Representational Issues in Analogical Transfer

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Abstract

Lack of transfer may result in part from a critical, though often ignored factor: the form of the initial representation of information during the process of analogical transfer. Using a Gick and Holyoak (1980, 1983) replication, in which subjects read a story in the guise of a memory experiment, subjects were later required to solve a problem which could be solved using an analogous strategy suggested by the story. Transfer performance was measured by the presence or absence of this target solution in subjects' protocols. The text of the original General story (from Gick & Holyoak) was modified slightly in one condition, where one role in the story was replaced by another type of actor. The changes were minor, as shown by the fact that the story modification did not affect similarity ratings between the story and problem. However the changes did appear to affect subjects' initial representation of the story and, as a result, improve subsequent transfer to the problem. The results indicate that forming an initial representation of the story that is congruent with important features of the problem is critical for analogical transfer. Subjects' abstraction of a general problem solving schema is an inadequate explanation of these results.

Introduction

Contrary to naturally occurring examples of analogical reminding, many psychological experiments have demonstrated that people have a difficult time remembering and utilizing prior examples that are only abstractly related to the current situation (Holyoak & Nisbett, 1988). Despite all the attention lack of analogical transfer has received, key factors remain to be addressed about the transfer problem. In this paper, we argue that the case against analogical reminding is limited by a failure to adequately take into account subjects' initial memory representation of presented material.

Analogical transfer is important to study because of its obvious significance in learning and problem solving (Ross, 1987). In addition, however, we believe that investigating analogy is an appropriate method to gain insight about the representation of information in memory. Retrieval has often been assumed to be an automatic process that is dependent solely on matching an input to the contents of memory (Holyoak & Nisbett, 1988). Our basic contention is that such a "simple memory" model of episode retrieval will not account for the examples of reminding that do occur in the world. This "simple memory" model, which underlies many investigators' approaches to analogical transfer, involves the use of an overall similarity metric to identify the episode in memory with the most feature overlap (after Tversky, 1977). However, it appears that content feature matching alone is not sufficient to account for the richness of analogy observed in natural settings. Instead, we argue for a more complex model of memory-based analogy, where the determining factor in retrieval is the quality of the original encoding. For example, a great deal of inference is required to fully understand a story containing abstract relations as well as content features. Analogical transfer will not occur if the understander fails to perform elaborative inferences describing the relations between features in the example. Building an initial representation that contains both the abstract and content features is critical for any later analogical use based upon them. Thus, the ability to use analogies depends on efforts towards elaborative encoding of initial episodes. That encoding may be the key to analogy is supported by Gick and Holyoak (1983), where multiple exemplars in encoding produced better transfer rates, and by Seifert, McKoon, Abelson, and Ratcliff (1986), where abstract remindings occurred when subjects were given plenty of time to encode and summarize the initial stories.

How might representation play a role in lack of transfer? Consider Gick and Holyoak (1980, 1983), which concluded that people are unable to apply a general strategy learned in one situation to another. In one of their experiments, subjects read a story under the guise of a memory experiment. The story, titled "The General", describes a general's exploits in overthrowing a dictator (see Table

1). Following the story, subjects were given a problem to solve, Duncker's (1945) ray problem (also included in Table 1).

Table 1

The General

A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned that the dictator had planted mines on each of the roads. The mines were set so that small bodies of men could pass over them safely, since the dictator needed to move his troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighboring villages. It therefore seemed impossible to capture the fortress. However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator.

The Ray Problem

Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either. What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue?

General Story and Ray/Tumor Problem from Gick and Holyoak (1980, 1983).

The plan used by the general to capture the fortress may be adapted into an analogous solution to the ray problem. The doctor can direct several low intensity rays from different sources to converge on the tumor. Gick and Holyoak's results were that only thirty percent of

subjects applied the strategy from The General story to the ray problem. Even when told to use the same solution, only some of the subjects (75%) were able to apply it correctly. According to Gick and Holyoak (1983), analogical transfer depends on subjects' ability to abstract a "convergence schema" from the story and problem. The schema, as proposed by Gick and Holyoak, describes problem types for which the convergence solution is an appropriate plan. It contains commonalities between separate episodes only in terms of problem solving actions and states.

In our view, the convergence schema cannot be the sole determinant of transfer. In order to be reminded of the prior story, one must have encoded that story with a similar set of dominating features. Subjects' original encoding may not have included the particular inferences necessary to generate the connection between the stories. Of course, it may be possible upon reflection to identify an analogous relationship; however, the critical question in spontaneous analogy is not whether you can generate such a link given the two cases, but whether each case individually sets up a memory representation such that they are likely to be similarly encoded into memory.

From this perspective, it becomes clear that an important factor is how each episode is structured for presentation, so that the dominant features one expects to be encoded a priori are in fact the ones encoded by subjects. In the present experiment, we attempted to manipulate the representation formed for the story to affect the rate of transfer to the problem.

The present experiment is, in part, a replication of Gick and Holyoak's (1980, 1983) transfer experiments. Subjects are presented with a story which introduces a solution to a problem. Later, they are given an analog problem in a different domain to solve. One condition included the story and problem as in Gick and Holyoak (1980), as shown in Table 1. In a second condition minor modifications were made to the story in an effort to alter subjects' initial representations of the story to facilitate transfer to the problem. Specifically, the problem suggests the need to destroy an "enemy within" the body-- the tumor. However, this role is more difficult to observe in The General story. In the original story, the presence of the dictator was the status quo. As far as the reader

can tell, the dictator had always controlled the fortress. A representation of this point may be quite different from that for the tumor in the analogous portion of the ray problem. A tumor is an object that has appeared (possibly suddenly) in the body. It would not be represented as the status quo. Rather, the appearance of a tumor is more like a sudden invasion of some foreign agent. The new version of The General story, shown in Table 2, retells the story, simply replacing the dictator from the original version with "terrorists".

Table 2

The General- Terrorist version

A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads led to the fortress through the countryside. **A small group of terrorists had taken over and barricaded themselves in the fortress. An army** general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned that the **terrorists** had planted mines on each of the roads. The mines were set so that small bodies of men could pass over them safely, since the **terrorists** needed to move troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighboring villages. It therefore seemed impossible to capture the fortress. However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the **terrorists.**

Revised General Story - terrorist version. Items in boldface were changed in this version from the original in Table 1.

By replacing the dictator with terrorists in the new version, we have highlighted this perspective, call it the "enemy within" perspective in The General story. When a memory representation for the terrorist version is set up, it should now reflect the "enemy within" perspective. The terrorist version thus highlights an additional commonality with the ray problem. Note that this new commonality is not part of the convergence schema.

Method

Subjects. Subjects were 36 University of Michigan undergraduates who participated for credit in a psychology course.

Materials. Duncker's (1945) ray problem and The General analog from Gick and Holyoak (1980, 1983) were used, along with The General- terrorist version. All materials are displayed in Tables 1 and 2.

Procedure. 21 subjects read the original version of The General and 15 subjects read the terrorist version for 3 minutes. They were then asked to write their recall of the story. After protocols were written, subjects attempted to solve the radiation problem. Following this, subjects were given a hint to "propose a solution suggested by the story." Finally, subjects were asked if they had seen the story or problem before in any context (and if so, discarded from the analysis).

Results

Table 1 shows the proportion of subjects who proposed the convergence solution to the ray problem after reading the original and the terrorist versions of The General. The left columns indicates the proportion who transferred the solution strategy spontaneously, without any hint to use the story. The second column gives the total proportion of subjects who transferred successfully after being told to use the story (this column includes the subjects from the first column). The last column gives the proportion of subjects who did not propose the convergence solution.

Table 1

	Before Hint	After Hint	No Transfer
Original Version	.19	.62	.38
Terrorist Version	.40	.60	.40

A chi-square test for association revealed that the proportion of subjects who transferred before the hint was significantly greater in the terrorist story condition ($\chi^2(2) = 3.94$, $p < .025$).

Discussion

The modifications in the General story, though minor in amount of textual change, were successful in increasing the rate of transfer. The point made by this manipulation is more subtle than saying that more similar stories result in better transfer; rated similarity when given both analogues is the same in the original and the changed versions. An independent group of 19 subjects given either the original version and the ray problem, or the terrorist version and the ray problem were asked to rate the similarity of problem to story on a scale from 0 - 10, where 0 was labelled "not at all similar" and 10 was labelled "extremely similar." No explicit instructions regarding similarity judgments were given. The mean ratings given were 7.9 for the original version and 7.6 for the terrorist version. This difference is not significant ($t(17) = 0.21$, $p > .8$).

Therefore, the changes in the terrorist version did not result in a "more similar" judgment when story and problem are compared. Instead, the representation formed when reading the changed story resulted in better analogical access and transfer when tested on the ray problem. The critical point to be made here is that the features likely to be used at encoding will dominate any use of the episode in analogical processing. Therefore, care must be taken to determine the nature of the representation built for each single presentation of each example, rather than the perceived similarity during comparison.

The ability to be reminded based on abstract features requires encoding both episodes with similar features. Because the analogues used in experiments require a fairly sophisticated representational system to characterize the target similarities, care must be taken to ensure that the representation subjects take away from their presentation must be ones that are candidates for transfer. Because of the dependence on materials, and in particular the use of a small set of classic examples for replications and extensions, conclusions are dependent on ensuring that the materials

satisfy the above constraints. When they do, they provide a methodology for examining the features people encode about the world that do lead to transfer to new problem domains.

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