosing the SEST over the DIFT (increased wait time), and a real environmental cost for choosing the DIFT over the SEST (deduction from carbon offset fund). After the waiting time, the waiting screen disappears and the next choice display is presented.

The PEBT consists of three blocks of 24 trials (72 trials overall). The amount deducted from the participants' carbon offset fund for choosing the DIFT varies across blocks (equivalent to approximately six, four, and two pounds of CO2 respectively). The order in which the blocks are presented is randomized. Additionally, the waiting time difference between the DIFT and the SEST varies within the 24 trials in each block. Waiting times for choosing the DIFT are either 5, 10, 15, or 20 seconds. Waiting times for choosing the SEST are either 0, 5, 10, 15, 20, or 30 seconds longer than waiting times associated with choosing the DIFT. Each of the waiting time combinations is presented once during each of the three blocks of PEBT trials. The order of trials within each block is randomized.

The task starts with the following instructions to the participants;

> *"For taking part in this survey, we will donate up to $4.25 towards TerraPass, a carbon offsets fund. This is in addition*

to your paid compensation.

A carbon offset is a reduction in emissions of carbon dioxide or greenhouse gases through funding projects in communities across the country that reduce greenhouse gas made in order to offset GHG emissions made elsewhere. Carbon offsets are purchased to fund these projects and diminish the impact of your own GHG emissions, even though the projects are located elsewhere.

$4.25 offsets about 1,000 pounds of CO^2, equivalent to 1/3 of the CO2 emissions the average American makes in a month.

In our computer task, you will have to choose a mode of transportation for a number of different trips.

After you have decided on a mode of transportation, you will have to wait until the trip is completed. When the trip is completed, you will have to choose a mode of transportation for the next trip.

You can choose between two newly developed transportation options, the 'SEST' and the 'DIFT'.

In most cases, taking the SEST will take more time than taking the DIFT. Depending on the nature of the trip, the travel time difference between the two options will be smaller or larger.

Also, taking the DIFT will consume some energy and produce CO^2 emissions. If you choose the DIFT option, a number of lights will be turned on for the duration of your trip. Each of these lights produces about half a pound of CO^2. This will lead to a deduction in your carbon offset fund equivalent to the CO^2 consumed during your trip, reducing the amount emission reductions you will make."

Before beginning the task, participants are shown an example of the choice display and the resulting waiting display. In the example, the DIFT is chosen and consumes $0.02 of the carbon offset fund, equivalent to about 4 pounds of CO^2. The participant waits for ten seconds. They then begin with the full task. The task takes approximately 30-50 minutes, depending on which transportation options the participant chooses. Stills from the task can be found in Appendix B.

2.2.3 Adapted PEBT pilot testing

The adapted PEBT was piloted twice to ensure the adapted measure was performing similarly to the original measure by Lange et al. (2018). The first pilot was run with a sample of ten participants recruited through Amazon's Mechanical Turk and participants were paid $5.50. The second pilot consisted of 25 undergraduate students recruited through an introductory psychology course at Oberlin College and participants were compensated with course credit. All participants signed a consent document and were informed that they may quit the study at any time without deduction from their compensation. I used Turk's exclusion capabilities to ensure that participants lived in the US and were 18 years old or older and participants in the undergraduate sample had to affirm they were 18 years or older to take the study.

Participants first completed the Systems Thinking Scale (α=.89 for MTurk sample; α=.86 for undergraduate) (Thibodeau et al., 2016) and the Environmental Attitudes scale (Milfont & Duckitt, 2010) to obtain a baseline for these measures. They then took the full adapted PEBT described in the section above. Participants were then asked to provide demographic information (age, education, ethnicity, gender, income, political party, political orientation, and belief in climate change). At the end of the study, participants were debriefed about the intentions of the study and given an opportunity to leave feedback.

Consistent with the original study, I expected that participants would choose the environmental option more for the trials with greater environmental costs (deduction from carbon offset fund) and that participants would choose the environmental option less for the trials with greater personal costs (wait time). Additionally, I expected that the total number of environmentally friendly choices would correlate with participants baseline systems thinking and environmental attitudes scores.

2.2.4 Adapted PEBT pilot testing results

A one-way repeated measures ANOVA with the within-subject factor of environmental cost (deduction from carbon offset fund) was run to determine if there was a significant effect of environmental cost on the number of environmentally friendly choices. The magnitude of the environmental cost marginally affected the number of environmentally friendly choices in the MTurk sample, $F(2, 19) = 3.26$, $p = .061$, but did not for the undergraduate sample, $F(1.57, 37.71) = 2.08$, $p = .148$. Consistent with our expectations, participants across both pilots chose the environmental option more often for the trials with greater environmental costs. See *Table 1*. Another repeated measures ANOVA with the within-subject factor of personal cost (wait time) was run to determine if there was a significant effect of personal cost on the number of environmentally friendly choices. The magnitude of the personal cost significantly affected the number of environmentally choices in the MTurk sample, $F(1.79, 19.95) = 5.64$, $p = .015$, and for the undergraduate sample, $F(1.95, 46.99) =16.00$, $p < .005$. Consistent with our expectations, participants across both pilots chose the environmental option less often for the trials with a greater personal cost. See *Table 2.*

Table 1 Environmental choices by environmental cost

	Number of environmental choices	
	MTurk sample	Undergraduate sample
Environmental cost	*M (SD)*	*M (SD)*
Small deduction (out of 24 trials)	15.36 (6.544)	17.92 (6.60)
Medium deduction (out of 24 trials)	16.68 (7.12)	18.48 (6.30)
Large deduction (out of 24 trials)	18.18 (6.92)	19.62 (6.18)
Overall (out of 72 trials)	50.80 (19.72)	55.56 (18.36)

Table 2 Environmental choices by personal cost

	Number of environmental choices	
	MTurk sample	Undergraduate sample
Personal cost	*M (SD)*	*M (SD)*
0 second delay (out of 12 trials)	10.36 (3.35)	10.72 (3.44)
5 second delay (out of 12 trials)	z10.36 (3.41)	10.80 (3.22)
10 second delay (out of 12 trials)	9.18 (4.02)	10.24 (3.67)
15 second delay (out of 12 trials)	7.71 (4.43)	9.20 (3.82)
20 second delay (out of 12 trials)	6.45 (4.78)	7.92 (4.11)

30 second delay (out of 12 trials)	5.82 (5.23)	6.00 (4.76)

Pearson correlation coefficients were calculated to assess the associations between the overall number of environmentally friendly choices and systems thinking and environmental attitudes. Consistent with our expectations, there was a significant positive correlation between the number of environmental choices and systems thinking in the MTurk sample, $r = .69$, $p < .001$, and the undergraduate sample, $r = .68$, $p < .001$, but no significant correlation was found with environmental attitudes in either the MTurk samples $r = .10$, $p = .765$, or the undergraduate sample, $r = .17$, $p = .424$, though directionality suggests that those higher in systems thinking were higher in pro-environmental attitudes.

2.2.5 Manipulation pilot testing

All stimulus videos were pilot tested prior to the full study. 96 participants were recruited through Amazon's Mechanical Turk and paid $2.00. All participants signed a consent document and were informed that they may quit the study at any time without deduction from their compensation. I used Turk's exclusion capabilities to ensure that participants lived in the US and were 18 years old or older.

Participants were randomly assigned to one of the four videos which they watched after signing the consent document. After watching the video, participants were asked to write what system/process (depending on condition) they had just learned about and what elements it consists of, to check for attention. They then took a shortened version of the PEBT, which only consisted of six trials. Participants completed the trials and then completed various measures relating to the key aspect of systems thinking that have shown responsivity to manipulations of systems thinking in previous studies: a task assessing holistic thinking by asking participants to select relevant information in a story about a crime committed, with those higher in holistic thinking selecting more pieces of information (Choi, Koo, & Choi, 2007); an environmental ripple effect task to assess sensitivity to indirect consequences and causal chains (Maddux et al., 2006); and a picture mapping task assessing relational reasoning by asking participants to identify relational matches in pairs of illustrated scenes (Vendetti, Wu, & Holyoak, 2014). Participants then completed the Systems Thinking Scale (α=.87) (Thibodeau et al., 2016) and answered a series of demographic questions (age, education, ethnicity, gender, income, political party, political orientation, and belief in climate change). After completion of the survey, participants were debriefed about the intentions of the study.

I expected that learning about systems thinking and learning about an environmental phenomenon would each independently increase participants' scores on the measures relating to the key aspect of systems thinking. As such the participants in the environmental system condition would score the highest in each of the measures relating to the key aspect of systems thinking, followed (equally) by the non-environmental system and environmental-system conditions, with the non-environmental non-system condition scoring the lowest.

2.2.6 Manipulation pilot testing results

This sample included a roughly equal number of males (56.7%) and females. The average age of participants was 37.50 ($SD = 10.78$) and 77.8% identified as white. Most (81.2%) had completed at least some college. The political affiliation of participants was skewed liberal, with 50.0%, 30.2% and 18.8% identifying as Democrat, Independent, and Republican, respectively.

Four participants were excluded due to failing the attention check questions, leaving 92 participants included in the data analysis. A Pearson chi-square test for independence was run to determine if there was an association between conditions (environmental vs. non-environmental; system vs. non-system) and failing the attention check. There was no difference in how many people failed the attention check by environmental condition, $\chi(1) = .00$, $p = 1.00$, or by system condition, $\chi(1) = 4.17$, $p = .117$.

Overall, participants tended to behave fairly pro-environmentally on the PEBT, with a notable positive skew towards choosing the pro-environmental option (SEST) for most trials (Shapiro-Wilk tests significant at the $p < .001$ level). The average time the SEST was chosen across 6 trials was 4.49 times ($SD = 1.70$). The PEBT total was transformed by taking the square root to correct for this.

A 2 (system: system vs non-system) x 2 (domain: environment vs pain) ANCOVA controlling for systems thinking was run to examine the effect of domain and system on the PEBT. There was no significant interaction between the effects of domain and system on the PEBT, $F(4, 87) = .00$, $p = .998$. The main effects showed no differences between environmental and non-environmental ($p = .353$)—though the direction of the means suggested that participants in the environmental condition chose the environmentally friendly more often, and no differences between system and non-system ($p = .851$). See *Figure 1.*

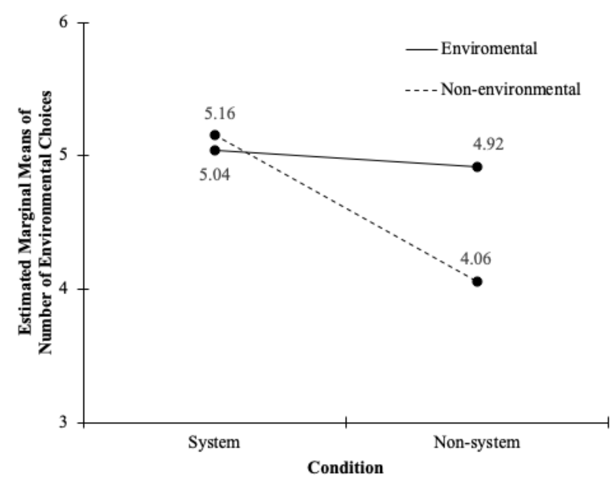

Figure 1 Estimated Marginal Means of Number of Environmental Choices by Condition

A 2 x 2 ANCOVA controlling for systems thinking was run to examine the effect of system and domain on the murder task assessing holistic thinking. There was no significant interaction between the effects of domain and system on holistic thinking, $F(1, 87) = .13$, $p = .716$. The main effects showed no differences between environmental and non-environmental ($p = .851$), and no differences between system and non-system ($p = .853$), though the direction of the means suggested that participants in the system condition were higher in holistic thinking. See *Figure 2.*

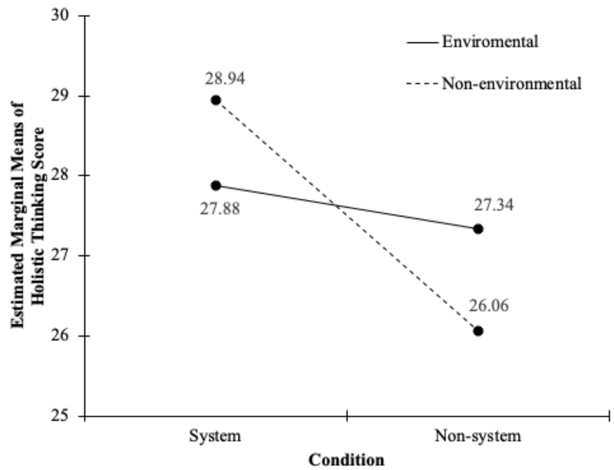

Figure 2 Estimated Marginal Means of Holistic Thinking by Condition

A 2 x 2 ANCOVA controlling for systems thinking was run to examine the effect of system and domain on the ripple task assessing sensitivity to indirect consequences and causal chains. There was a significant interaction between the effects of domain and system on sensitivity, F (1,87) = 4.07, p = .047. The main effects showed no differences between environmental and non-environmental (p = .559), and system was significantly higher in sensitivity to indirect consequences than non-system (p = .004). See *Figure 3.*

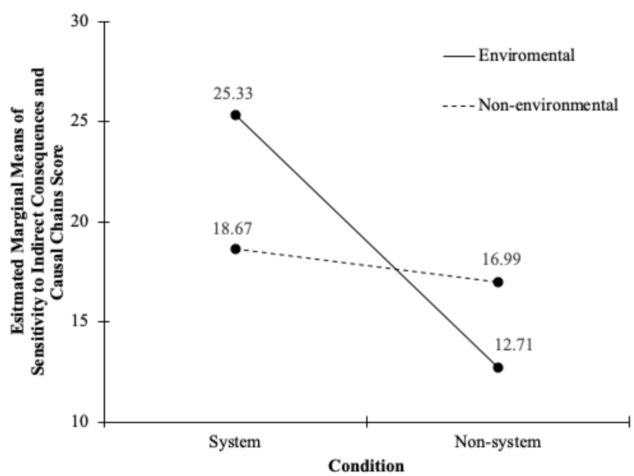

Figure 3 Estimated Marginal Means of Sensitivity to Indirect Consequences and Causal Chains by Condition

A 2 x 2 ANCOVA controlling for systems thinking was run to examine the effect of system and domain on the picture mapping task assessing relational reasoning. There was no significant interaction between the effects of domain and system on relational reasoning, F (4, 87) = .00, p = .993. The main effects showed no differences between environmental and non-environmental (p = .469)—though the direction of the means suggested that participants in the environmental condition demonstrated more relational reasoning—and no significant differences were found between system and non-system (p = .598). See *Figure 4*.

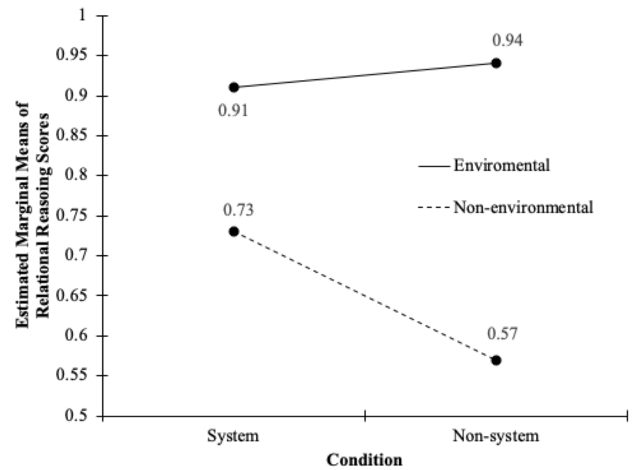

Figure 4 Estimated Marginal Means of Relational Reasoning by Condition

Though few statistically significant results were found in the pilot study (likely due to the small sample size and the small number of PEBT trials run), the direction of means provided some support that the learning about systems thinking and learning about an environmental phenomena would each independently increase participants scores on the measures relating to the key aspect of systems thinking. Notably, the ripple task provided significant evidence that the stimulus videos were manipulating participants' sensitivity to indirect consequences. Participants in the system condition overall scored higher in sensitivity than participants in the non-system condition. Further, it seems as if learning about the environment in a non-systemic way reduced sensitivity (using the non-system non-environmental condition as a baseline), perhaps suggesting that thinking about the environment in such a disconnected and unsystemic way leads people to disregard the way the environment is affected by indirect consequences.

2.2.7 Main experiment

The study was administered using the Qualtrics survey platform. 400 participants were recruited through Amazon's Mechanical Turk and paid $5.50. All participants signed a consent document and were informed that they may quit the study at any time without deduction from their compensation. I used Turk's exclusion capabilities to ensure that participants lived in the US and were 18 years old or older. Participants who did not meet these requirements were excluded from participation and were not compensated for their time.

Participants first completed the Systems Thinking Scale (Thibodeau et al., 2016) to assess baseline systems thinking (α=.81). They then proceeded to the learning video, to which they were randomly assigned to one of the four videos for a between-subjects design. The video was three minutes in length and participants were not able to proceed to the rest of the survey for the duration of that time. They were additionally instructed to pay close attention to the video and told they would be asked questions about it later. After watching the learning video, participants were asked to write what system/process (depending on condition) they had just learned about and what elements it consists of, to check for attention.

Participants then read the instructions for the PEBT, watched an example trial, and completed the task. The task consisted of 72 randomized trials, split up between three blocks. After the PEBT, demographic questions (age, education, ethnicity, gender, income, political party, political orientation, and belief in climate change) were presented. After the survey participants were debriefed about the intentions of the study and thanked for their participation.

3. RESULTS

Examination of the attention check revealed a total of 42 participants whose answers indicated they hadn't watched or paid attention to the learning video. Those participants were excluded from further analysis; leaving 78 participants in the environmental system group, 79 in the environmental non-system group, 95 in the non-environmental system group, and 90 in the non-environmental non-system group. A Pearson chi-square test for independence was run to determine if there was an association between conditions (environmental vs. non-environmental; system vs. non-system) and failing the attention check. There was a significant difference between groups in how many people failed the attention check, $\chi(1) = 4.24$, $p = .039$, with more attention check failures in the environmental system condition than the other three conditions. Re-examining the answers to the attention check questions did not reveal any notable differences in why participants were marked as inattentive.

A 2 (condition: system vs non-system) x 2 (domain: environment vs pain) ANOVA of baseline systems thinking was run to determine if there were pre-existing differences in systems thinking between groups. There was no statistically significant interaction between the system and domain conditions on pre-test systems thinking, $F(3, 338) = .43$, $p = .730$. The main effects showed no significant differences between the environmental conditions ($p = .759$) and no significant differences between the system conditions ($p = .314$). The average systems thinking score was 5.37 (SD = .71) out of 7 points.

Totals for all trials of the PEBT and each block of the PEBT were calculated. For each trial, choosing the SEST (more environmentally responsible option) was coded as 1, choosing the DIFT (less environmentally responsible option) was coded as 0; thus higher totals indicate more environmentally friendly choices. For the small consequence block, participants chose the environmentally friendly option 59.4% of the time, 64.8% for the medium block, and 70.2% for the large block. This increase in the selection of the SEST as the environmental consequence for the trial increases indicates this adapted version of the PEBT functions similarly to the original PEBT tested by Lange et al. (2018), as was additionally confirmed by earlier pilot testing. Overall participants chose the SEST 65.8% of the time. Descriptives also revealed that this data was strongly skewed in the positive direction (Shapiro-Wilk tests significant at the $p < .001$ level), due to 62 out of 358 participants who chose the environmentally friendly option for all 72 trials.

A Pearson chi-square test for independence was run to determine if there was an association between conditions (environmental vs. non-environmental; system vs. non-system) and choosing the environmental option every time. There was no significant difference between groups in how many people chose the environmentally friendly option for all 72 trials, $\chi(1) = .06$, $p = .792$. Due to the large cell size of this study, the PEBT total variable was left un-transformed for ease of interpretation and the participants who chose the environment option every time were not dropped since this behavior did not differ across condition. Further, transforming this variable or dropping the aforementioned participants did not notably change the results of later analysis.

Next, a Pearson correlation matrix of the PEBT total with our a-priori potential covariates—systems thinking scale, belief in climate change, and political orientation—was run to determine which variables to include as covariates in the following analyses. Results indicated that PEBT total was significantly positively correlated with systems thinking ($r(341) = .23$, $p < .001$), political orientation ($r(341) = -.189$, $p < .001$), and belief in climate change ($r(341) = .21$, $p < .001$). All these variables were initially included in the following analysis as covariates, but political orientation was not significant in the analysis and was thus removed.

To test whether there was a difference in the number of pro-environmental choices by condition, a 2 (system: system vs non-system) x 2 (domain: environment vs pain) ANCOVA controlling for systems thinking and belief in climate change was run. See Table 3. There was no statistically significant interaction between the effects of domain and system on the number of pro-environmental choices, $p = .735$. The main effects showed a marginally significant difference between the environmental conditions ($p = .094$), with those in the environmental conditions choosing the pro-environmental choice more often than those in the non-environmental conditions. There was no significant difference between the system conditions ($p = .309$). See Figure 1 for the estimated marginal means.

Table 3 ANCOVA of number of pro-environmental choices by condition controlling for baseline systems thinking and belief in climate change

Predictor	Sum of Squares	*df*	Mean Square	*F*	*p*
(Intercept)	536.572				
System	418.124	1	418.124	1.040	.309
Domain	1136.123	1	1136.123	2.826	.094*
System * Domain	46.210	1	46.210	.115	.735
Systems Thinking	3236.433	1	3236.433	8.051	.005***
Belief in Climate Change	1720.349	1	1720.349	4.279	.039**
Error	135072.459	336	402.001		

* p < .1 ** p < .05 *** p < .01

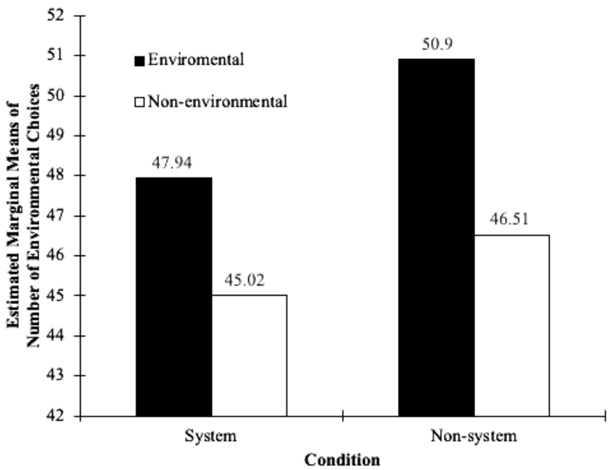

Figure 1 Estimated marginal means of the number of pro-environmental choices by conditions

To determine if lack of significance was due to participants becoming fatigued from the length of the task and making less meaningful decisions as time passed, the 2 x 2 ANCOVA was run again with only the first block for each participant (which varied the between small, medium, and large environmental consequence blocks due to the randomization of the task). No meaningful differences from the initial analysis were found when the data from the two latter blocks were excluded.

3.1 DISCUSSION

Many researchers believe that through promoting systems thinking, people may be more likely to engage in environmentally responsible behavior. Such an application, if effective, could be a critical tool in efforts to mitigate the effects of global climate change and other ecological crises. The current study is the first to experimentally test a causal link between learning systems thinking and actual pro-environmental behavior.

Based on previous research and theoretical work, I predicted that learning about systems thinking and learning about an environmental phenomenon would each independently increase participants' number of pro-environmental behavior choices. However, results from this study only found the domain of the learning task to have an effect on the number of pro-environmental choices, with participants who learned about an environmental phenomenon making marginally more pro-environmental choices than those who learned about a non-environmental phenomenon, as hypothesized and as demonstrated by previous research (Arendt & Matthes, 2016). No effect was found for whether participants learned about systems thinking and no interaction effect was found.

The lack of significant differences between the system vs. non-system conditions may reflect inadequacy of the manipulation stimuli developed for this study to significantly influence one's systems thinking, despite pilot testing results demonstrating some small effects of the videos on measures related to systems thinking. First, the participants only had one learning opportunity and the videos were only three minutes in length. The may have not been long enough to impact one's understanding of systems, though past studies have shown malleability in measures related to systems thinking from brief interventions (Thibodeau et al., 2015). In a study by Ben-Zvi Assara and Orion, elementary school students were taught about systems through a course curriculum that consisted of 30 hours of activities (2010) and another study by Hung aimed to teach systems thinking to undergraduate students with a semester-long course (2008). Future studies may require a longer time frame for learning, allowing for more instruction time with the content.

Additionally, the creation of the manipulation stimuli was based on the limited number of previous works that examined methods for teaching systems thinking in the literature, many of which are theoretical in nature. As such, the approaches used in this study may have not been effective strategies. Future studies may need to explore and employ different methods to teach systems thinking.

The significant difference in the number of participants failing the attention check by condition, with more participants failing the attention check for the environmental system condition, may also point toward issues with the manipulation. Previous studies have demonstrated aversion and resistance by conservatives to environmental messaging (Hoffarth & Hodson, 2016; Bail et al., 2018; Zhou, 2016). Participants who lean more conservative may have been more reluctant to watch a video that discussed an environmental issue, though no political stance was promoted in the video. I considered the possibility that aversion to environmental messaging might have led to some participants to intentionally submit incorrect and combative answers; however reexamination of open-ended question answers did not support this explanation. Additionally, I ran post-hoc chi-square test of independence to determine if there was a difference in failing the attention check by political party or political orientation. There was no significant difference found by political party, $\chi(4) = 1.45$, $p = .834$, or for political orientation, $\chi(6) = 10.32$, $p = .112$. Another explanation could be that there was some aspect of the environmental system video that was harder to follow than the other videos. For example; learning about wastewater treatment might have come off as more complicated than learning about pain. Pain is a phenomenon that most people have some level of familiarity with, while wastewater treatment may be an entirely new phenomenon to some participants. However, these explanations do not address why significantly more participants in the environmental system condition failed the attention check but not participants in the environmental non-system condition.

Despite a lack of support for my hypothesis, the present study builds on a recent empirical effort to explore the utility of systems thinking in promoting environmentally responsible behavior (Lezak, 2016; Davis, 2016; Kunsch, Theys, & Brans, 2007; Sweeney et al., 2011) and contributes to the body of theoretical and empirical work that seeks to develop a better understanding of how systems thinking can be taught (Thibodeau et al., 2015; Roberts 1978; Petersen, Frantz, Tincknell, & Canning, 2018; Ben-Zvi Assaraf et al, 2010). Future researchers can draw on the methodology of the present study and address its limitations in their own studies. Additionally, this study involved the creation and validation of a pro-environmental behavior task adapted for use in online studies. This assists in addressing the limitations of self-report measures, which were used in 80% of studies of environmentally responsible behavior in the Journal of Environmental Psychology from 2015-2016 (Lange et al., 2018). Enabling the assessment of actual pro-environmental behavior with online samples allows one to obtain actual behavior of participants almost as conveniently as self report measures. This measurement tool can be easily employed in future studies assessing pro-environmental behavior either with lab or online samples.

4. CONCLUSIONS

With the growing threat of anthropocentric climate change, failure to effectively operate our economic, social and biophysical systems will have enormous costs to all life on earth. As such, many researchers have proposed that through promoting systems thinking, people may be more likely to engage in environmentally responsible behavior. While this study failed to find a causal link between learning systems thinking and pro-environmental behavior, past correlational studies of systems thinking and environmentally responsible behavior and attitudes suggest that such a relationship may exist. Further studies should be carried out to test for this relationship as well as to determine how to most effectively teach a systems thinking mindset.

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