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Systemic Metaphors Promote Systems Thinking

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Abstract

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. 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.

Keywords: systems thinking; metaphors; intervention, framing; decision making

Introduction

The greatest challenges humans currently face – climate change, poverty, epidemics, financial meltdowns – involve enormously complex 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).

There are three 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; e.g., 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 (e.g., Capra, 1985). And third, it requires an appreciation that systems are in constant, but patterned, flux (e.g., Sweeny & Sterman, 2007). Here, we offer theoretical and empirical support for designing metaphor-based interventions to promote systems thinking.

Metaphors are powerful 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, have found that describing cancer using war metaphors, as an *enemy* that must be *fought*, increases general support for cancer research but decreases 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 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.

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 domain of crime. Thibodeau and Boroditsky (2011; 2013) found that describing crime as a *beast* led people to support direct crime-fighting measures like hiring more police officers. Framing crime as a *virus*, on the other hand, led to support for reform-based measures like increasing education and investigating the origins of crime in the community. One way of characterizing the difference between *virus* and *beast* metaphors for crime is that the *virus* metaphor invites people to build a deeper causal structure of the problem, so people think more about the root causes of crime and try to address them (i.e. the *virus* metaphor is more systemic).

In this paper we first describe a method for identifying the degree to which metaphors are systemic (Experiment 1). This dimension is similar to a distinction that is commonly made in the analogy literature between *attributional* (e.g., "The sun is an orange") and *relational* (e.g., "The atom is a solar system") comparison (Gentner, 1983; Lakoff, 2002; Wolff & Gentner, 2011). Relational analogies and metaphors highlight complex structural relationships (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 correspondences 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 results from Experiment 1) before they completed a set of tasks that have been used to measure holistic (Maddux & Yuki, 2006) and relational reasoning (Rottman, Gentner, & Goldwater, 2012). 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 holistic and relational reasoning.

Experiment 1

Methods

Participants We recruited and paid 600 participants through Amazon's Mechanical Turk. We used Turk's exclusion capabilities to ensure that participants lived in the US and had a good performance record on pervious 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 completion code, leaving data from 582 participants for analysis.

This sample included an equal number of males (50%) as females. The average age of participants was 32.8 (*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.

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). 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 metaphor conditions in this experiment, and completed a set of three tasks for just one of the metaphors described above.

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?"

Next, they 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 asked people to rate the extent to which, for instance, talking about income inequality as a failing organ captures the idea that…

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".

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 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." Then they were asked a set of background demographic questions including their age, sex, first language, educational background, geographic location, and political affiliation.

Results and Discussion

Metaphor Interpretations We used the Linguistic Inquiry and Word Count software (LIWC; Pennebaker, Chung, Ireland, Gonzales, & Booth, 2007) to analyze participants' interpretations of the metaphors. We predicted that people would write longer and more intricate interpretations for the metaphors that we considered relatively systemic. We also predicted that people who were high in systems thinking would write longer and more intricate interpretations. Accordingly, we fit an ANCOVA with main effects for issue, metaphor type (systemic or not), and systems thinking. We also included an interaction term between metaphor type and systems thinking.

We found a significant main effect for issue, *F*[2, 574]= 10.439, *p*<.001: people wrote more about the economy (*M* = 33.55, *sd*=31.49) than crime, *t*[296.79; variances not assumed to be equal]=3.29, *p*=.001, (*M*=24.30, *sd*=21.59) or education, *t*[264.81] = 3.94, *p*<.001, (*M*=22.92, *sd*=17.73). There was no difference between the crime and education stories in terms of length, *t*[398.57]=.71, *p*=.481.

In addition, we found a significant main effect of systems thinking, *F*[1, 576]=9.673, *p*=.002. People who were higher in systems thinking wrote more, *B*=.774, *SE*=.219, *p*<.001. We also found an interaction between systems thinking and metaphor type, *F*[1, 574]=4.4390, *p*=.037. In general, people wrote more in response to systemic metaphors (*M*=27.33, *sd*=23.51 compared to nonsystemic metaphors *M*=25.74, *sd*=25.21), *B*=43.31, *SE*=20.08, *p*=.031. At the same time, however, people who were high in systems thinking wrote slightly less about systemic metaphors than people who were low in systems thinking, *B*=-.619, *SE*=295, *p*=.036. In other words, 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. There was no interaction between issue and metaphor type, *F*[2, 574]=.070, *p*=.932.

Ratings of Systemic-ness We fit the ratings data to an ANCOVA with the same terms for main effects and interactions (i.e. main effects for issue, metaphor type, and systems thinking; interactions between issue, metaphor type, and systems thinking). In this case, we found main effects of issue, (*F*[2, 574]=3.28, *p*=.038), systems thinking (*F*[1, 574]= 15.538, *p*<.001), and metaphor type (*F*[1, 574]=5.331, *p*=.021). People considered the economy (*M*=21.36, *sd*=4.56) to be more systemic than crime (*M*=20.16, *sd*=4.56) or education (*M*=20.27, *sd*=4.77), *t*[381.323; variances not assumed to be equal]=2.25, *p*=.017 and *t*[367.44] = 2.25, *p* = .025, respectively. There was no difference in ratings between crime and education, *t*[405.31] =.22, *p*=.824.

People who were higher in systems thinking considered the metaphors more systemic overall, *B*=0.116, *SE*=.030, *p*<.001, and systemic metaphors were rated as more systemic (*M*=20.99, *sd*=4.88, compared to nonsystemic metaphors, *M*=20.05, *sd*=4.92), *t*[565.45]=2.304, *p*=.022.

There were no interactions between systems thinking and metaphor type, *F*[1, 574]=1.643, *p*=.200, or between story and metaphor type, *F*[2, 574]=1.977, *p*=.140.

Metaphor Comparison Participants viewed the systemic metaphors as situating the target problems in a broader context, χ^2[1]=208.08, *p*<.001, as more complex, χ^2[1]=220.21, *p*<.001, and as less simple χ^2[1]=163.00, *p*<.001. They also thought that the systemic metaphors made the target problems seem more involved but tractable, χ^2[1]=43.99, *p*<.001, and more appropriate, χ^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)	0.89	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	0.58	0.603

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

Experiment 2

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 metaphors (systemic or not) and made one of two kinds of judgments 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.

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*.

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) to facilitate 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[1].

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 relates to constructs like holistic thinking 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.

Method

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 also participated in Experiment 1.

There were slightly fewer male participants (39%) than female. The average age of participants was 36.47 (*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 (*M* = 68.14, *sd* = 6.95; median = 68).

[1] 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 this represents a novel exploration in cognitive science, we designed the experiment to maximize our chances of seeing an effect.

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 a metaphor exposure task. They read two metaphors that 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. In the more systemic condition, participants read reports that framed crime as a *virus* and income inequality as a *failing organ*. In the less systemic condition, participants read reports that framed crime as a *broken bone* and income inequality as a *blemish*.

Next, participants were presented with a policy intervention for each 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 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 participants were asked to describe "why this course of action is likely to improve the crime / income equality situation."

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

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. It was found that participants with a scientific background were more likely to categorize the descriptions by causal structure than content domain.

We adapted this study 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 (environmental, economic, biological). There were two potential matches: one that described a similar causal system and one that described a similar content domain. There were five trials of this task, presented in a randomized order.

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

Results and Discussion

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. We also included systems thinking as a covariate.

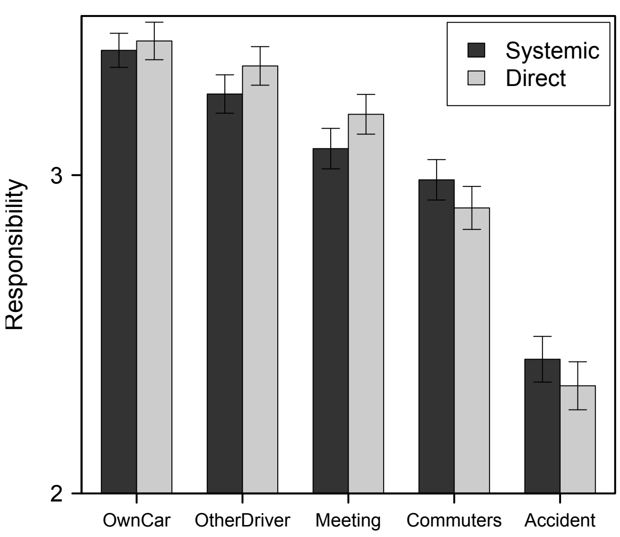

Figure 1. Attributions of responsibility to proximally (left) and distally (right) related outcomes by metaphor condition. Error bars reflect standard errors of the means.

Consistent with prior research, people attributed less blame to the student as the outcomes became more distally related to the car accident, $F[1, 1627] = 578.63$, $p < .001$. However, we found an interaction between condition (systemic or not) and outcome, $F[1, 1627] = 4.02$, $p = .045$ (see Figure 1). People who were exposed to systemic metaphors were more likely to attribute blame to the student for distally related outcomes, $B = .056$, $SE = .028$, $p = .022$. There was no interaction between task (evaluation or generation) and outcome, $F[1, 1627] = 1.30$, $p = .255$, nor was there a three way interaction between metaphor, task, and outcome, $F[1, 1627] = .933$, $p = .334$.

There were also no main effects of condition or task, nor was there an interaction between metaphor and exposure task (all *F*s < 1). There was, however, a main effect of systems thinking, $F[1, 424] = 24.80$, $p < .001$, and an interaction between systems thinking and outcome, $F[1, 1627] = 13.71$, $p < .001$. Systems thinkers were more likely to attribute blame to the student overall (i.e. for all of the outcomes), $B = .041$, $SE = .006$, $p < .001$. However, as the outcomes became more distally related to the accident systems thinkers attributed less blame to the student, $B = -.005$, $SE = .001$, $p < .001$. This interaction came as a surprise to us and warrants further research.

Relational Thinking Two analyses revealed the effect of metaphors on relational thinking. In the first, participants were characterized as relational thinkers if at least four (out of five) of their responses matched the causal structure of the sample description. A logistic regression with predictors for metaphor type (systemic or not), initial task (evaluation or generation), and scientific/mathematical background was fit 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, *p*s > .2. People who read the systemic metaphors were more likely to judge similarity on the basis of causal structure, as were people with more mathematical training.

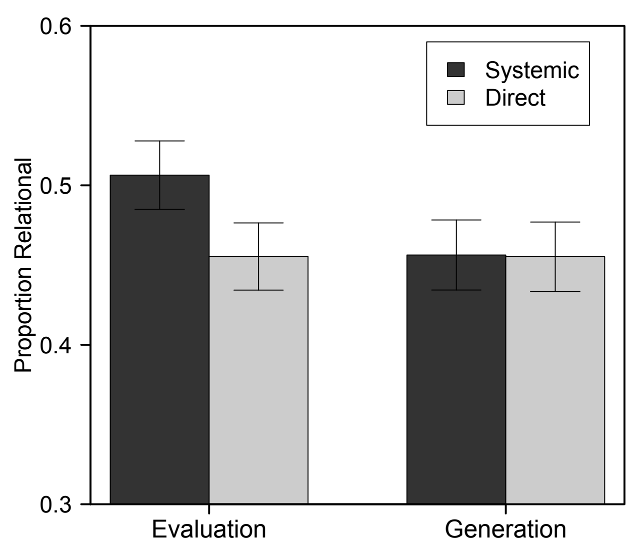

Figure 2. The proportion of structure-based similarity choices in the relational match to sample task. Error bars reflect the standard errors of the proportions.

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 (systemic or not), 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 2). People exposed to the systemic metaphors were more likely to match descriptions that described similar causal systems. 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, *p*s > .2.

General Discussion

This study 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: a distinction between metaphors that highlight the dynamic nature 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 versus 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.

In addition to these important theoretical advances, this work has promising practical value. Metaphors are simple and scalable 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.

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