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The mind is an ecosystem

Systemic metaphors promote systems thinking

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Is income inequality more of a *blemish* or a *failing organ* in our economy? Both metaphors capture something about wealth disparities, but only *failing organ* seems to emphasize the fact that our economy is a complex system, where activity in one region may lead to a cascade of problems in other parts of the system. In the present study, we introduce a novel method for classifying such 'systemic' metaphors, which reveals that people can reliably identify the extent to which a metaphor highlights the complex causal structure of a target domain. In a second experiment, we asked whether exposing people to more systemic metaphors would induce a systems-thinking mindset and influence reasoning on a seemingly unrelated task that measured the degree to which people reasoned about a domain in terms of complex causal relations. We found that participants who were primed with systemic metaphors scored higher on subsequent tasks that measured relational and holistic thinking, supporting the view that these metaphors can promote systems thinking. Our discussion highlights the potential role of systemic metaphors in facilitating reasoning and decision-making in complex domains.

Keywords: systems thinking, metaphor, analogy, intervention, framing, decision-making

1. Introduction

The greatest challenges humans currently face — climate change, poverty, viral epidemics, financial meltdowns — involve enormously complex physical and social systems. To facilitate effective decision making in these critical areas, scholars from diverse fields have emphasized a need to promote a 'systems thinking' mindset among policy experts and the lay public (e.g., Checkland, 1972; Davis & Stroink, 2015; Maani & Maharaj, 2004; Richmond, 1993; Rozenblit & Keil, 2002).

Metaphor and the Social World 6:2 (2016), **225–242.** DOI 10.1075/msw.6.2.03thi
ISSN 2210–4070 / E-ISSN 2210–4097

There are four core components of 'systems thinking'. First, it requires people to move away from 'reductionist' modes of inquiry (explaining a system in terms of the behavior of individual components) and towards 'holistic' modes of thinking (explaining a system in terms of the dynamic interrelationships between constituent elements; Richmond, 1993). Second, it requires a broader conception of causality, because outcomes in systems are determined by a complex set of frequently non-linear, direct and indirect causes (Capra, 1985). Third, it requires an appreciation that systems are in constant, but patterned, flux (Sweeny & Sterman, 2007). And fourth, when appropriate (as in the case of the global climate), the systems thinker must recognize the self as an active participant in the system — an element in the complex chain of causality (Maani & Maharaj, 2004; Richmond, 1993). Here, we offer theoretical and empirical support for the claim that linguistic metaphors can be categorized as more or less 'systemic', and for the prospect of designing metaphor-based interventions to promote systems thinking.

Metaphors are powerful social and cognitive tools for conceptual and behavioral change (Dweck, 2006; Hauser & Schwarz, 2014; Lakoff & Johnson, 1980; Landau, Sullivan, & Greenberg, 2009; Thibodeau & Boroditsky, 2011, 2013). Hauser and Schwarz (2014), for instance, found that describing cancer using war metaphors, as an *enemy* that must be *fought*, increased general support for cancer research but decreased individual propensities to engage in healthy preventative behaviors. Dweck (2006) has similarly shown that metaphor-based interventions can fundamentally change children's epistemic beliefs. By comparing the brain to a muscle, she and her colleagues induced a *growth* mindset for intelligence, which led students to engage more deeply and deliberately in their coursework.

Metaphors influence our thought most strongly in areas where direct experiential or perceptual knowledge is limited, as is the case with complex systems. Many scholars have argued that the concept of time, for instance, requires metaphoric thinking — a reliance on our conception of space — because we cannot experience time in a direct and tangible way (e.g., Boroditsky, Fuhrman, & McCormick, 2010; Clark, 1973; Traugott, 1978). Although people have some direct experience with complex physical and social systems like the environment and the economy, the full scope and dynamics of systems cannot be experienced all at once and are difficult to conceptualize on their own. Indeed, the sophisticated models that researchers develop and use to reason about systems like the economy, chemical compounds, and the brain can themselves be thought of as metaphors for the real world phenomena they represent (Brown, 2003; Flusberg, Thibodeau, Sternberg, & Glick, 2010).

Implicit in several findings on the role of metaphor in reasoning is an appeal to a distinct class of *systemic* metaphors that invite people to build a richer, more nuanced representation of the target domain that includes multiple causal entailments. Consider the complex social issue of crime. Thibodeau and Boroditsky (2011, 2013, 2015) found that describing crime as a *beast* led people to support relatively direct crime-fighting measures like hiring more police officers. Framing crime as a *virus*, on the other hand, led to support for more reform-based measures like increasing education and investigating the origins of crime in the community.[1] One way of characterizing the difference between the *virus* and *beast* metaphors for crime is that the *virus* metaphor leads people to build a deeper causal structure of the problem — by situating the crime problem in a larger body of the community — so people think more about the root causes of crime and try to address them. People do not typically address literal viral epidemics simply by attacking the virus, but rather by encouraging community-wide reform measures like containment, education about hygiene, and social network analysis to identify the source of the issue. The *beast* frame, on the other hand, identifies a singular agent (the beast) as the cause of the crime problem. On this metaphor, simply catching, caging, or killing the beast (e.g., by hiring more police officers or sentencing criminals to longer prison sentences) seems to be sufficient for reducing crime. In other words, the *virus* metaphor is more 'systemic' because it activates a mental model of the crime scenario that highlights the complex web of causal relations between elements in the domain rather than isolating a singular causal factor (describing the brain as a <u>muscle</u> or cancer as an <u>enemy in a war</u> may similarly lead people to instantiate relatively systemic mental models of intelligence and cancer, respectively (Dweck, 2006; Hauser & Schwarz, 2014).

Of course, people may also have systemic associations with a concept of a beast (e.g., that any organism is part of a larger ecosystem). Therefore, in the present study we developed novel pairs of metaphors for social issues that seem to differ even more clearly in the degree to which they highlight systemic relationships. We then empirically assess whether this intuitive *systemic* distinction can be reliably operationalized and measured by naïve observers, and whether being exposed to systemic metaphors really promotes thinking about domains in terms of deeper networks of causal relations (i.e. systems thinking).

We first describe a method for identifying the degree to which metaphors are systemic, since this is better thought of as a continuous dimension rather than a categorical classification scheme (Experiment 1). This dimension is similar to a distinction that is commonly made in the analogy literature between 'relational' (e.g., "The atom is like the solar system") and 'attributional' (e.g., "The sun is like an orange") comparisons (Gentner, 1983; Lakoff, 2002; Wolff & Gentner, 2011). Relational analogies and metaphors highlight complex structural correspondences

1. See Steen, Reijnierse, & Burgers (2014) and Thibodeau & Boroditsky (2015) for an extended discussion of this set of findings and what factors moderate participant responses.

(e.g., a national park is the *backbone* of the park system because it provides support and structure to the whole system, without which the system would not function properly) whereas attributional analogies and metaphors focus on relatively superficial, feature-level similarity between domains (e.g., a national park is the *pearl* of the park system since it is particularly beautiful).

In a second experiment, we exposed participants to more or less systemic metaphors (based on the results of Experiment 1) before they completed a set of tasks that have been used to measure holistic (Maddux & Yuki, 2006) and relational (Rottman, Gentner, & Goldwater, 2012) reasoning. Holistic thinking and relational thinking both share marked similarities with systems thinking — these constructs have received more attention in the psychological literature and have overlap to some degree with systems thinking.

Holistic thinking is a focus of cross-cultural work in psychology and shares commonalities with each of the components of systems thinking discussed above. Like systems thinkers, holistic thinkers are more likely to attend to an entire visual or conceptual field (i.e., the whole), rather than focal sub-components. Holistic thinkers are also more likely to endorse an interactionist, rather than a dispositional, view of causality when thinking about social systems, and to see change as constant and cyclical (Choi, Koo, & Choi, 2007; Masuda & Nisbett, 2006; Nisbett, Peng, Choi, & Norenzayan, 2001). For instance, holistic thinkers are more likely to see how the effects of one action (e.g., laying off employees) can ripple into other areas of society (e.g., lead to an increase in crime (see, e.g., Choi, Dalal, Kim-Prieto, & Park, 2003; Maddux & Yuki, 2006).

Relational thinking, which is a focus of work on problem solving and analogical reasoning (Gentner, 1983; Gick & Holyoak, 1980; Rottman, Gentner, & Goldwater, 2012), also shares important commonalities with systems thinking. Relational thinking, like holistic and systems thinking, requires that people recognize the totality of a system and focus on relationships between elements rather than surface features of the system (Vendetti, Wu, & Holyoak, 2014). For instance, although the sun is superficially very different from the nucleus of an atom (they differ in almost every perceptible way — e.g., size, weight, temperature, color), Rutherford (1911) speculated that they may serve similar functions in their respective environments (i.e., both are relatively high in mass and, as a result, may cause other objects — planets and electrons — to orbit around them); this is a relational analogy that led to a profound breakthrough in physics and chemistry.

Importantly, these constructs also differ from systems thinking: for instance, whereas cross-cultural research on holistic thinking identifies a dichotomy between holistic and analytic thinking (Choi, Koo, & Choi, 2007), such a distinction may not be relevant to systems thinking. Further, while both of these constructs (holistic and relational thinking) capture important properties of systems thinking, it would be premature and perhaps too simplistic to jump to the conclusion that holistic or relational thinkers automatically engage in systems thinking or make better systems-level decisions than less-holistic or less-relational thinkers. For these reasons, we have identified a particular set of tasks from prior work on holistic and relational reasoning that seem to be most consistent with the proposed distinction between more and less systemic metaphors. However, investigating the conceptual differences between these constructs will be an important step for future research.

We predicted that exposing people to systemic metaphors would help induce a systems thinking mindset that would transfer to seemingly unrelated tasks, thus leading to enhanced performance on established measures of holistic and relational reasoning. This would suggest that framing a complex social issue like climate change or a financial crisis using systemic metaphors might help promote the sort of systems-thinking approach better suited to effectively reason about these domains.

2. Experiment 1: Operationalizing metaphor systemicness

2.1 Methods

2.1.1 *Participants*

We recruited and paid 600 participants through Amazon's Mechanical Turk, using the website's exclusion capabilities to ensure that participants lived in the US and had a good performance record on previous tasks. At the end of the survey, participants were given a random completion code; data from 18 participants were excluded because they did not provide an accurate code, leaving data from 582 participants for analysis.

This sample included an equal number of males (50%) and females. The average age of participants was 32.8 yr (*sd* = 11.46). Most (84%) had completed at least some college. The political affiliation of participants was skewed liberal, with 43%, 43% and 14% identifying as Democrat, Independent, and Republican, respectively.

2.1.2 *Materials & Procedure*

We created three pairs of metaphors in which one was thought to be more systemic than the other (based on author intuitions and prior research, as detailed above). Each pair was used to frame one of three important socio-political domains: crime, education, and the economy.

To control for the valence, arousal, and additional linguistic associations of the metaphors, each pair of metaphors was developed from the same source domain.

For instance, the two metaphors that were used to describe the economy both represented the financial system as a body. One, however, focused on a relatively superficial and isolated feature of a body by comparing income inequality to a *blemish*. The other highlighted the body as a holistic system by comparing income inequality to a *failing organ*. Body-related metaphors were also used to describe crime: the more systemic frame compared crime to a *virus*; the less systemic frame compared crime to a *broken bone*. Plant metaphors were used to describe the educational system: the more systemic frame compared education to a *garden*, while the less systemic frame compared education to a *flower*.

Participants were randomly assigned to one of six between-subjects conditions, where they had to make a set of judgments about one of the six metaphors from one of the three domains (a *failing organ* or *blemish* frame for income inequality; a *virus* or *broken bone* frame for crime; a *garden* or *flower* frame for the educational system).

Interpretations

First, participants were presented with one of the six metaphors and were asked to provide an interpretation. For instance, "How is income inequality like a failing organ?"

These data were analyzed in two ways. First, we used the Linguistic Inquiry and Word Count software (LIWC; Pennebaker, Chung, Ireland, Gonzales, & Booth, 2007) to count the number of words generated in the explanations. We predicted that people would write longer interpretations for the metaphors that we considered relatively systemic.

The second way in which the qualitative data were analyzed was by coding them along a dimension of systemic-ness. Two independent coders were instructed to rate the extent to which "each of the responses seems to exhibit systems thinking" on a scale from 1, "low in systems thinking," to 5, "high in systems thinking." Coders were familiar with the concepts of systems thinking and were told to look, in particular, for evidence of 'complex causality' and 'embeddedness' in the explanations. Inter-rater reliability on the coding scheme was acceptable ($ICC = .701$) and disagreements were resolved by averaging ratings.[2]

Rating

Next, participants were asked to rate the metaphor using an adapted version of Davis and Stroink's (2015) Systems Thinking Scale. There were six items on this scale that required people to rate the extent to which, for instance, talking about income inequality as a failing organ captures the idea that…

2. The results were nearly identical for separate analyses conducted with ratings from one or the other coder.

1. …everything in the universe is somehow related to each other.
2. …nothing is unrelated.
3. …everything in the world is intertwined in a causal relationship.
4. …even a small change in any element of the universe can have significant consequences.
5. …any phenomenon has numerous causes, although some of the causes are not known.
6. …any phenomenon entails numerous consequences, although some of them may not be known.

Participants indicated their response using a five-point Likert scale that ranged from, 1, "Strongly Disagree", to 5, "Strongly Agree".

Comparison
For the first two tasks, participants only saw one metaphor for a given issue. In the third task, they were presented with both metaphors for that issue at the same time (e.g., income inequality can be described as a *blemish* or a *failing organ*). They were then asked to make five judgments about the pair of metaphors:

1. Which seems to situate the issue in broader context?
2. Which seems to make the issue seem more complex?
3. Which seems to make the issue seem more simple?
4. Which seems to make the issue seem more involved — something you can really influence and change?
5. Which do you find more appropriate?

After completing these three tasks, participants completed the standard version of Davis and Stroink's (2015) Systems Thinking Scale, a 15-item questionnaire designed to measure "the tendency to perceive and understand relevant phenomena as emergent from complex, dynamic, and nested systems." It should be noted that an adapted version of the scale was used to characterize the metaphors themselves as more or less systemic; the standard version of the scale was used to characterize the degree to which participants tended to engage in systems thinking in general. Participants were then asked a set of background demographics questions including their age, gender, first language, educational background, geographic location, and political affiliation.

2.2 Results and discussion

2.2.1 *Metaphor interpretations*
To test whether interpretations of the metaphors differed by metaphor type, we first analyzed the number of words generated by participants in their interpretation.

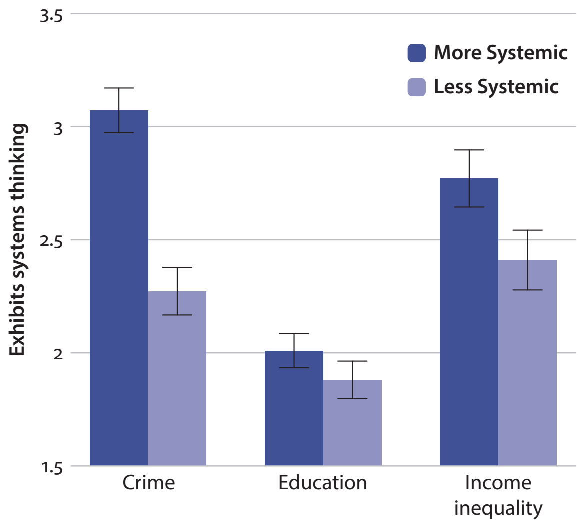

Figure 1. Mean level of systems thinking exhibited in interpretations by metaphor type and domain. Error bars denote standard errors of the means.

We fitted a two-way between-subjects ANCOVA with tests for metaphor type (systemic or not) and systems thinking on word count; issue was treated as a random effect in the model. As predicted, we found that people who were higher in systems thinking wrote more, $F[1, 576] = 9.008$, $p = .003$ ($r[580] = .126$, $p = .002$). We also found an interaction between systems thinking and metaphor type, $F[1, 576] = 4.405$, $p = .036$. People who were high in systems thinking wrote longer responses regardless of metaphor type, but people who were lower in systems thinking wrote more in response to systemic metaphors ($M = 27.33$, $SD = 23.51$) than non-systemic metaphors ($M = 25.74$, $SD = 25.21$).

We used a similar ANCOVA to predict the coded ratings of how systemic the interpretations were. We found that participants high in systems thinking gave more systemic interpretations, $F[1, 576] = 10.405$, $p < .001$, and that interpretations of systemic metaphors were rated as more systemic ($M = 2.62$, $SD = 1.12$) than non-systemic metaphors ($M = 2.18$, $SD = 1.03$), $F[1, 576] = 26.658$, $p < .001$ (see Figure 1). In this case, there was no interaction between systems thinking and metaphor type, $F[1, 576] = .026$, $p = .872$.

2.2.2 *Ratings of systemicness*

A two-way between-subjects ANCOVA revealed similar results for participants' ratings of the degree to which the metaphors exhibited systems thinking. Crucially, the metaphors we regarded as more systemic were rated as more systemic ($M = 3.50$, $SD = .81$) than metaphors we regarded as less systemic ($M = 3.34$, *SD* = .82), $F[1, 576] = 5.090$, $p = .024$. In addition, people who were higher in systems thinking considered the metaphors more systemic overall, $F[1, 576] = 15.300$, $p < .001$ ($r[580] = .160$, $p < .001$); there were no interactions between systems thinking and metaphor type, $F[1, 574] = 1.638$, $p = .201$.

2.2.3 *Metaphor comparison*

Finally, participants viewed the systemic metaphors as situating the target problems in a broader context, $\chi^2[1] = 208.08$, $p < .001$, as more complex, $\chi^2[1] = 220.21$, $p < .001$, and as less simple $\chi^2[1] = 163.00$, $p < .001$. They also thought that the systemic metaphors made the target problems seem more involved but tractable, $\chi^2[1] = 43.99$, $p < .001$, and were more appropriate for the target issue, $\chi^2[1] = 165.12$, $p < .001$ (see Table 1).

Table 1. Proportions of participants who judged the systemic metaphor as a better answer to the five comparison questions.

	Context	**Complex**	**Simple**	**Involved**	**Appropriate**
Crime (n = 210)	0.890	0.771	0.271	0.562	0.848
Education (n = 198)	0.879	0.753	0.293	0.768	0.823
Economy (n = 174)	0.598	0.914	0.126	0.580	0.603

The results of Experiment 1 suggest that metaphors can be quantified in terms of the degree to which they highlight the systemic nature of a given domain. As predicted, people wrote more (and wrote more systemically) in response to systemic metaphors, rated them as more systemic, and viewed them as more systemic in a comparison task.

3. Experiment 2: Does reading systemic metaphors induce a systems-thinking mindset?

In Experiment 2 we tested whether exposing people to a pair of systemic metaphors could induce a systems thinking mindset. There were four between-subjects conditions in the metaphor exposure task: people read one of two types of metaphor (systemic or not) and made one of two kinds of judgment about the domains that the metaphors framed (an evaluation or an explanation). Half of the participants were asked to rate the degree to which a policy proposal would address the target problem, while the other half were asked to explain how and why a policy would address the target problem. This manipulation was included because prior work has found that people may be more likely to engage in a particular mode of reasoning (e.g., relational reasoning) when they are required to generate an explanation rather than simply evaluate a statement (Vendetti, Wu, & Holyoak, 2014).

The policy proposals were designed to be consistent with the distinction between the metaphor frames. After reading a more systemic metaphor, people were asked to evaluate or explain a more systemic intervention; after reading a less systemic metaphor, people were asked to evaluate or explain a less systemic intervention. For instance, people in the more systemic condition were asked whether "reforming educational programs" would be likely to reduce a crime *virus*. In contrast people in the less systemic condition were asked whether "increasing street patrols" would be likely to reduce crime when it was framed as a *broken bone*.[3]

We chose to pair policies with matching metaphors (i.e. relatively systemic policies with relatively systemic metaphors and less systemic policies with less systemic metaphors) so as not to interfere with the influence of the metaphor frames. For instance, evaluating a systemic policy (e.g., reforming educational practices) after reading a less systemic metaphor might disrupt the mindset induced by the metaphor frame.[4]

After completing the metaphor exposure task, participants completed two follow-up tasks that were designed to measure their tendency to engage in systems thinking. As the conceptual foundation of systems thinking overlaps with constructs like holistic and relational thinking, one of the follow-up tasks was adapted from studies of holistic thinking (Maddux & Yuki, 2006) and the other was adapted from studies of relational thinking (Rottman, Gentner, & Goldwater, 2012).

Our hypothesis was that people who were exposed to systemic metaphors would be more likely to show patterns of behavior consistent with holistic and relational thinking. We also predicted that the effect might be strongest in the explanation conditions, as these conditions would seem to require that participants think more deeply about the target domains.

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3. Prior work has found that people are more likely to associate systemic, social reform-based solutions with a crime problem that has been framed as a *virus* (see, e.g., Thibodeau & Boroditsky, 2011, 2013, 2015).

4. There is, however, a drawback to this method, in that it introduces another variable into the design: if people in the systemic condition show an increased propensity to engage in relational reasoning, it may be because they read two systemic metaphors, or it may be because they thought about two systemic policy approaches. In future work, we plan to include additional conditions in which the policies are incongruent with the metaphor frames (i.e. some people evaluate a less systemic policy approach to a systemic framing of the issues and vice versa). As the present study represents a novel exploration in the field, we designed the experiment to maximize our chances of seeing an effect.

3.1 Method

3.1.1 *Participants*

We recruited and paid 450 people through Mechanical Turk, using the same exclusion criteria as in Experiment 1. Data from 42 participants were excluded because they either did not provide an accurate completion code or because they had participated in Experiment 1.

There were slightly fewer male participants (39%) than female. The average age of participants was 36.47 yr (*SD* = 12.99). Most (86%) had completed at least some college. The political ideology of the participants was skewed slightly liberal: 38%, 32% and 22% identified as a Democrat, Independent, Republican, respectively; 9% identified as 'other'.

In line with prior work on relational reasoning (Rottman, Gentner, & Goldwater, 2012), we asked participants to report their level of mathematical and scientific training on a 4-point scale: 6%, 37%, 45%, and 11% of participants identified as having no background, not much background, some background, and a lot of background in math and science, respectively. The sample also included participants with a range of scores on the Systems Thinking Scale (Range: 45 to 85; $M = 68.14$, $sd = 6.95$; median = 68).

3.1.2 *Materials and design*

Before completing the experimental tasks, participants completed the Systems Thinking Scale (Davis & Stroink, 2015). This measure was presented at the beginning of the study so that the manipulation would not influence participants' responses on the scale.

Then participants completed the metaphor exposure task. They read two metaphors that either did or did not emphasize a holistic system. We used the crime and economy metaphors from Experiment 1 because they showed a clear dichotomy on the systemic dimension and because both conceptualized the target domain as a body, allowing us to control for other associations participants might have with the specific source domains. In the systemic condition, participants read reports that framed crime as a *virus* and income inequality as a *failing organ*. In the non-systemic condition, participants read reports that framed crime as a *broken bone* and income inequality as a *blemish*.

Participants were presented with a policy intervention for each issue (immediately after reading the issue). The policies, like the metaphors, were designed to differ in the degree to which they emphasized a system. People in the systemic condition were presented with systemic policies (for crime: reforming educational practices; for income inequality: forgiving student loan debt). People in the non-systemic condition were presented with less systemic policies (for crime:

increasing street patrols that look for criminals; for income inequality: raising the minimum wage).

Half of the participants evaluated the policy proposals on a 5-point Likert scale (1 = "Very unlikely to improve the crime / income inequality situation"; 5 = "Very likely"). The other half of the participants were asked to describe "why this course of action is likely to improve the crime / income equality situation" in a free response format.

After completing the metaphor task, participants completed measures of holistic and relational thinking (the order was counter-balanced across participants). As a measure of holistic thinking, people read a story about a student who had caused an accident on the freeway and evaluated the student's responsibility for five outcomes (Maddux & Yuki, 2006). The outcomes were increasingly distally related to the accident, and were rated on a 4-point scale that ranged from "Not responsible at all" to "Completely responsible".

Table 2. Questions for the measure of holistic thinking (Maddux & Yuki, 2006). Outcomes ordered from most proximally to most distally related to the driver's actions.

If you were the student, how responsible would you feel for…
1. …damaging your own car.
2. …the driver you hit.
3. …missing a meeting that you were rushing to attend.
4. …delaying other commuters in traffic.
5. …causing an accident that occurred further back in traffic.

Prior work has shown that people attribute less responsibility to the student as the outcomes become more distally related to the accident. However, holistic thinkers have been shown to be more likely to attribute responsibility to the student for distally related outcomes (Maddux & Yuki, 2006).

As a measure of relational thinking, participants read and made judgments about verbal descriptions of causal systems (Rottman, Gentner, & Goldwater, 2012). In the original version of this task, participants were given descriptions of 25 systems — five particular kinds of causal systems from five target domains — and asked to sort them into groups. Results indicated that participants with a scientific background were more likely to categorize the descriptions by causal structure than by content domain.

We adapted this task so that it could be more easily included in a web-based experiment by making it a 'match to sample' task. The 'sample' described a particular kind of system (e.g., positive feedback loop, negative feedback loop, causal chain) in a target domain (e.g., environmental, economic, biological). There were two potential matches: one that described the same causal system from a different content domain and one that described a different causal system from the same content domain. There were five trials of this task, presented in a randomized order.

After completing the three experimental tasks, participants were asked to indicate their sex, first language, educational history, "general math and science ability," geographic location, and political affiliation.

3.2 Results and discussion

3.2.1 *Holistic thinking*

Ratings of responsibility for outcomes related to the car accident were subjected to a repeated-measures ANCOVA with condition (systemic or not) and task (evaluation or generation) as between-subjects predictors, and outcome (coded continuously from most proximal to most distal) as a within-subjects predictor. Systems thinking was included as a covariate.

Consistent with prior research, we found that people attributed less blame to the student as the outcomes became more distally related to the car accident, $F[1, 1627] = 578.63$, $p < .001$: participants thought the protagonist was more responsible for damaging their own car than for potentially causing an accident further back in traffic. However, we found an interaction between metaphor condition (systemic or not) and outcome, $F[1, 1627] = 4.02$, $p = .045$ (see Figure 2). People who were exposed to systemic metaphors attributed more blame to the student for distally related outcomes, $B = .056$, $SE = .028$, $p = .022$, than did people who were exposed to non-systemic metaphors.

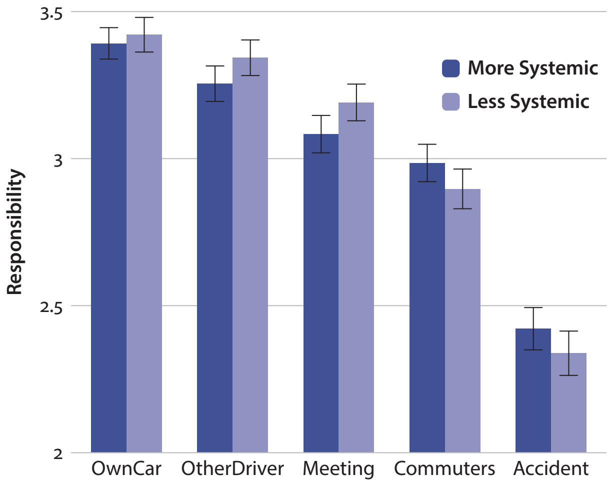

Figure 2. Attributions of responsibility to proximally (left) and distally (right) related outcomes by metaphor condition. Error bars reflect standard errors of the means.

In addition, participants who identified as high in systems thinking were more likely to attribute blame to the student overall (regardless of how proximally or distally related the outcome), $F[1, 403] = 24.800$, $p < .001$. There were no main effects of metaphor condition (systemic or non-systemic metaphor) or task (generation or evaluation) or other interactions between these variables (all $Fs < 1.5$, $ps > .2$).

Results from this task suggest that exposing people to systemic metaphors can promote a transferable mindset. Participants exposed to more or less systemic metaphors attributed a similar amount of responsibility to a protagonist for proximal outcomes, but participants exposed to more systemic metaphors seemed to consider a broader range of consequences in attributing responsibility for more distally related outcomes.

3.2.2 *Relational thinking*

Two analyses revealed a similar effect of systemic metaphor on relational thinking. In the first, participants were characterized as relational thinkers if at least four (out of five) of their responses in the match to sample task were based on the causal similarity of the descriptions, rather than the domain similarity of the descriptions (e.g., matching a description of a feedback loop for the economy to a feedback loop for biology, rather than to a description of an economic causal chain).[5] A logistic regression with predictors for 'metaphor type' (more or less systemic), 'initial task' (evaluation or generation), and 'scientific/mathematical background' was fitted to the data. The model revealed significant effects of metaphor type, $B = .916$, $SE = .381$, $p = .016$, and mathematical training, $B = .507$, $SE = .191$, $p = .008$. It did not reveal an effect of the initial task or an interaction between metaphor type and the initial task, $ps > .2$. Among those participants who read systemic metaphors, 19% responded to at least four of the trials by identifying the relational match, compared to 12% of participants who read the non-systemic metaphors. For context, this difference was similar to the difference between people who identified as having "some" or "a lot" of training in mathematics and science (18%) compared to people who identified as having "none" or "not much" training in mathematics and science (11%).

In a second analysis, individual responses on the relational thinking task were subjected to a repeated measures logistic regression. Predictors for this model included 'metaphor type' (more or less systemic), 'initial task' (evaluation or generation), and 'scientific or mathematical training', as well as an interaction between metaphor type and initial task. Here, too, we found a main effect of metaphor type, $B = .278$, $SE = .140$, $p = .048$ (see Figure 3). People exposed to the systemic

5. Roughly 3 of the 5 responses would be expected to be 'relational' by chance; the probability of choosing 4 or 5 'relational' matches by chance is about 1/5.

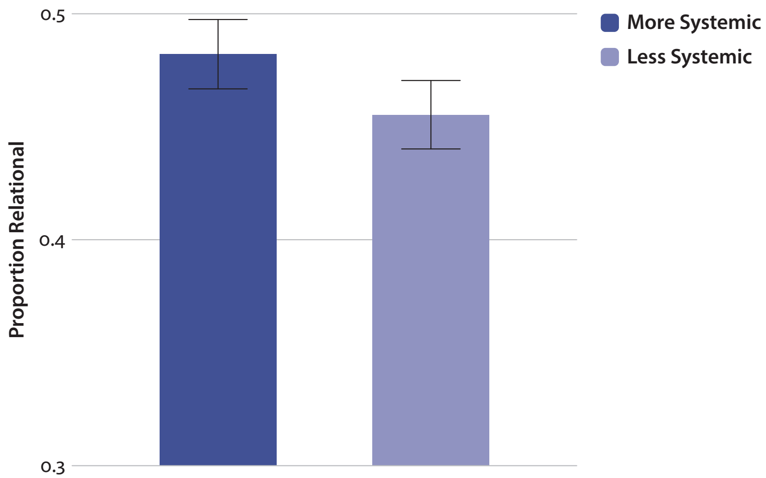

Figure 3. The proportion of structure-based similarity choices in the relational match to sample task by metaphor condition. Error bars reflect the standard errors of the proportions.

metaphors were more likely to match descriptions that described similar causal systems ($M = 2.41$, $SD = 1.10$) compared with people exposed to the non-systemic metaphors ($M = 2.28$, $SD = 1.05$). In this case there was a marginal main effect of mathematical training, $B = .110$, $SE = .066$, $p = .097$. There was no main effect of initial task or interaction between initial task and metaphor type, $ps > .2$.

4. General discussion

This research offers three important advances in research on the relationship between metaphor and thought. First, it identifies a dimension of metaphors that has been underappreciated in previous work on metaphor framing: namely a distinction between metaphors that highlight the dynamic causal structure of complex systems and metaphors that highlight relatively superficial features of systems (i.e. a distinction between metaphors that emphasize the complexity of target domains and metaphors that simplify target domains).

Second, we have presented a method for operationalizing and quantifying this dimension for metaphors. We found that, as predicted, people wrote longer and more intricate descriptions in response to systemic metaphors, that they explicitly rated these metaphors as more systemic, and that they viewed systemic metaphors as more complex in a comparison task.

Third, we have found support for the hypothesis that exposing people to systemic metaphors can induce a transferable systems thinking mindset. People who were exposed to two highly systemic metaphors showed higher levels of holistic and relational reasoning than people who were exposed to two less systemic metaphors. Though these effects were relatively small, we found that systemic metaphor priming conferred the same advantage in relational reasoning as having additional math and science training.

In addition to these important theoretical advances, this work has promising practical value. Metaphors are simple scalable social and cognitive tools for increasing systems thinking and enhancing decision-making: tools that may help people approach some of the most difficult and complex problems that we face today. The present findings suggest that framing complex issues like climate change or economic catastrophes using systemic metaphors might help promote the sort of systems-thinking approach better suited to effectively reasoning about these domains. For example, scientists and progressive policy makers are often vexed by climate change denial that relies on the observation that it still snows in the winter and that the summer may be temperate at times. This line of reasoning is based on a simplistic (and erroneous) mental model of the climate that assumes evidence for global warming should be apparent consistently in daily experience for everyone on the planet. The current study highlights the potential role of systemic metaphors in fostering a more sophisticated and systemic mental model that could help persuade the public to take climate change more seriously. The persuasive power of systemic metaphors in social discourse is an important topic for future research.

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