Relational labels can improve relational retrieval

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Abstract

Retrieval that is based on common relational structure, such as an underlying principle or pattern, is useful but typically rare. Based on evidence that comparison-derived schema abstraction can improve relational retrieval, we asked whether the use of relational labels can also promote abstraction and improve relational retrieval. Using a cued-recall paradigm, we varied the presence of relational labels at encoding and test. As compared to a no-label baseline condition, relational retrieval improved when relational labels were given at encoding and at test and also when relational labels were given only at encoding. The findings demonstrate that one way to improve relational retrieval is through the use of labels that name relational structure.

Keywords: relational retrieval; relational language; inert knowledge

Introduction

When encountering a new example or problem, we sometimes retrieve examples from memory that share relational structure with the current example. This can be very useful as it allows us to transfer existing knowledge to the new example. For instance, if a social psychology student learns about the classic findings that a person's attitude can become resistant against very persuasive arguments after the person has argued against weak versions of such arguments (e.g., McGuire, 1961; McGuire & Papageorgis, 1961), then this might remind the student of how someone can become immune to a disease after being exposed to a weakened form of that disease. Based on this connection, they may be able to draw some conclusions about the new situation, such as why the attitude becomes resistant to change, or why the initial arguments against the attitude have to be weak.

As useful as it can be, relational retrieval—retrieval based only on common relational structure—is typically rare (e.g., Gentner, Rattermann, & Forbus, 1993; Gick & Holyoak, 1980, 1983; Holyoak & Koh, 1987; Ross, 1987, 1989). Instead, memory retrieval is likely to be based either on overall similarity or on surface commonalities, such as matching entities (e.g., Brooks, Norman, & Allen, 1991; Gentner et al., 1993; Holyoak & Koh, 1987; Ross, 1987, 1989). This is an instance of the *inert knowledge* problem (Whitehead, 1929) – that people are often unable to retrieve knowledge and apply it to new situations even when that information has been stored in memory (e.g., Barnett & Ceci, 2002; Bransford, 1979).

Even though relational retrieval is typically rare, it is more likely for experts in a domain. For example, when solving challenging science problems, experts often retrieve problems that share common relational structure (e.g., Clement, 1988). Likewise, the likelihood of relational retrieval is better for students with greater mathematical expertise than for novices (Novick, 1988), and mathematical expertise can predict the likelihood of transferring a solution strategy to analogous math problems (Novick & Holyoak, 1991).

What contributes to experts' improvement in relational retrieval? Two factors that might be involved are having experienced many opportunities to compare examples and acquiring a technical vocabulary. There is abundant evidence that comparison of examples can improve the likelihood of relational retrieval. When learners compare two instances of the same relational structure, the process of alignment renders their common structure more salient. This process of schema abstraction increases the likelihood of retaining this common relational structure and transferring it to other instances (e.g., Gentner Loewenstein, Thompson, & Forbus, 2009; Gentner & Markman, 1997; Gick & Holyoak, 1983; Markman & Gentner, 1993; Reeves & Weisberg, 1994; Ross & Kennedy, 1990).

In the current research, we focus on the second factor and ask how acquiring a vocabulary may impact relational retrieval[1]. As someone develops expertise in a domain, they may acquire terms that name common relations or relational patterns in that domain. We ask whether the use of such relational language can improve relational retrieval.

Relational Language

In the current research, we ask whether an abstraction process like the one that operates during comparison also applies when relational language is used. Specifically, we ask whether using known relational terms like *reciprocity* or *inoculation* to label examples promotes the abstraction of their relational structure and leads to improved relational retrieval. The idea is that using a relational term to label a situation can promote the abstraction of relational structure

[1] The value of relational language and comparison might in some cases be related because using the same term for different examples can invite comparison of these examples (e.g., Gentner, 2003, 2010; Gentner & Medina, 1998; Gentner & Namy, 1999). However, our focus here will be on the individual effects of relational language and comparison.

and change the construal of the situation by shifting the focus to its relational structure (e.g., Gentner, 2003, 2010; Genter, Angorro, & Klibanoff, 2011; Gentner & Loewenstein, 2002). This may result in improved relational retrieval in response to another example that shares the same relational structure.

Applying relational labels shares some similarities with comparison of examples, in that both involve the extraction and retention of relational structure. The difference is that in the case of relational labels, the alignment is between a labeled example and the relational structure conveyed by the label (which has already been abstracted). For instance, if the label *inoculation* is applied to a situation in which someone becomes immune to the stronger form of smallpox after being exposed to a milder form of smallpox, this invites a construal of the situation with a heightened focus on the common relational structure, such as 'exposure to a weakened form of something protects against the stronger form'. If so, then this might increase transfer to a further, more distant example of the relational structure. For instance, if someone encodes the example from medicine labeled *inoculation* and later receives an example about attitude change labeled *inoculation*, then both of the examples should be construed with a focus on the relational structure that each shares with *inoculation*. These similar relational construals should then improve the likelihood of relational retrieval of one example given the other.

The logic of the current experiment is to vary the presence of relational labels and to test the likelihood of subsequent relational retrieval. In the experiment, participants read a series of stories at encoding either with or without relational labels. Later, they were given test stories that shared relational structure with the encoding stories and asked to write out of the encoding stories they were reminded of. In one condition, the same relational labels were used at encoding and at test. The prediction is that this will lead to heightened relational retrieval, because the labels will invite the same construal across examples. Of course, if the same label is used at encoding and at test, then this leaves open the possibility that the label may also be acting as a common surface feature between examples that share relational structure.

We will also test a more interesting possibility: that labels may improve relational retrieval even if they are only present at encoding. If a relational label is applied to the initial example, then this can result in a construal in which there is a greater focus on the invited relational structure. Later, if the relational structure of the test example is apparent (or even partially apparent), then it should be more likely to match the initial (stored) example than it would have been had the initial example not been labeled. For instance, if the initial medical example is labeled *inoculation*, then this may increase its likelihood of being retrieved given a new passage involving the analogous phenomenon in attitude change.

Finally, it is possible that relational labels present at test only may likewise improve relational retrieval. There is some evidence that deriving a relational abstraction from comparison can improve relational retrieval of past examples that share the same relational structure (Gentner et al., 2009). If, as we have suggested, labels also promote abstraction of relational structure in much the same way as comparison, then they may also improve relational retrieval when they are given at test.

In the current experiment, we tested whether relational labels can improve relational retrieval in one of the ways described above. We varied the presence of labels at encoding and at test. As outlined above, the pattern of results can inform us about the underlying processes through which relational labels might be having their effect.

Logic of the Experiment

We used a cued recall paradigm similar to that used in previous studies of relational retrieval (e.g., Gentner et al, 1993). Participants studied one set of stories during an encoding phase. After a delay, in the test phase they received a new set of stories. For each story, their task was to write down any stories that they were reminded of from the encoding phase.

Each story in the test phase described the same relational pattern (e.g., positive feedback, reciprocity) as one story in the encoding phase and came from the same domain (e.g., medicine, political science) as another story in the encoding phase. Thus for each test story there were two likely retrieval candidates, one sharing the same relational pattern as the test story (the relational match), and one coming from the same domain as the test story (the domain match).

We expected that domain matches would be quite likely to be retrieved because stories from the same domain often involve both surface commonalities and associative connections. As reviewed earlier, retrieval is likely to be based on surface commonalities (e.g., Gentner et al., 1993; Holyoak & Koh, 1987; Ross, 1987) and there is also evidence that the degree of association between examples affects retrieval (e.g., Howard & Kahana, 2002; Pollio, Richards, & Lucan, 1969; Wolfe, 2005). Assuming that domain retrieval would be dominant and relational retrieval relatively rare at baseline, we could assess improvement in relational retrieval when relational labels were added.

We varied whether participants received relational labels during the encoding and test phases in a 2 x 2 between-subjects design (no relational labels at encoding or at test; relational labels at encoding only, relational labels at test only, or relational labels at both encoding and at test). The condition in which no relational labels were given during either the encoding or test phases provides a baseline of performance against which we could measure gains in relational retrieval. We tested whether (a) the use of relational labels can improve the likelihood of relational retrieval, and (b) whether this benefit occurs only when the

same relational labels are used both at encoding and at test, or whether there is also a benefit for the use of relational labels only during encoding or only during test.

The relational labels we used were schema noun labels that named the relational patterns described by the stories (e.g., *positive feedback, reciprocity, inoculation*). Schema nouns are a subtype of relational nouns, which name categories whose members share relational structure (e.g., Gentner & Kurtz, 2005; Goldwater, Markman, & Stilwell, 2011; Markman & Stilwell, 2001). Since schema nouns name entire relational structures, they seemed particularly well-suited for promoting abstraction and a relational construal of the stories.

The most obvious prediction is that giving relational labels at encoding and at test should improve relational retrieval. This effect would be consistent with the interpretation that the label invited a similar relational construal for the two examples. Unfortunately, this result by itself is subject to another interpretation. Perhaps relational labels also act as a common surface feature between examples that share relational structure. If labels invite relational construal and/or act as a common feature, there should only be a benefit of relational labels on retrieval if labels are present at both encoding and test.

The two conditions of most interest are whether participants' relational retrieval improves when relational labels are given only during the encoding phase or during the test phase. If relational labels promote a construal in which there is a greater focus on the invited relational structure, then this may enable it to be retrieved more easily if the same relational structure (or a part of this relational structure) is encountered in future situations. If this is the case, then providing relational labels at encoding should also improve retrieval. It is possible that providing relational labels at test might also improve relational retrieval. If relational labels help people abstract the named relational structure and retrieve prior examples that share the same structure, then receiving labels during the test phase may also lead to improvement in relational retrieval. In sum, the two single labeling conditions allow us to examine the effects of selective abstraction on relational retrieval. The pattern of results will inform us about how relational labels might be having their effect.

Method

Participants

Participants (N = 60, 39 female, mean age = 22.48) were recruited from the Northwestern University community and were paid or received course credit for their participation in the experiment. All participants were native English speakers.

Participants were assigned to one of the four conditions as follows: 15 participants received no relational labels at encoding or at test, 15 participants received labels only at encoding, 16 participants received labels only at test, and 14 participants received labels at encoding and at test. An additional four participants were tested but excluded from further analyses, either for failing to follow the test instructions (one participant), or for failing to respond to at least half of the test items (three participants).

Materials and Design

The materials consisted of two sets (A and B) of fourteen stories each that served as the encoding and test story sets (with A/B assignment counterbalanced). Each of these two story sets was made up of ten key stories and four filler stories. The ten key stories described relational patterns. The relational patterns were chosen to be applicable in different domains. For example, as described earlier, the relational pattern *inoculation* can appear in domain of medicine and also in the domain of psychology. Half of the key stories described causal systems (e.g., *a positive feedback system*), and the other half described other relational schemas (e.g., *reciprocity*). Some of the causal systems stories were adapted from an earlier study by Rottman, Gentner, and Goldwater (2012).

Within each of the two story sets (i.e., the encoding and test sets), each of the test stories was set in a different domain (e.g., mechanical engineering, political science, psychology). Across the two story sets, each test story matched one encoding story in terms of its relational structure, and matched a different encoding story in terms of its domain. For example, in one set, the story describing *reciprocity* was set in the domain of political science. In the other set, the story describing *reciprocity* was set in the domain of psychology, and the story set in the domain of political science described a different relational pattern.

As a check on our manipulation of domain-relatedness, we used Latent Semantic Analysis (LSA) to measure the degree of relatedness between the stories (Landauer & Dumais, 1997). For each of the ten test stories in story set A, we calculated the LSA relatedness scores (Landauer & Kintsch, 1998) to the story in set B that came from the same domain and to the story from set B that described the same relational pattern. Stories that came from the same domain had higher relatedness scores (M = 0.35, SD = 0.20) than did stories that shared relational structure (M = 0.14, SD = 0.07), $t(9) = 3.38$, $p = .008$, d =1.40. This confirmed that, as intended, stories that came from the same domain were more semantically related than stories that described the same relational pattern.

Each of the two story sets also contained four filler stories. Across the two story sets, the filler stories were matched both in their relational pattern and in their domain setting.

The presence or absence of relational labels during the encoding and test phases was varied in a 2 (label present vs. absent at encoding) x 2 (label present vs. absent at test) between-subjects design.

Procedure

There were two phases: an encoding phase and a test phase. Before the encoding phase, participants were informed that the experiment was composed of two parts. They were told that they would read a number of stories and that they would use the information they read about during the second part of experiment.

In the encoding phase, participants read one set of stories, either story set A or B. The order of the stories was randomized. If participants were in either of two labeling conditions (labels at encoding, labels at encoding and test), an additional sentence was added to the end of each story that described the relational pattern (e.g., "This is an example of *reciprocity*"). Participants were allowed as much time as they needed to read the stories.

After the encoding phase, participants completed a 15 minute filler task and then began the test phase of the experiment. In the test phase, participants received the set of stories that they did not receive during the encoding phase. For each story, they were asked to write down any of the original stories of which they were reminded. They were told that they could write down multiple original stories if they were reminded of them by one test story. Likewise, they could write down an original story multiple times if they were reminded of it by multiple test stories.

The test stories were presented one at a time on the screen, with a large text box below each story for participants to write down their responses. Participants were allowed as much time as needed to make their responses. As in the encoding phase, in the two labeling conditions (labels at test, labels at encoding and test), each of the stories ended with a sentence describing the relational pattern.

For each participant, we calculated two measures: the number of relational matches retrieved and the number of domain matches retrieved. A trained research assistant, who was blind to condition, coded the responses as *relational matches*, *domain matches*, or *other* responses. *Other* responses included extraneous retrievals that were neither *domain matches* or *relational matches,* and responses that were ambiguous or that did not provide enough information to be classified.

Results

As predicted, relational labels led to more relational retrievals and fewer domain retrievals overall. Label condition had an effect on the number of relational matches, $F(3, 56) = 15.51$ $p < .001$, $\eta^2 = 0.454$, and domain matches, $F(3, 56) = 3.51$, $p = .021$, $\eta^2 = 0.158$, retrieved. As expected, Tukey HSD tests[2] revealed that participants who received labels at encoding and at test retrieved more relational matches ($M = 6.86$, $SD = 2.45$) than participants who received no labels ($M = 1.87$, $SD = 1.60$), $p < .001$, $d = 2.52$, participants who received labels at encoding ($M = 4.13$, $SD = 2.23$), $p = .005$, $d = 1.21$, and participants who received labels at test ($M = 2.81$, $SD = 2.04$), $p < .001$, $d = 1.87$ (see Figure 1). More interestingly, participants who received labels only at encoding also retrieved more relational matches than participants who received no labels, $p = .023$, $d = 1.21$.

Domain matches showed a somewhat complementary pattern. Participants who received no labels retrieved more domain matches ($M = 3.60$, $SD = 1.96$) than participants who received labels in both the encoding and test phases ($M = 1.43$, $SD = 1.55$), $p = .015$, $d = 1.27$. There were no other differences between conditions in the number of domain matches retrieved. There were no differences between conditions in the total number of items (*domain*, *relational*, and *other*) retrieved, $F(3, 56) = 1.76$, $p = .166$, $\eta^2 = 0.086$.

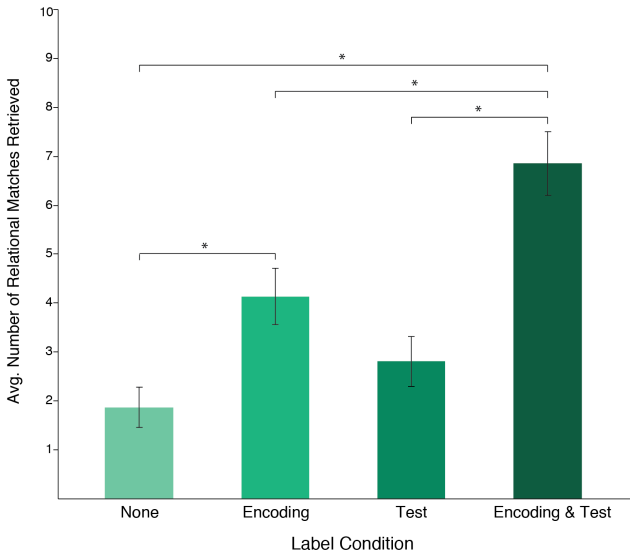

Figure 1: The average number of relational matches retrieved by condition.

Discussion

As predicted, we found that relational labels are able to improve relational retrieval. Relational retrieval improved over the baseline level when participants received relational labels at encoding and at test. More interestingly, relational retrieval also improved significantly when participants received relational labels only at encoding. There was evidence that relational labels can also promote a relational focus: participants who received relational labels at encoding and at test retrieved fewer domain matches than did participants who did not receive labels.

Earlier, we suggested that the use of known relational labels might improve relational retrieval by promoting a consistent relational construal of examples that share the same label. Further, we proposed that if an example is construed with a focus on the relational structure invited by the label, then this construal might be more likely to be

[2] All of the post-hoc tests were Tukey HSD tests.

retrieved in response to another example that shares the same relational structure. Finally, we suggested that if a label promotes abstraction of relational structure, that this might improve the likelihood of retrieving prior examples that share this relational structure. We found evidence for the first and the second predictions, but not for the third.

The likelihood of relational retrieval was greatest when relational labels were present at both encoding and test, consistent with our hypothesis that labels promote a consistent relational construal (though, as noted earlier, it could also have resulted simply through labels acting as a common feature). Turning to the second prediction, we found that relational labels at encoding improved relational retrieval. This suggests that the labels promoted abstraction and storage of the named relational structure so that it could be retrieved more easily when a test example shared the same relational structure.

We did not find an effect of labels at test. One reason for this asymmetry between encoding and test may be that relational labels at encoding could have primed people to adopt a relational focus that carried over into the test.

At the start of the paper, we raised the question of why relational retrieval becomes more likely with domain expertise. Our findings suggest that one factor may be learning a technical vocabulary to name relational patterns in the domain.

The present findings have implications for learning and education. In order to promote relational retrieval and transfer, it could be useful to provide learners with labels for important relational structures. Our findings suggest that relational labels may highlight relational structure and make it more likely that it will be accessed again in the future. Additionally, the finding that relational retrieval is best when the same labels are used at encoding and retrieval suggests that labels for relational structures should be consistent. This fits with Forbus et al.'s (1995) claim that uniform relational encoding promotes relational retrieval.

Our findings are compatible with prior work demonstrating that other kinds of relational language can improve relational retrieval and transfer. For example, Clement, Mawby, and Giles (1994) found that using the same or synonymous verbs to describe relational structure in analogous situations improved the likelihood of relational retrieval. This suggests that using relational terms that invite a similar construal of situations, even if the labels are not identical, can increase the likelihood of noticing their similarity. Another finding related to this work is that receiving relational terms when learning about a new domain can improve the likelihood of relational transfer (Son, Doumas, & Goldstone, 2010). In Son et al.'s (2010) studies, participants completed a tutorial about a domain they did not know about (Signal Detection Theory) and later solved transfer problems that involved the same principles. Half of the participants received relational terms (e.g., *target, distracter, false alarm*) in the tutorial. Since the domain was new to participants, these particular uses of the terms were novel to them. The studies manipulated whether the semantics of the relational terms matched the tutorial scenario and whether the tutorial and transfer scenarios were easily alignable. The use of relational terms improved transfer performance the most dramatically when the semantics of the relational terms matched the tutorial and when the tutorial and transfer situations were easily alignable. These findings are consistent with the framework we presented earlier. If a relational term already had some initial stored meaning, then if it were applied in a new context (the tutorial scenario), this should lead to an alignment that resulted in the abstraction of their common relational structure. If participants then received the easily alignable transfer scenario and attended to its identical relational structure, then they should be able to retrieve the past case that shared this relational structure and transfer solution strategies from it to the transfer scenario.

In sum, the current research suggests that one way to improve relational retrieval is through the use of relational labels. This raises a number of interesting questions about how relational labels bring about this improvement. In this research, we investigated the effects of known relational labels. What effects would unknown or partially understood labels have? What would be the most effective way to introduce new vocabulary to improve relational retrieval and transfer? Would the benefits of relational labels on retrieval remain with greater delays? This line of research promises to shed light on the way in which symbolic learning and analogical processes combine in the acquisition of expertise.

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