The Fate of Irrelevant Information in Analogical Mapping

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Abstract

Research on analogical mapping has not yet focused on the fate of information about the base and target domains that is not relevant to the correspondence. We suggest that there are two methods for dealing with irrelevant information in analogies. Nonalignable objects are ignored, while irrelevant attributes of alignable differences are packed away using a process that is a long term equivalent to the suppression process observed in the text comprehension literature. We report one study that supports this hypothesis by demonstrating that unpacking irrelevant information interferes with memory for domains involved in a comparison.

Introduction

Analogical reasoning allows people to compare across domains that might not seem similar on the surface (Gentner, 1983; Holyoak & Thagard, 1995; Keane, Ledgeway, & Duff, 1994). For example, the atom is like the solar system, because something (electrons and planets) revolves around something else (the nucleus and the sun) in each. An open question in analogy research is what happens to the knowledge that is not relevant to this similarity (e.g., electrons are very small and planets are very large)? Most research on comparisons and analogies has focused only on the relevant information. However, the fate of irrelevant information such as the size of the orbiting object in the above example can have important implications for models of analogy and comparisons in general.

In order to place this issue in context, we first discuss the structural alignment process. We then propose a mechanism for dealing with irrelevant information, called *packing*, and compare it to a similar mechanism in language comprehension. Finally, we report an experiment testing this mechanism.

Irrelevant information in analogy

The structural alignment process is used to compare two domains in an analogy. The process operates over structured representations in which the relations between objects are explicit. This leads to two types of information that can be used in the analogy: relational information and object information. Relational information is simply information about the relations between objects, while object information includes the relations the object participates in and the attributes of the object. In an analogy, the two domains are aligned so that their common relational structures are placed in correspondence, and this leads to relational information becoming focal (Markman & Gentner, 1997).

In structural alignment's original formulation, only relational information was used in the comparison of domains (Gentner, 1983, 1989). However, when the theory was extended to ordinary similarity comparisons (Gentner & Markman, 1997; Markman & Gentner, 1993; Medin, Goldstone, & Gentner, 1993), object attribute information became relevant. In a similarity comparison, if the object match is better than the relational match, then it will be preferred. There is also evidence that attribute information influences analogical comparisons. For example, analogs are easier to retrieve if they share attribute similarity to the target than when they share only relational similarity (Gentner, Rattermann, & Forbus, 1993). The fact that attribute information is available in analogical comparisons raises an important question: How does structural alignment deal with attribute information in analogies, where it is not relevant?

One way in that superfluous attribute information might adversely affect the comparison process is by taxing working memory. Recently the role of working memory in analogy has become a topic of study (Hummel & Holyoak, 1997; Waltz, et al., 2000). One finding from this work is that straining working memory hinders the discovery of common relational structures. This is because relational matches take up more working memory capacity than do surface (attribute) matches. Thus anything that decreases the working memory load (e.g., making attribute information less available) will facilitate relational comparisons.

Structural alignment handles some irrelevant information through the concept of alignability. Alignable objects, or objects that participate in the relational correspondence, are relevant to the comparison. In analogies, these objects are generally *alignable differences*, i.e., nonidentical objects that are

placed in correspondence by virtue of playing a common role in a matching relational structure. Alignable differences can be contrasted to *nonalignable differences*, which are objects that do not participate in the common relational structure. Alignable differences are more focal to comparisons than are nonalignable differences.

In this paper we are interested in a second type of irrelevant information that has not received much attention in the analogy literature. In particular, when an alignable difference is found, some of the attributes of the corresponding objects are likely to be irrelevant to the relational match. For example, in Figure 1, the pig in the top scene and the baby in the bottom scene are an alignable difference, because each is making a mess. Attribute information about the pig such as its snout and ears are not relevant to the relational match. Is information like this treated as focal to the comparison because it is part of an alignable difference, or is it treated like a nonalignable difference because it is irrelevant to the relational correspondence?

Packing and Suppression

The comparison process might deal with irrelevant attribute information by packing it away, or making it less available for processing. On this view, when a representation is packed during a comparison, the representations involved are changed so that only the information relevant to the match between domains is immediately available.

A similar mechanism—called *suppression*—has been suggested in the language comprehension literature. Suppression inhibits superfluous information about a word or concept during comprehension. For example, in the sentence "He won the match," borrowed from Gernsbacher & Robertson (1999), the inappropriate meaning of "match as a stick used to light a fire is inhibited. This mechanism is also useful for limiting the amount of information in working memory during processing. Nonetheless, there are key differences between the processes of analogical comparison and language comprehension that might limit the utility of a suppression mechanism in analogical reasoning. For one, language comprehension - and therefore suppression - occurs very rapidly, while analogies form over a longer period of time. In addition, suppression is short-lived, because the suppressed meaning of a word might be needed (and therefore accessed) in subsequent sentences. In contrast, packing involves representational change, and so we would expect longer-term effects than those observed with suppression.

If irrelevant information about a comparison is packed away, then attributes of alignable differences that are irrelevant to the relational match should be treated like nonalignable differences in comparisons. We tested this possibility by extending a previous study

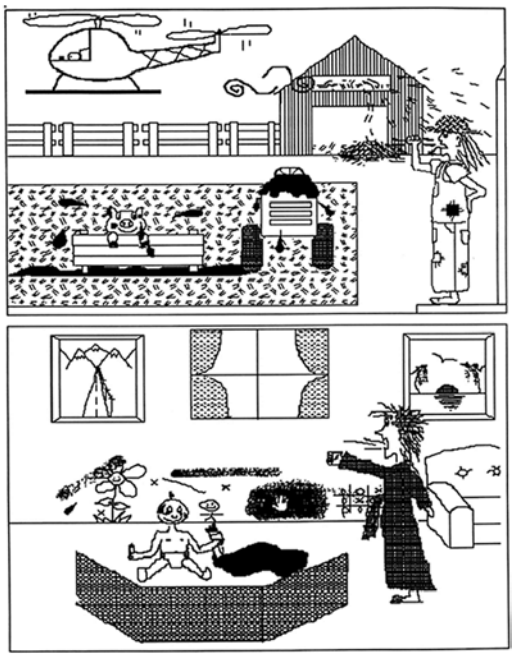

Figure 1: Example Scene Pair. In the top scene the pig is an alignable difference and the helicopter is a nonalignable difference.

by Markman & Gentner (1997). Their study showed that nonalignable differences make poor recall cues, while alignable differences make effective recall cues. In this experiment, subjects were shown pairs of scenes like the one in Fig. 1, and were asked to rate their similarity. As in Fig. 1, there was a *target scene* on top, which contained both alignable differences (e.g., the pig) and nonalignable differences (e.g., the helicopter) with the *comparison scene* on the bottom. After a filler task, subjects were given pictures of objects that were either alignable differences (the pig) or nonalignable differences (the helicopter), and they were asked to recall as much as they could about the scene in which the object had originally appeared. Subjects recalled more information when given the alignable cues than when given the nonalignable cues. This finding suggests that alignable differences are more focal than nonalignable differences.

What aspect of the alignable object is making it a good retrieval cue? The packing mechanism we propose suggests that the connection of the object to relational information is important for retrieval, and that the attributes of the object that are irrelevant to the relational match are packed away. If these attributes are made more salient, the alignable object may be treated more like the nonalignable object, and its efficacy as a recall cue will decrease. To test this idea we added an *unpacking task* in between the comparison and recall tasks of the Markman and Gentner (1997) experiment. In the unpacking task subjects were shown either the alignable or nonalignable difference from the

original scene, and were asked to describe what the object looked like. Listing properties of the objects should cause subjects to focus on the attribute information. If the comparison process made this information less available by packing it away, then when this object is later used as a retrieval cue, it should be ineffective. In particular, the encoding specificity principle suggests that the likelihood of retrieving an item in memory increases with the similarity between the context at retrieval and the context at encoding (Tulving & Thompson, 1973). Thus, if the unpacking task focuses subjects' attention on irrelevant information that was packed away during comparison, the alignable object should no longer be an effective recall cue. In addition, because nonalignable objects are not emphasized by the comparison process, unpacking them should not have any effect on their efficacy as recall cues.

In addition to the unpacking task, we added a packing task in between the comparison and recall tasks. This task was designed to reinstate the analogical mapping. First, during the initial comparison, people were asked to label each pair. This label generally referred to the relational match between the pictures. Later, subjects were asked to recall the titles. Recalling the titles should reinstate the relational mapping for the pair of scenes given that title, resulting in a pattern of recall similar to that observed by Markman and Gentner (1997), with alignable objects serving as effective cues and nonalignable differences as poor recall cues.

In pilot experiments conducted with the packing and unpacking tasks, the results fit with these predictions. When given the unpacking task, alignable cues were no longer effective recall cues. In contrast, when given the packing task, alignable objects retained their efficacy as recall cues. In the present experiment, each subject completed both the packing and unpacking tasks before recall. We predict that the tasks that subjects do last (before recall) should have the most influence on their ability to recall the original scenes. If subjects complete the unpacking task last, the unpacked alignable cues should be no better than the nonalignable cues because attention is focused on the irrelevant attributes. In contrast, if they complete the packing task last, and thus reinstate the relational mapping between scenes, the alignable cue should be a better recall cue than the nonalignable cue.

Method

Participants

Subjects were 172 undergraduates at the University of Texas, Austin, who participated for course credit. The data from 44 subjects was not used due to their failure to follow directions. Most of these either listed properties during the recall task or failed to complete one of the tasks. This left 128 subjects for analysis.

Procedure

The procedure is summarized in Figure 2. As this is a between subject design, each subject saw the tasks in the order specified by either the right or left column in this figure.

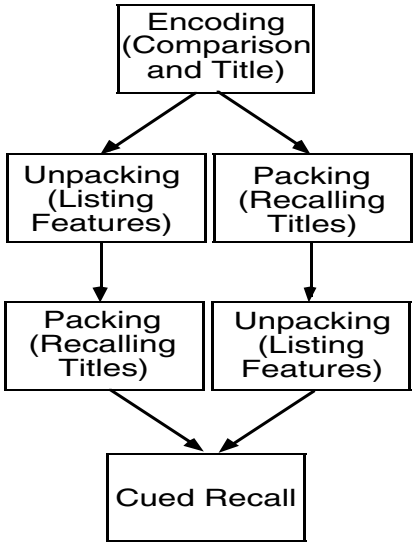

Figure 2: Design of the Experiment.

Subjects sat in cubicles and performed the experiment at their own pace. They were instructed to fill out a set of packets in order, from top to bottom, without looking back or ahead. The Comparison Task packet, which was always completed first, instructed subjects to look at each pair of scenes and rate their similarity on a nine-point scale. They were also instructed to write a descriptive title for the pair of scenes at the bottom of the page after rating their similarity. Participants took approximately 5-10 minutes to complete this task. Subjects then completed an unrelated filler task that took approximately 15-20 minutes.

After the filler task, subjects were given either the Packing Task packet or the Unpacking Task packet. In the Packing Task, subjects wrote down as many of the titles that they had given the scene pairs as they could remember. In the Unpacking Task, subjects wrote down as many properties of the objects, which had been either alignable or nonalignable objects in the comparison scenes, as possible on the lines provided. Each subject completed both the Packing and Unpacking Task. They then completed another unrelated filler task, which took approximately 15-20 minutes.

Finally, subjects were given the cued-Recall Task packet. They were told that they would see a series of objects that had appeared in the scenes they had seen earlier. They were instructed to write down as much as they could remember about the scenes in which the objects had originally appeared. These objects were

either the alignable or nonalignable objects from the comparisons scenes, as in the Unpacking Task.

Design

The study used a 2(Task Order: Packing Last vs. Unpacking Last) X 2(Unpacked Object: Alignable vs. Nonalignable) X 2(Recall Object: Alignable vs. Nonalignable) design. All ten items were run in all conditions. Task order was between subjects. A total of 8 subjects was required to get one observation for each item in each condition.

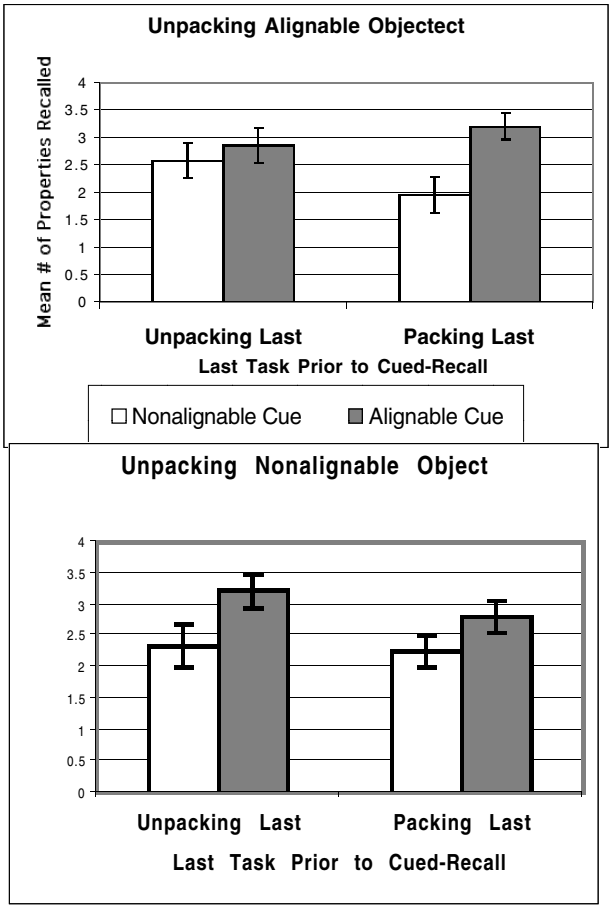

Figure 3a & 3b: Mean number of Properties Recalled.

Results

Figure 3a shows the pattern of recall for subjects who unpacked the alignable object during the Unpacking task. Figure 3b shows the recall data for subjects who unpacked the nonalignable object.. A repeated measures 2(Task Order) X 2(Unpacking) X 2(Recall) ANOVA was performed, by item, on the mean number of properties recalled. There was a main effect of recall, $F(19,1) = 6.33$, $p < .05$. This reflects the fact that alignable cues are generally better than nonalignable cues. There was also a significant Task Order by Recall interaction, $F(19,1) = 2.41$, $p < .05$. As predicted, there was a significant Task Order by Unpacking by Recall interaction, $F(19, 1) = 8.76$, $p < .05$.

The critical predictions for this study center on the conditions in which the alignable difference was unpacked. When the unpacking task was done last (i.e., most recently before recall), we expected this task to interfere with recall. In this case, the alignable difference should not be a good retrieval cue. In contrast, when the packing task was done last, subjects should be able to reinstate the analogical mapping. In this case, the alignable difference should be a much better retrieval cue than the nonalignable difference. Consistent with this prediction, when subjects completed the unpacking task last and unpacked alignable objects, the difference between alignable vs. nonalignable recall cues was not significant, $t(38) = .27$, $p > .10$. However, as predicted, when the packing task was completed last, the alignable cue was a better recall cue than the nonalignable cue, for subjects who unpacked the alignable object, $t(38) = 3.03$, $p < .05$. These data are shown in Figure 3a.

A different pattern of data was obtained when the nonalignable difference was unpacked. In this case, unpacking should not affect the efficacy of the alignable difference as a retrieval cue. Consistent with this prediction, subjects recalled more differences given the alignable difference cue than given the nonalignable difference cue regardless of whether the nonalignable difference was unpacked before or after the packing task was performed. These data are shown in Figure 3b.

Further tests were performed taking into account whether subjects remembered the title for the scene. This analysis is important for determining if it was the reinstatement of the relational mapping through recalling the title that resulted in the different patters of recall. For this analysis an additional factor, Title Recall, was added to the previous analysis. In the packing last condition, subjects who unpacked the alignable object and received the alignable recall cue recalled significantly more properties of the original scene when they recalled the title ($m = 3.97$) than when they did not ($m = 2.48$), $t(38) = 2.36$, $p < .05$. The same was true for subjects in the unpacking last condition. They recalled more when they remembered the title ($m = 3.47$) than when they did not ($m = 2.08$), $t(38) = 2.63$, $p < .05$. This finding suggests that successfully recalling the title of a pair, and thus reinstating the mapping, was beneficial for later recall.

We also looked at whether subjects recalled at least one thing about the original scene in the recall task. This tells us whether they were able to retrieve the original representation of the scene. The mean

proportions of subjects recalling at least one property of the scene are presented in Table 1. The proportions data shows the same pattern that the mean recall data showed. A 2(Task Order) X 2(Unpacking) by 2(Recall) ANOVA was performed on the proportions data, and showed the same results as the mean recall data. There was a main effect of recall, $F(19, 1) = 18.92$, $p < .05$, again showing that alignable cues are generally better than nonalignable cues at facilitating recall. Again, there was also an Order by Recall interaction, $F(19, 1) = 6.35$, $p < .05$. Most importantly, the Order by Unpacking by Recall interaction was significant, $F(19, 1) = 9.22$, $p < .05$. Thus the results exhibited the same pattern both for total amount of recall as well as proportion of subjects who recalled anything about a scene. This finding suggests that the packing task facilitates access to the original mapping rather than increasing the availability of additional properties of the scene.

Table 1: : Proportion of trials on which one or more properties were recalled

	Unpacking Alignable Object	
	Alignable Cue	Nonalignable Cue
Packing Last	0.70	0.39
Unpacking Last	0.58	0.51
	Unpacking Nonalignable Object	
	Alignable Cue	Nonalignable Cue
Packing Last	0.63	0.47
Unpacking Last	0.66	0.46

Discussion

This study provides evidence that information about alignable differences that is not relevant to the relational match is packed away during comparison. As expected, when people unpacked information about the alignable difference by listing properties of it, the efficacy of the alignable difference as a retrieval cue was reduced. Nonalignable differences, which are not focal in comparison, were not influenced significantly by the unpacking task. These data did not simply reflect a general interaction between the packing task and the retrieval task, because performing the packing task (in which subjects recalled titles they had given to the pair) restored the efficacy of the alignable difference as a recall cue.

It is straightforward to view the packing task as increasing the salience of properties of the alignable differences that had been packed away. It is less clear what is happening during the packing task. We suggest that recalling the title causes subjects to reinstate the relational mapping. One piece of evidence in favor of this interpretation is that recalling the title provides a significant boost in the level of recall. One aspect of the data that bears further scrutiny is the observation that successfully recalling the title of a pair increased the efficacy of the alignable cue regardless of whether the unpacking task was done before or after unpacking the alignable object.

This experiment raises several questions about the packing phenomenon that can be addressed in future research. First, how long lasting are the representational changes that occur when a representation is packed or unpacked? The results of this experiment demonstrate that the effects of packing or unpacking a representation last at least 10-15 minutes. This time course contrasts with the suppression mechanism (Gernsbacher & Robertson, 1999), which lasts a much shorter period of time. Future research could examine the effects of these tasks over longer delays.

A related question involves how packing or unpacking a representation affects future comparisons using that representation. One possibility is that the role of surface similarities, which have been shown to figure prominently in the early stages of comparisons (Goldstone & Medin, 1994; Ratcliff & McKoon, 1989) might be attenuated if packing makes these surface features less available than relational information.

This research is an initial step toward exploring the fate of irrelevant information in comparisons. The packing phenomenon is likely to be useful in guiding future research. It is consistent with the current interest in the role of working memory in analogical mapping, and may prove useful in answering questions about how relational information and working memory interact. In addition, it may provide valuable constraints for current models of analogy, which typically focus selectively on the relevant information in a comparison.

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