Advanced Review

Metaphor and analogy in everyday problem solving

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Early accounts of problem solving focused on the ways people represent information directly related to target problems and possible solutions. Subsequent theory and research point to the role of peripheral influences such as heuristics and bodily states. We discuss how metaphor and analogy similarly influence stages of everyday problem solving: Both processes mentally map features of a target problem onto the structure of a relatively more familiar concept. When individuals apply this structure, they use a well-known concept as a framework for reasoning about real world problems and candidate solutions. Early studies found that analogy use helped people gain insight into novel problems. More recent research on metaphor goes further to show that activating mappings has subtle, sometimes surprising effects on judgment and reasoning in everyday problem solving. These findings highlight situations in which mappings can help or hinder efforts to solve problems.

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INTRODUCTION

People face important everyday problems that are difficult to understand with complete certainty or great detail. Indeed, entire fields of study are devoted to helping people make sense of elusive problems such as cancer, depression, housing markets, international conflict, and crime. Until experts deliver a complete understanding, people must address these problems using whatever resources are at hand. How do they do it? In this article we focus on the unique contribution of *structure mapping* as it is realized in conceptual metaphor and analogy.

Problem solving encompasses several processes including judgment (determining whether something is a problem), reasoning (deciding between alternative solutions), and self-monitoring (determining whether an approach is effective).[1] What unites these processes in problem solving is their common effort to modify or overcome some aspect of the environment that presents a barrier to goal pursuit—i.e., a *problem*.[2] Under this inclusive definition, problem solving takes forms as modest as solving a crossword puzzle and as significant as winning a national election.

Structure mapping enables problem solvers to access a conceptual structure common to both a well-known concept and a less familiar problem (or solution). In this way, the well-known concept serves as a framework that can influence one or more stages of problem solving. As we review below, these mappings can shape how individuals reason about a problem, their ability to generate applicable solutions, and ultimately how they choose from among candidate solutions. Although beneficial in many cases, accessing a mapping is not guaranteed to produce accurate perceptions of the problem or useful inferences about potential solutions. Indeed, it can actively interfere with effective problem solving.

To unpack these claims, we elaborate on their theoretical basis and review findings from cognitive and social psychology. Our presentation underscores two points: (1) metaphor and analogy influence cognition through a shared process of structure mapping

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and (2) this influence has practically important consequences for everyday problem solving.

FROM COMPUTATION TO COMPARISON: THE BROADENING SCOPE OF PROBLEM SOLVING

Initial computational models of problem solving were premised on an intuitive assumption that people reason about a problem by processing information that is specific to that problem[2] and its candidate solutions.[3] Problem solvers identify a state of affairs as a problem, locate a desired resolution state, and generate a pool of candidate solutions for attaining that end state.[3] Across these stages, they rely exclusively on what they perceive and know about the problem at hand.[4] For example, to address the problem of cancer people acquire relevant information to build up a mental set of solutions (prevention behaviors, medical treatments) and the criteria for evaluating their effectiveness.[5] Optimally, this creates a sufficiently complete conception of the problem and candidate solutions to allow the problem solver to successfully address the problem.

This traditional assumption is reflected in early accounts of solution selection.[6] They posited that, through a process called *progress monitoring*, people mentally transform aspects of candidate solutions until one approximates the desired end state. Someone attempting to find an answer on a crossword puzzle might generate a pool of candidate responses ('Okay, it's a six-letter word starting with *M* that means…') and mentally fit several of them to the puzzle before settling on the choice that meets all the criteria necessary for a correct answer.

Although this straightforward empirical approach inspired a great deal of research and computational models capable of solving simple problems,[7] it falls short of capturing the complexity of problem solving. Research increasingly points to influential factors originating outside of the immediate problem. These include fixation on well-worn (but suboptimal) solutions[2,8] and a simple lack of creativity necessary to generate a solution.[9] A comprehensive review of these peripheral factors is beyond our scope; here we mention two examples—heuristics and embodiment—that set the stage for our discussion of structure mapping.

Heuristics

Judgments about a problem are susceptible to heuristic biases, cognitive 'rules of thumb' that sometimes lead to inaccurate conclusions.[10] One is the availability heuristic: the tendency to assume that information that comes easily to mind (or is readily available) is more frequent or common. An individual exposed to graphic depictions of airplane crashes may perceive the relative risk of flying to be more problematic than it really is due to the ease of retrieving examples.[11,12]

Heuristic judgments are also influenced by affect.[13] For example, affect informs evaluations of goal progress, such that positive (vs. negative) feelings cause people to perceive that they are closer to achieving a desired goal.[14,15] Thus the perceived effectiveness of a solution may depend in part on how the problem solver *feels*, rather than an objective appraisal of its effectiveness.

Embodiment

The early information processing models portrayed knowledge about the problem as represented in an amodal, symbolic format. This view leaves little room to consider how problem solving is connected to modal systems for perceiving and interacting with the environment. As a corrective, recent research has uncovered connections between problem solving and bodily states and experiences.[16]

Illustrative studies point to the role of gesture.[17] When addressing a problem that seems abstract or difficult to represent in working memory (e.g., patterns of unconnected dots), people enact more bodily gestures than they do when solving more easily represented problems.[18] Such gestures are not mere byproducts of thought; they facilitate learning and problem solving cognition by enhancing working memory capacity.[19,20]

Other work reveals visuospatial biases that may be peripheral to the problem at hand. Researchers have proposed that the left-to-right spatial arrangement of written English leads people to associate temporally earlier events with *left*. Written Mandarin, on the other hand, orients up and down, supporting perceptions of early events as *up*. Studies indeed show that people's temporal arrangement of events matches their writing direction,[21] and that their proficiency in Mandarin positively predicts their tendency to organize temporal events vertically.[22]

STRUCTURE MAPPING: THE ROLES OF METAPHOR AND ANALOGY

Like heuristics and embodied influences, structure mapping influences problem solving by introducing information that falls outside of the parameters of a specific problem. In structure mapping, a person 'fits'

aspects of the target problem into a template borrowed from a superficially unrelated concept, commonly referred to as the *source*. This mapping can intervene during critical stages of problem solving, guiding the person to apply schematic knowledge of the source to think through the target problem, despite the differences they have at a surface level.

This process differs from heuristics and embodied influences in important ways. While heuristic and embodied influences are relatively pervasive and automatic, structure mapping is often more *selective*. As we will see, this process involves a targeted transfer of *specific* information from the source to the target rather than the more integrative blending of concepts (e.g., space and time) observed in research on embodiment.[23] This selectivity extends to *when* mapping influences thought; typically only if cued by a feature of a problem, such as the language used to represent it. As a result, the process of structure mapping is often more deliberate than heuristic effects and can sometimes require active effort to find a useful structure to apply to a problem.

Two well-studied forms of structure mapping are conceptual metaphor and analogy. Traditionally, they have been the focus of separate research programs. One goal of this review is to highlight their common contributions to everyday problem solving.

Conceptual metaphor theory (hereafter: CMT) distinguishes between linguistic metaphor—a communicative device—and *conceptual metaphor*: a cognitive tool that people use to represent an abstract target concept in terms of a superficially unrelated, typically more concrete source concept.[24–26] CMT posits that a conceptual metaphor operates by linking the target's aspects (e.g., features, relations) to analogous source aspects. Doing so highlights a shared structure common to the target and source. In this way, thinking with a metaphor enables people to apply a familiar source schema to represent and reason about the target.[27]

Many empirical assessments of CMT come from observational studies of metaphors in everyday discourse.[28,29] The key discovery is that conventional metaphoric expressions cluster into patterns that would be unlikely if those expressions were isolated idioms or mere 'figures of speech.' More likely, in line with CMT, they are motivated by an underlying structure mapping. For example, across different languages and cultures we find remarkably similar expressions comparing *understanding* to *vision* (e.g., 'Look at the *big picture*'; 'Do you *see* my point?').[30] These cross-cultural patterns support CMT's claim that people make sense of *understanding* by mapping the structure of that experience onto the corresponding structure of *seeing*, meanwhile downplaying surface-level differences.

Analogy operates through essentially the same mapping process.[31,32] It requires a systematic mapping between elements of a familiar or well-known source and a less familiar target. For example, a student might make sense of *nuclear fission* by systematically comparing it to the opening shot in a game of *pool*. Comparing known elements (e.g., cue ball, pool cue) to unfamiliar elements (e.g., neutron, emission source) provides a cognitive framework for representing the structural relations between elements in fission.

If metaphor and analogy operate through the same underlying process, then we can see them as differing in degree rather than kind. Bowdle and Gentner propose that the crucial dimension along which metaphor and analogy differ is *conventionality*.[33,34] The mappings in metaphor are conventional in everyday thought and language and, as such, can be activated automatically and with little effort.[35,36] Drawing novel or unconventional mappings in analogy, on the other hand, is relatively more deliberate or difficult, as we shall see.

An example illustrates the difference. Comparing *life* to a *journey* is highly conventional[37] and this mapping can be contextually activated quickly and effortlessly. In one study, students exposed to visual images comparing their time in college to a *journey* (vs. no metaphor) reported greater academic motivation, presumably because they transferred their knowledge that, on a typical journey, current 'steps' determine one's ability to reach a destination (which corresponds to graduation in the mapping).[38] In contrast, comparing *life* to a *football game* is less conventional and requires a deliberate search for corresponding structure ('Okay, so if I'm the quarterback then my family must be the team…'). To reiterate, both cases instantiate a structure mapping process whereby schematic knowledge of a well-known source is transferred to represent and reason about the target. But the metaphor is conventional and easily activated whereas the analogy is less so.

Research on structure mapping has shed light on the underlying cognitive and neurological processes implicated in this common mapping process. Given space limitations, we can mention only a couple insights. Gentner[39] notes that structure mapping, unlike literal comparisons between targets, involves the transfer of comparatively few aspects from the source to the target. While comparing two novels by the same author may involve the detection of many parallels in characters or story elements, comparing a *novel* to a *trainwreck* selectively transfers negative

implications about the novel's organization while fully acknowledging that most features of train-wrecks do not apply. This selectivity is made possible by the detection of structurally similar relations between elements of the source and target, in this case perhaps being *in disarray*. Successful computational models reproduce this complex process [Learning and Inference with Schemas and Analogies (LISA)[40]; Structure Mapping Engine[41]] by formally detecting and comparing abstract structure between conceptual domains. We encourage interested readers to explore the extent to which these models shed light on the underlying processes in structure mapping.

Below we highlight the importance of these structure mapping processes for everyday problem solving with a selective review (for more comprehensive treatments, see Refs 42,43). In keeping with our inclusive definition of problem solving, we review studies looking at a range of outcomes, including judgment and reasoning outside of problem solving *per se*. Bringing together these discoveries gives us a richer overall picture of how people deal with problems in their daily lives.

When Mapping Is Unconventional: Analogy in Problem Solving

Pioneering research by Gick and Holyoak examined whether people could detect that the structure of a previous problem helps them to solve a novel problem.[44] Participants read a scenario in which an army successfully besieged a well-defended city by splitting up and surrounding it. Later, they were asked to find a way for doctors to focus enough radiation on a tumor to destroy it without damaging the surrounding tissue. One solution is to have several emissions of radiation converge on the tumor, with no single emission powerful enough to damage the surrounding healthy tissue. Among participants prompted to think back to the military scenario, 76% generated this convergence solution, whereas only 10% of the control participants, who received no prompting, did so. With a little extra prompting, participants in the former condition apparently noticed that although the medical and military scenarios differ, aspects of the medical problem fit into the structure transferred over from the military scenario. The tumor corresponded to the city center, radiation emissions are like soldiers, and so on.

Further research shows that novel or unconventional structure mapping depends in part on the relative difficulty of this mapping. In one follow-up study, researchers reasoned that one way to make this process simpler is to increase the similarity between the target problem and the source analog.[45] Participants read about a source problem that was solved using a convergence of either lasers or ultrasound waves, depending on condition. Then they were asked to solve the target tumor problem mentioned above. On the surface, X-rays are more similar to lasers (another form of electromagnetic radiation) than they are to ultrasound waves. As hypothesized, that similarity helped participants transfer the solution from the source to solve the tumor problem.

Indeed, as long as the target problem and the source analog are sufficiently similar, problem solvers can spontaneously draw analogies on the basis of just a few important cues. Gilovich[46] asked participants to imagine that they were officials at the State Department faced with a diplomatic crisis: A militaristic country was set to invade a weaker country, which was asking for U.S. support. In the materials that some participants received, maps and documents suggested subtle similarities between this hypothetical crisis and prior U.S. military engagements. For one group, the map of the region included labels like the 'Gulf of A' as well as other subtle cues (e.g., the President was said to be from Texas) to suggest similarity to Vietnam. For another group, cues instead suggested similarity to World War II (e.g., the impending invasion was described as a 'Blitzkrieg invasion'). If these framings of the crisis trigger mappings in participants' minds, then their evaluations of a candidate solution should conform to their knowledge of the respective source concepts. Supporting this reasoning, when the materials subtly framed the target crisis in terms of Vietnam, participants were the least supportive of military intervention; by contrast, priming a WWII framing increased participants' support of military intervention.

Recall that analogy use in problem solving is more effortful because the mapping is unconventional. We would therefore expect that representing a target problem in terms of its structure (the relations among its parts) will make it easier to spontaneously detect a relevant mapping. Supporting this reasoning is evidence that students easily generated equations to calculate the acceleration of an object if they were initially trained to generate algebraic expressions of rates of change in other contexts.[47] In contrast, students who learned to calculate acceleration first were unlikely to apply that mathematical procedure to equivalent calculations in other domains, presumably because they were focused on the specific content, rather than the underlying structure, of the acceleration problems.

When Mapping Is Conventional: Metaphor in Problem Solving

Compared with analogy, metaphor use involves more conventional mappings that are easier to bring to mind and often less explicit than the deliberate comparisons drawn in analogy. Still, it is important to recall that conventionality is a *continuum* along which any given metaphor may fall. In fact, at the level of the individual, all metaphors initially appear as analogies—dissimilar concepts that lack an easily accessible mapping.[34] By means of repeated pairing in language and thought, structure mappings reach a level of conventionality whereby the target concepts take on secondary, metaphoric meanings without effortful structure mapping. To illustrate, thinking about *business* in metaphoric terms as a *game* may initially require efforts to find their parallels (e.g., both have rules; both have winners and losers). After repeated exposure, people may spontaneously categorize aspects of business in game-metaphoric terms. Eventually they form a category for *games* that represents the higher-order *structure* of this concept; that is, they know that one sense of *game* applies to literal games like chess and checkers while another sense of *game* refers more abstractly to rule-based systems for competition (including business).

The notion that metaphors lie along a continuum of conventionality is useful for generating new predictions. It also serves as a corrective to the current trend in metaphor research to focus on individual metaphors with minimal consideration for how they are alike and different.[35] Thus, our empirical review is organized around this dimension.

One important caveat to this approach is that differences in conventionality are proposed on the basis of the extent to which mappings are made explicit. Recall that analogy is achieved through a deliberate and explicit process of structure mapping. In contrast, metaphor researchers typically test whether situationally-cued metaphors influence cognition through relatively well-worn mappings in observers' minds.

In some cases, researchers test the implications of a metaphor for which differences in thought or behavior are observed only when a particular mapping is made explicit (we term these *less conventional*). Critically, these explicit metaphors do not make reference to a given outcome, allowing researchers to test whether individuals spontaneously employ a salient mapping. In other cases, metaphors are assumed to be chronic and their effects are tested with few or no cues designed to encourage structure mapping (we refer to these as *more conventional*).

Less Conventional Metaphors

Some metaphors require environmental cues to encourage less conventional structure mapping. To test their effect on problem solving, researchers expose people to metaphoric language or imagery intended to cue a particular mapping that would otherwise not be chronically accessible. Studies using this strategy have shown metaphoric influences on a range of processes involved in everyday problem solving.

Some of these studies show that cued mappings influence expectations about the future, which determine whether a state of affairs is identified *as* a problem. Morris et al.[48] asked participants to read stock market commentaries that framed a downward price trend in terms of either the deliberate action of a living *agent* (e.g., 'the Nasdaq starting climbing downward'), the activity of an inanimate *object* (e.g., 'the Nasdaq was swept downward'), or in nonmetaphoric terms (e.g., 'the Nasdaq index posted a loss'). Next, participants predicted what would happen to the price trend the next day. Morris et al. reasoned that because people generally know that living things move with intention toward destinations, the agent-metaphoric framing would lead people to transfer that knowledge to think about the stock market, inferring that the price trend would continue along its trajectory the following day. Neither the object-metaphoric or nonmetaphoric framing would support that inference, in contrast, because people generally know that inanimate objects and price trends do not move with intention. This is exactly what they found.

Cued metaphors also influence solution generation in a manner consistent with their mapping. Thibodeau and Boroditsky[49] showed that participants who read an article comparing a city's crime problem to an aggressive *beast* spontaneously generated more aggressive and punitive crime-reduction strategies, whereas those who read an article framing the same facts in *disease*-metaphoric terms recommended addressing the root causes of crime, consistent with their knowledge of curing disease. In both metaphor activation conditions, participants applied knowledge of the respective source concepts to determine how best to solve the crime problem. Follow-up studies showed that participants who read either the animal- or virus-metaphoric framings judged the city's crime problem to be more severe than those who read a closely-matched but nonmetaphoric framing.[50] Indeed, severity ratings did not differ between the *beast* and *virus* framing conditions, demonstrating that both metaphors heightened perceived severity by invoking familiar hazards.

Strong emotional reactions also urge immediate action. Accordingly, vivid metaphors transfer emotional worry from concrete hazards to evaluations of abstract target risks and this motivates people to take preventative action. Scherer et al.[51] exposed participants to a health message that framed the flu in terms of a *wild animal* that attacks one's health, a *weed* that grows in the body, or an invading *army*. Compared to a nonmetaphoric description of the flu, the metaphoric framings increased intentions to seek a flu shot, presumably because each triggered fears of a concrete hazard.

These experimental findings are consistent with linguistic analyses showing that public discourse often features rhetorical metaphors designed to manipulate perceptions of a problem's importance. What makes these metaphors persuasive, theorists argue, is that they compare a complicated problem to another problem with a familiar structure and a manageable set of agreed-upon solutions. Several researchers have argued that vivid metaphors helped to convince the American public of the acceptability of military interventions, particularly the 1991 Gulf War[52] and the U.S.-Iraq conflict in 2003.[53] In one illustration, Schön[54] highlighted the ways in which metaphoric language about slums in the DC area sometimes deployed vivid imagery, such as presenting *slums as a disease*, to encourage efforts to 'treat' that disease through demolition. Linguists have also noted Hitler's systematic use of *health* and *disease* metaphors to foment Anti-Semitism by appealing to the need for a 'healthy' state free of 'parasites' and other 'pests.'[55] Similarly, anti-immigration rhetoric in the early 20th century described the *nation as a physical body* that is vulnerable to 'contamination' by invading external entities.[56]

Inspired by this last finding, Landau and colleagues[57] tested whether, by means of a situationally cued metaphor, concern with protecting one's own body from contamination fuels the perception that immigration is a major problem. The researchers manipulated contamination threat by priming participants to view airborne bacteria in their environment as either harmful to their physical health or innocuous. Participants—all American citizens—then read an ostensibly unrelated essay describing the United States. In the metaphoric framing condition, the essay contained statements subtly comparing the United States to a *body* (e.g., the 'The U.S. experienced a growth spurt'); in the nonmetaphoric framing condition, those statements were replaced with literal paraphrases ('The U.S. experienced a period of innovation'). Heightening participants' bodily contamination fears led them to see immigration as more problematic, but only if they were additionally primed to think of their country as a *physical body*. This finding provides evidence that metaphoric framing effects depend on a systematic structure mapping between the source and the target, and not by a simple spillover of negative affect from thinking about bodily contamination without the metaphor.

Along with the outcomes mentioned thus far, cued metaphors inform evaluations of candidate solutions. Consider, e.g., the task of evaluating how best to prevent the failure of a large social system, such as financial crisis of 2008. We[58] examined one metaphor comparing system failure to a *vehicle accident*, which is reflected in common expressions such as 'the economy is veering off course' and 'student senate is headed for a ditch.' We assumed that people generally blame vehicle accidents on the vehicle's driver, not on passengers or other parties. Accordingly, exposure to a metaphoric framing comparing a system failure to a vehicle accident supported the judgment that blame for the system failure lies primarily with the highest-ranking individual in charge of that system—that is, the person in the 'driver's seat.' Note that that the original message did not address the topic of blame for the system failure. This is important because it supports our theoretical claim that message recipients transferred source knowledge—of vehicles, in this case—to assess responsibility for the problem at hand. For our current purposes, the implication of this finding is that a metaphoric representation of a problem may bias solution evaluation. We would expect, e.g., that participants primed with the vehicle metaphor would prefer solutions that target the system's leader (e.g., a company's CEO) and reject solutions targeting other parties or factors. Future research could test this possibility.

More Conventional Metaphors

When a metaphor is unconventional, it influences problem solving only when people are exposed to *explicit* cues prompting them to map the structure of the target onto the source. Other lines of research focus on more conventional metaphors. In these cases, even very subtle or implicit cues are sufficient to prompt perceivers to apply source knowledge to process a target problem, suggesting that their structure mapping is chronically accessible.

For example, common linguistic expressions suggest a metaphoric association between *importance* and *physical weight*: some topics are *heavy*; some considerations carry more *weight* than others; and so on.[59] Jostmann et al.[60] showed that these conventional figures of speech express a highly accessible

structure that directly informs estimates of importance. They gave participants a survey asking them how important it was to have students give input on university issues. Participants completed the survey on either a heavier or lighter clipboard. Simply hefting the heavy clipboard led students to assess the issues as more important. A related study Lee and Schwarz[61] showed that performing a gesture that metaphorically 'weighs' what is on one hand against what is on the other increased the preference for 'balanced' solutions to everyday problems, suggesting that the gesture led people to assign equal importance to relevant considerations.

Subtly activating conventional metaphors can also increase creativity generally and thereby facilitate solution generation. Slepian and Ambady[62] asked participants to trace either a fluid, rounded shape or an angular shape, ostensibly as part of a hand-eye coordination test. Consistent with metaphoric depictions of creativity as *fluid* thinking (and *rigidity* as a lack of creativity), participants who traced fluid shapes generated more uses for an object and more readily formed associations between remote targets. Another study by Slepian et al.[63] tested the impact the metaphor linking insight to illumination (e.g., 'a *bright* idea'). Participants tasked with solving problems near a bright lamp (vs. more diffuse fluorescent light) were better able to solve problems relying on creative insight. Finally, Leung et al.[64] explored the effect of 'box' metaphors for creativity (e.g., 'think outside the box'). Participants physically sitting outside (vs. inside) of a box performed better on creative tasks, despite the fact that no explicit mention was made of this conventional metaphor.

Other studies reveal the effect of chronically salient mappings on solution evaluations. Hauser and Schwarz[65] focused on conventional descriptions of cancer and cancer treatment employing *military* metaphors (e.g., 'fight back against cancer'). While these metaphors may be helpful in encouraging public support for research and treatment, they imply a strategic approach to cancer that is primarily aggressive and not restrained. Accordingly, participants primed with military cancer metaphors were less motivated to engage in self-limiting behaviors (e.g., dieting) that reduce the risk of cancer. In this case, structure mapping lead people to judge certain behaviors as ill-suited to fight the 'War on cancer,' even though, in reality, these behaviors may be quite effective. Metaphor use may support understanding, but it does not guarantee accurate or healthy decisions about which course of action to take.

Note that these studies start with the assumption that a candidate solution has a clear meaning that corresponds in a straightforward manner to an analogous source solution. But there are cases where candidate solutions are themselves abstract or open to multiple interpretations. For example, self-limiting health behavior may seem obviously restrained and thus ineffectual when viewed through the lens of military strategy; but what about the effects of a specific radiation treatment? Is that treatment seen as an offensive 'salvo' in the war against cancer or is it a defensive 'barrier' against further growth? This ambiguity creates room for metaphor to direct solution evaluation by changing representations of the solution itself, in addition to the target problem.

Building on this idea, we[66] conducted a series of studies exploring the interactive effects of both problem and solution metaphors in the context of depression treatment. We reasoned that if people understand depression metaphorically as a problem of being spatially low or down (as reflected in phrases like 'feeling low'; 'stuck in a rut'[67]), then they would more favorably evaluate depression treatments framed metaphorically as 'solving' that spatial problem (e.g., 'lifting people out of depression'). Put differently, when the metaphoric framing of the solution 'fits' the metaphoric framing of the problem, people should prefer the solution, despite the fact that neither metaphoric framing is literally true (i.e., depression is not a drop in vertical space; and depression treatments do not lift).

Several studies support this metaphoric fit hypothesis. Participants positively evaluated an antidepressant medication when spatial metaphors were salient for that medication and the problem of depression, but not when either of those metaphors was absent. We conceptually replicated this effect in the context of *illumination* metaphors that portray depression as darkness and medication as brightening one's mood. Also as hypothesized, a metaphoric misfit led to more negative solution evaluations. Specifically, individuals implicitly cued to represent depression as *darkness*—by viewing negative (vs. positive) affect words in black (vs. white) font—rated a *spatial*-metaphoric treatment more negatively than a neutral, nonmetaphoric alternative. People ostensibly drew on their knowledge of both concepts, reasoning that spatial movement ultimately would fail to address darkness.

Conclusion

A large body of experimental research supports the claim that structure mapping plays significant roles in several stages of everyday problem solving:

whether people see a state of affairs as a problem, how they generate solutions to that problem, and how they evaluate the effectiveness of candidate solutions. While research on analogy reveals structure mapping's contribution to novel or difficult problems (e.g., the tumor problem), metaphor research highlights structure mapping's potential to intervene automatically, producing source-consistent effects on judgment and reasoning. Metaphor research has also gone further to demonstrate the importance of structure mapping processes on a wide range of practically important problems (e.g., crime, cancer treatment attitudes).

QUESTIONS FOR FUTURE RESEARCH

One goal for future research is to develop a more refined understanding of when (under what conditions) people are likely to employ structure mapping when confronted with a practical problem. One factor already mentioned—conventionality—likely plays a crucial role. In the case of conventional metaphors, even subtle aspects of the situation may be sufficient to prompt problem solvers to recruit source knowledge to think through the target problem. Other factors warrant further study:

Motivation

As noted, some mappings are unconventional and require deliberate, effortful thought to create. Because processing capacity is a limited resource, we can expect that people's motivation to think about the target problem will determine whether or not they invest that effort. One candidate motive is labeled the *need for nonspecific closure*–the desire to reach *any* certain knowledge about a target rather than feel uncertain about it.[68] Initial research demonstrates that people are particularly likely to rely on metaphor when a target seems uncertain[58] or abstract,[69] suggesting that a heightened need for nonspecific closure motivates the application of structure mapping. In contrast, people with more confident knowledge about a target may feel little motivation to deploy mapping, particularly when these mappings require effort.

Another, less researched motivation is the *need for specific closure*—the desire to maintain a particular belief or attitude about a target.[68] Even if a familiar or situationally available mapping could offer a useful structure, people may reject it if that mapping highlights or downplays aspects of the target in a way that conflicts with their other ideological commitments (and initial evidence supports this view[58]). In other situations, people may employ relatively unhelpful structure mappings if only because they prop up desired beliefs about the problem or its solutions.

A third epistemic motive that may influence the role of structure mapping in problem solving is *the need for accuracy*—the desire to achieve a truthful understanding of the target problem and arrive at the objectively best solution. Here there are competing possibilities. Someone highly motivated to be accurate may seek structure in the target that can help them to gain a firmer grasp on that idea. Hence, a need for accuracy may encourage people to embrace a structure mapping that seems 'true' or useful. On the other hand, a need for accuracy may motivate people to reject *any* mapping because surface-level differences convince them that any source is irrelevant or that a target problem in best approached in strictly literal terms. In short, it is an open question whether this need for accuracy pushes people toward greater sensitivity to shared underlying structure or an emphasis on strictly literal thought.

Past research also shows that metaphor can transfer source-specific motivation to a target domain, and this can have important implications for cognition. Specifically, individuals who are highly motivated to avoid relationship-specific information similarly avoided information about political events presented using relationship (but not alternative) metaphors.[70] In the context of problem solving, selective attention motivated by the content of a source concept may similarly influence attention to the details of a target problem or its solutions. This presents an important avenue for research because it suggests that structure mapping can transfer *how* people process information about a source, in addition to the structure itself.

Affect

While we've focused thus far on purely cognitive processes and effects in structure mapping, there is a relative lack of research on how these processes interface with affect. As we noted above, there is considerable evidence that affect is a common heuristic in evaluating the effectiveness of problem solving efforts. Furthermore, many of the source domains people employ in structure mapping are often far from affectively neutral (e.g., disease, military conflict).

One possibility is that affect could transfer through structure mapping to influence responses to a problem. For example, fear appeals that communicate the disastrous effects of some problematic

behavior (e.g., smoking), motivate action only when an audience feels both (1) sufficiently afraid of the problem and (2) capable of actually addressing it.[71,72] With respect to the first, we have reviewed studies showing that mappings evoking negative imagery (e.g., *crime is a disease*) can elicit fears about the magnitude of a problem.[50,51]

Because mapping also transfers cognitive structure, it could also help people to feel capable of actually addressing salient fears. If, e.g., skin cancer is metaphorically framed as an invading army,[73] this directly implies a course of action to prevent it (e.g., setting up 'defenses,' such as using sunblock). In other words, in addition to transferring over specific affect about the source, structure mapping may also import cognitions that moderate how people respond to that affect.

Implications

The effects of mapping on problem solving span a wide range of practically important domains. This includes efforts to address political, health, and consumer problems, although the processes highlighted above likely extend to a wide range of domains.

On one hand, this role of structure mapping may be seen as a boon for problem solvers. While depression, the stock market, and cancer may be dauntingly complex at a literal level, structure mapping enables people to apply their knowledge of more familiar problems. Indeed, there may even be cases in which salient mappings for a problem or solution help people to make more optimal choices. For example, an individual who understands cancer as a *journey* may be more attuned to the need for ongoing treatment efforts and more attentive to the long-term nature of cancer recovery.

But because mapping selectively highlights structurally-consistent aspects of a target, it may downplay other critical aspects. Research shows that a single metaphor for a particularly complex concept often leads to errors in judgment through oversimplification.[74] For example, representing muscle fiber activation as the coordinated activity of a rowing team highlights the ways in which many small sources of energy create a larger force, but inaccurately implies that individual fibers work in synchrony like rowers. It is likely that many problems similarly are too complex for any single mapping to capture all of the nuances of a problem. Understanding crime as a *disease*, e.g., highlights the role of systemic causes of crime (as shown in Ref 49) but at the same time may erroneously imply that criminals lack personal agency and other aspects of human mental life.

This raises the important possibility that structure mapping may be a source of cognitive rigidity in problem solving. If a mapping downplays or misrepresents some aspect of a problem, it may prevent problem solvers from fully considering the problem or candidate solutions. To note one example above, framing cancer prevention in military terms weakened motivation to enact self-limiting behaviors that are, in fact, effective means of preventing cancer.[65] Individuals ostensibly became so focused on the implications of the mapping that the full range of helpful steps toward cancer prevention was not considered.

Does this potential for error in problem solving mean that structure mapping is best avoided? Ultimately this may be an impossible goal: Analogy and metaphor play an essential role in allowing individuals to process concepts crucial to human social life, including morality, the nature of the self, important political issues, and so on. A more reasonable goal is to encourage people to attend to the potential influences of mappings in their understanding of a problem and related concepts. This awareness may help them to make more informed and optimal choices.

CONCLUSION

The wide range of cognitive processes in problem solving has received extensive attention. Research on the role of analogy and conceptual metaphor enriches this work with an acknowledgement of the ways in which structure mapping sometimes informs efforts to solve everyday problems. Despite their differences, analogy and metaphor reflect a common and unique process of mapping, with interesting variations in conventionality (among other dimensions, of course).

Studies demonstrate that structure mapping influences whether a state of affairs is identified as a problem, how solutions are generated, and how solutions are evaluated. This research demonstrates that through structure mapping, problem solving sometimes involves information drawn from a wide range of sources outside the specific scope of a single problem at hand.

This research also points to further questions whose answers are of great scientific and practical importance. Research on problem solving requires a more integrative and nuanced understanding of the roles of structure mapping and other sources of information. Understanding how best to enhance the positive benefits of mapping in problem solving while avoiding its potential pitfalls presents an important question for future research.

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