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Mundane Comparisons Can Facilitate Relational Understanding

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Abstract

This paper addresses the role of comparison in highlighting relational structure. Specifically, we investigated whether even literal similarity comparisons (where both objects and relations match) can lead to a focus on common relations over equally suitable object matches. Whereas previous studies have demonstrated the highlighting of relations during analogical comparisons (where only relations match), the study presented in this paper suggests that even literal similarity comparisons can promote relational focus. In addition, we explore the role of types of comparison tasks (listing commonalities or listing differences). This extension follows naturally from structure-mapping theory, which predicts that in certain cases, listing differences between two things can actually lead to a heightened focus on the structure common to both.

Introduction

Newton is said to have comprehended the far-reaching influence of gravity when it occurred to him that an apple falling from a tree was in some sense *like* the motion of the planets. Einstein is said to have conceived his alternative view of gravity when it occurred to him that a man falling from the roof of a house was in some sense *like* an object freefloating in space. Both examples illustrate the power of comparison. To be sure, the thought processes leading to these ideas must have been complex and diverse, but what is common to both is that something similar was drawn from something that was prima facie very different. As such, the examples hint at the far-reaching scope of comparison and the perception of likeness.

Examples like these have led some researchers to propose that comparison acts to create a focus on common relational structure (Gentner, 1983; Gentner & Medina, 1998; Markman & Gentner, 1993b). Comparison has been shown to facilitate schema abstraction and to promote knowledge transfer. In Gick & Holyoak's (1983) classic studies that investigated analogical transfer using the Duncker tumor problem, people who compared two prior analogous stories were far more likely to transfer the solution to the tumor problem than those who read only one of the stories. Additional empirical data suggest this as well. Comparison facilitates transfer even to 'hot' interactive situations. MBA students who compared analogous cases depicting negotiation strategies were more successful in extending the learned principles to new situations than those students who did not compare cases, but were instead given them separately (Loewenstein, Thompson, & Gentner, 1999). Comparison has also been shown to facilitate comprehension of spatial relations in young children. Adapting the methods from the classic studies of DeLoache and her colleagues (e.g., DeLoache, 1987), Loewenstein and Gentner (2001) found that children who directly compared similar rooms were more likely to find an object in a similar new room than children who had not compared rooms. These findings lead to the conjecture that comparison processes may be an important route to learning deep relational knowledge (Gentner & Medina, 1998; Gentner, 2003).

In the above studies, the analogous pairs given to subjects were designed so that only the relational structure matched—e.g., X-rays and an army. This paper asks whether the highlighting of relational structure can also occur in mundane overall comparisons in which object commonalities are also present. In order to be clear about what we are claiming, consider the sentences below.

> a. The plumber inspected the new faucet.
> b. The plumber tested the pipes.
> c. The accountant checked the totals.

The process of comparison operates over both relations and object descriptions (Gentner, 1989; Holyoak & Thagard, 1989). Thus, the resultant common system can include both relations and objects in a literal similarity comparison, such as between *a* and *b*; or it can contain only common relations in an analogical comparison, such as between *a* and *c*.

The claim that comparison promotes relational focus has two forms, one obvious and one not so obvious. The obvious form is illustrated by the *a* and *c* match. In this case the resulting commonalties contain just the relational match. In this case, relational highlighting is not surprising. The less obvious claim is that *even in the case of a and b,* in which the commonalities include object descriptions as well as relational structure, the effect of the comparison process is to heighten the focus on common relations. This claim may at first seem implausible: Why should common relations be more salient than the equally preserved common objects?

The starting point for this research comes from a theory of similarity that emphasizes structural alignment and mapping of mental representations. We first briefly describe this theory and its application to similarity comparisons. Then we lay out the predictions and how these tests go beyond prior demonstrations of relational focus.

Similarity is like Analogy

According to structure-mapping theory, the core process in comparison (whether literal similarity or analogy) is aligning the representational structure of mental representations (Gentner, 1983). There is considerable empirical support for the claim that similarity involves alignment processes akin to those involved in analogical mapping (Markman & Gentner, 1993b; Gentner & Markman, 1997). This emphasis on the relations between representational elements contrasts with other approaches, such as the spatial and featural models (Shepard, 1962; Tversky, 1977).

The structure-mapping process model is instantiated in a computer simulation (SME—the Structure-Mapping Engine), which has successfully modeled a number of phenomena (Falkenheiner, Forbus, & Gentner, 1989). In SME, analogical mapping occurs via a local-to-global matching process that begins by finding all possible local matches among both objects and relations. It then invokes two structural consistency constraints—one-to-one mapping and parallel connectivity—to arrive eventually at the maximal alignment of common structure. This maximal alignment is determined in part by a bias for systematicity (that is, for interconnected relations over isolated ones, and for deeper systems of relations over shallower ones) (e.g., Gentner & Markman, 1997). A number of studies provide evidence supporting these constraints (Gentner & Clement, 1991; Gentner & Toupin, 1986).
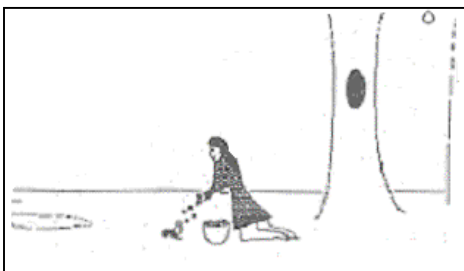
A.
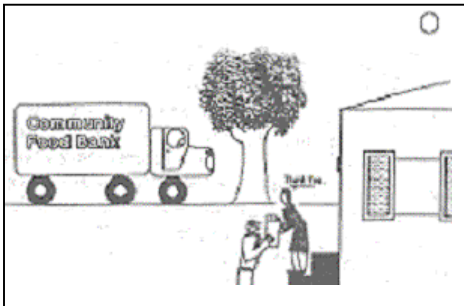
B.

Figure 1. Sample stimuli used in a cross-mapping task (from Markman & Gentner, 1993b, study 1).

In structure-mapping, because predicates that belong to connected systems are weighted more heavily than isolated predicates, the theory predicts that relational matches will in general outweigh object matches. Prior evidence for this claim has utilized cross-mapping studies, in which objects and relations are pitted against one another (Gentner & Toupin, 1986). For example, Markman & Gentner (1993b) showed people pairs of cross-mapped scenes like those in Figure 1. In A, a man from a community food bank is shown giving food to a woman; and in B, the same woman is shown giving food to a squirrel. For each pair, subjects were asked to match an object in one scene—always the cross-mapped object (the woman in scene A)—to its corresponding part in the other scene

The pairs were designed to show a strong object match, and indeed subjects who simply performed a one-shot mapping task (that is, without rating the similarity of the scenes beforehand) tended to choose the woman→woman match. However, as predicted by structure-mapping, when subjects first rated the similarity of the two scenes, they mostly chose the relational match for the woman in A—namely, the squirrel in B. This is evidence that the comparison process favors finding common relational structure rather than common object descriptions when the two are in competition.

Testing relational focus – beyond cross-mapping competition

To understand how the present study goes beyond the Markman & Gentner study, consider the following sentences.

> d. The plumber pounded the jammed nozzle.
> e. The gushing fire hose bludgeoned the plumber.
> f. The plumber hammered on the faulty stopper.

Like the picture pairs used in Markman and Gentner's study, the sentences *d* and *e* constitute a cross-mapping. There is an obvious object mapping of "plumber" to "plumber" and "nozzle" to "fire hose". Alternatively, one could align the central events described in the two sentences (*pounded* and *bludgeoned*), so that "plumber" in *d* would map to "fire hose" in *e*, and "nozzle" in *d* would map to "plumber" in *e*. Thus, this pair requires that one choose between object matches and relational matches. For adults, when relational matches are pitted against object matches, the relational match is likely to win out. Thus, cross-mapped comparisons result in relational highlighting.

But what about the pair *d* and *f,* in which both the objects and relations match? This research investigates the possibility that even in this case, common relations will become more salient than common objects.
One key line of support for the claim that even mundane overall comparisons can lead to a focus on common relations comes from a set of studies by Gentner & Namy (1999) that used a word-learning task

with children. In one study, 4-year-olds were presented with triads composed of either one standard or two standards, along with two response options. For example, in one triad the single standard was either a bicycle or a tricycle (in the single standard condition) or both (in the comparison condition). One of the response options (a pair of eyeglasses), was perceptually similar to the standard(s) but was from a different taxonomic category. The other option (a skateboard) was perceptually dissimilar to the standards, but was from the same taxonomic category. Children in the one-standard condition were told that the standard was a 'blicket' in dinosaur language and asked which option would also be a blicket. Most of the children in this condition chose the perceptual response, consistent with much prior research (Baldwin, 1989; Imai, Gentner & Uchida, 1994; Smith, Jones, & Landau, 1992).

What is more interesting, however, is that when children in the two-standard condition (the comparison condition) were given the parallel task, they behaved quite differently. When told that both standards were blickets, and asked to choose the other blicket, they chose the taxonomic response. This is a counterintuitive result: when either single standard was presented alone, the perceptually similar response was preferred. Further, the two standards shared the *same* perceptual features with each other as each did with the perceptual option. Thus, on a feature-based account, presenting the two together should have reinforced those featural commonalities, thereby leading to even more perceptual responding. However, this was not the case. When children compared the two standards, they chose the taxonomically similar alternative. Gentner and Namy concluded that the comparison task highlighted the common relational structure between the standards, and that this in turn led to the greater perceived similarity to the taxonomic response option.

However, the conclusion that this pattern of results implies highlighting of relational structure could be challenged. The claim rests on the assumption that the similarity of the taxonomic members was relational. Though there is evidence that people may form categories on the basis of common relational structure (Ahn, 1999; Gentner & Medina, 1998; Kurtz & Gentner, 2001), it is still a speculative claim. Direct evidence that comparison leads to noticing of common relational structure is needed, without the intermediate assumption that the category members share relational structure.

The present study uses stimuli that clearly separate relational similarity from object similarity. To accomplish this, sentences were used as stimuli. There are several reasons for using sentences, but the most important reason is that they allow us to establish clear relational commonalities and clear surface commonalities. As in the Gentner and Namy study, we used triads in which there were two response options: an object match and a relational match.

Experiment

In designing this experiment, one goal was to ensure that participants engaged in an active comparison process. Prior evidence suggests that participants are more likely to arrive at a common relational abstraction for a pair of items when they engage in more intensive comparison processes (such as stating commonalities) than when they merely give similarity ratings (Kurtz, Miao, & Gentner, 2000). Accordingly, participants in one comparison condition were asked to write out the commonalities for each sentence pair.

In addition to the commonality-listing task, we also included a difference-listing task. This group of participants was asked to write out the differences between sentence pairs. The task was included for two reasons. First, it addresses a potential alternative explanation for the finding, should it occur, that listing commonalities increases relational responding: namely, a kind of carryover from the first task. Suppose, as is likely on our account, that participants list relational commonalities for the pairs. Then a simple carryover or priming effect might increase their subsequent likelihood of choosing the consistent response—that is, the relationally similar response. However, if subjects who list differences also show a shift towards relational choices, then we can rule out this carryover explanation. Second, and more importantly, the difference-listing task provides an opportunity to test further predictions concerning the process of similarity comparison.

According to structure-mapping, finding differences is normally accomplished by aligning relational structure and then reading off aligned differences (Markman & Gentner, 1993). For example, Gentner and Markman (1994) found that people listed differences for similar objects more easily than for dissimilar objects, and listed more differences for similar objects than for dissimilar objects. This surprising result is complemented by a recent study in which listing the differences between similar objects actually *increased* judged similarity (Boroditsky, in press). Also, listing the commonalities among word pairs has been shown to facilitate later listing of differences for the same word pairs (Gentner & Gunn, 2001).

This suggests that even a comparison task that highlights *differences* should also lead to alignment of common structure. Thus there should be a shift towards the relational choice following a difference-listing task as well as a commonality- listing task, though the effect of the difference-listing task may not be as strong.

By using these sentence stimuli, we can test the claim that comparison processes heighten attention to common relational structure, even when there are also common aligned objects. Such a result would extend Markman and Gentner's finding that comparison highlights common relations when object and relational matches conflict. The main prediction, then, is that listing commonalities and listing differences should both lead to higher rates of relational responding than processing the sentences separately. An open question is whether, as seems plausible, listing commonalities will lead to more relational responding than listing differences.

Method

Participants Seventy-nine Northwestern students participated for partial course credit.

Design The three levels of task, listing commonalities (*N*=26), listing differences (*N*=31), and rating comprehensibility (*N*=22), were run between subjects. The purpose of the comprehensibility ratings task (the control group) was to equate the three groups in their prior experience with the standards.

Materials and procedure Participants were randomly assigned to the three conditions. In the first part of the commonality-listing (or difference-listing) condition, 18 sentence pairs were presented (12 test items and 6 filler items), and space for written responses was provided below each pair. Participants were instructed to compare the sentences and then to write out as many of their commonalities (or differences) as possible. In the comprehensibility condition, participants rated the comprehensibility of individual sentences on a scale from 1 (*not at all comprehensible*) to 9 (*completely comprehensible*). In all, 45 sentences were presented: 36 from the 18 pairs of test items and fillers, plus 9 low comprehensibility fillers specific to the first part of this condition that were designed to anchor the ratings scale.

The second phase was identical for all three groups. All participants received 18 triads (12 test item triads and 6 filler triads) in random order. Each triad consisted of a pair of sentences serving as standards (those presented in the first part of the commonalities and differences conditions, with both the order between and within pairs re-randomized); and the two response options, one an attribute match with the standards, and the other a relational match with the standards. The subject, object, and verb for the standards were chosen so that the action described in the sentences would be familiar to participants. The superficially similar option had the same subject as the standards, but was otherwise semantically unrelated. The relationally similar option conveyed an event that was similar to those in the standards, but had no object match. It was constructed with the intent of establishing a matching predicate argument structure with the standards. A sample triad is presented in Figure 2.

> The plumber tested the new faucet.
> The plumber inspected the pipes.
>
> The plumber mailed the   The accountant
> customer the bill.   checked the totals.

Figure 2. Sample test stimulus used in the experiment.

The filler triads were designed so that the correct response option shared both object and relational matches with the standard(s). The fillers were included in order to circumvent formulaic responding. The order of items and left-right placement of response options was randomized.

Even though the second task is a comparison task for all conditions, our prediction is that the more intensive prior comparison tasks of listing commonalities or listing differences should affect the rate of relational responding accordingly. The tasks were self-paced, and took about 15-20 minutes to complete.

Results

As predicted, participants who listed commonalities responded relationally more often (*M* = .84, *SD* = .14) than those who rated the comprehensibility of individual sentences (*M* = .65, *SD* = .15), $t_I(11) = 7.32$, $p < .001$, by a paired-samples t-test over items. Further, those who listed differences also responded relationally more often than those who rated single-sentence comprehensibility, $t_I(11) = 1.74$, $p = .05$. An ANOVA confirmed an overall between-subjects effect, $F(2, 76) = 3.08$, $p = .05$. A marginally significant trend suggested that people who listed commonalities responded relationally more often than those who listed differences (*M* = .76, *SD* = .15), $t_I(11) = 1.30$, $p = .10$.

Thus, the chief prediction was borne out: listing commonalities led to a gain in relational focus. In addition, the difference-listing group also showed a gain in relational focus, allowing us to discount the explanation that listed relational commonalities were simply carried over from the first part of the task.

General Discussion

We tested the prediction that comparison would lead to the highlighting of common relational structure even for literally similar pairs. Two different comparison tasks were used: a commonality-listing task and a difference-listing task. In both cases, the prediction that structural alignment would lead to a focus on common relational structure was supported.

The finding that difference listing as well as commonality listing led to heightened relational responding supports Markman and Gentner's (1996) claim that finding differences typically invites structural alignment just as does finding commonalities. Not surprisingly, the relational highlighting effect appears weaker for difference listing than for commonality listing.

The results of the study buttress the claim that comparison leads to the noticing of common relational structure. However, there are still issues to explore. Structure-mapping predicts that the differences advantage should happen primarily in the case of alignable differences (which is the result of a shared property between objects, but with each object possessing different values for that property). However, the way in which the stimuli in the experiment were structured doesn't provide evidence that alignable differences were responsible for the heightened relational focus. For example, for one item in the difference-listing task, a participant wrote, "Both coaches, but one is for the Bears and the other is for the Raiders", whereas another participant wrote, "Bears/Raiders". Now, it appears that these are both alignable differences, but it is not entirely clear that the

participants thought of them as such. It may have been the case that the second participant engaged in a rather shallow level of processing, perhaps only noting that words in the same relative location within each sentence happened to be different. It seems, then, that the written responses do not provide very many clues as to the types of differences involved in the task. However, sentence stimuli that are not matched completely may get around this limitation.

Conclusions

The current results add to the set of findings suggesting that similarity is most tractable when viewed, not as an end product or as a static mental rating, but rather as a process operating over mental representations (Medin, Goldstone, & Gentner, 1993). Furthermore, these findings suggest that similarity comparison processes may have important psychological consequences – notably, leading to a focus on relational commonalities (Gentner & Medina, 1998; Gentner & Namy, 1999). Spontaneous comparison processes may be one route by which children can use experiential learning to bootstrap their way to abstract rule-like knowledge. Clearly, this ability to sharpen our grasp of relational similarity is crucial: it is what enables the Newton or the Einstein to note the spectacular in the mundane.

Acknowledgments

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