Bulletin of the Psychonomic Society
1993, 31 (5), 485-487

Analogical transfer: The roles of schema abstraction and awareness

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This study investigated two aspects of analogical transfer: first, whether transfer to a target domain can be facilitated by particular kinds of encoding of the base domain, and second, whether conscious reminding of the base domain is necessary for transfer to occur. Two experiments showed that transfer can be facilitated when only a single exemplar from the base domain is used if the exemplar is encoded in such a way that the underlying schema is represented. It was also shown that conscious reminding of the base domain is not a necessary condition for transfer, but when subjects are aware of the underlying schema while solving the target problem, transfer always occurs.

Traditionally, analogical problem solving has been broken down into four basic processes: (1) constructing a mental representation of a problem (the target domain), (2) noticing a base domain of preexisting knowledge as a potentially relevant analog to the target, (3) constructing a partial mapping between the base and target domains by identifying the components that play similar roles, and (4) extending this mapping to generate rules that can be applied to the target in order to achieve a solution (Holland, Holyoak, Nisbett, & Thagard, 1986). Less emphasis has been placed on how the base domain itself has been encoded and thus how its components have been represented. The underlying structure of the base domain is often not salient, because it is "buried" within a context that is superficially dissimilar to that of the target. One would expect it to be difficult to notice an analogy spontaneously if the base domain was represented in terms of its specific objects rather than the relations among them (Gentner, 1989).

Gick and Holyoak (1983) suggested that the induction of an abstract explicit schema that highlights the similar structural components of the analogs and ignores their distracting surface features facilitates analogical transfer. They asked one group of subjects to compare two stories that were similar in structure to Duncker's (1945) radiation problem, and another group to compare two stories, only one of which was structurally similar to the radiation problem. It was assumed that comparing two structurally similar stories would induce an abstract schema, whereas comparison of dissimilar stories would not. Consonant with this hypothesis, facilitation of transfer was found only in the group that received the structurally similar stories. Gick and Holyoak suggested that an abstract schema formed through comparison of two or more concrete exemplars was optimal for transfer since it highlighted structural correspondences and deleted irrelevant surface differences between the base and target domains. If this assumption is correct, then one should expect transfer to be improved even from a single exemplar of the base domain, as long as an abstract schema of the domain has been encoded as well. The present experiments explored this hypothesis. They also explored how abstract such a schema needs to be. It is possible that emphasizing those surface features of the base domain that highlight the shared structural similarities is sufficient to mediate transfer, without couching that information in a highly abstract form.

Although not explicitly discussed in the literature, it appears that the process of "noticing" the base domain has been assumed to be a conscious process. It is for this reason, presumably, that Gick and Holyoak called the requisite schema "explicit." Surprisingly, this assumption appears not to have been experimentally tested. Therefore, the current experiments also asked whether or not conscious reminding of the base domain is a necessary condition for transfer to take place.

EXPERIMENT 1

Method

Eighty-nine undergraduate subjects were randomly assigned to one of three encoding conditions in which they were asked to describe a base story at a particular level of abstraction. The materials were the same for all conditions, with the exception of the instructions for describing the base story. The base story was the General story used by Gick and Holyoak (1983). After encoding the base story, the subjects were given three distractor reasoning problems. Then they were given Duncker's (1945) radiation problem as the target problem. This problem and the General story are drawn from different domains, but they share the same abstract "convergence" schema. Finally, the subjects were asked whether they had used any of the previous problems while solving the radiation problem.

The Detail condition was designed to provide a concrete encoding of the General story. Subjects in this condition were instructed to give a detailed summary of the story, including specific characters, places, and actions. For example, "The evil dictator lived in the middle of the

Preparation of this paper was supported in part by NSF Research Grant BNS89-19035. Requests for reprints should be addressed to Jean M. Mandler, Department of Cognitive Science, University of California, San Diego, La Jolla, CA 92093-0515.

country. He planted bombs to allow his troops to come and go, but to deter others, etc." The Gist condition was designed to provide the underlying schema of the story but still in a concrete form. Subjects in this condition were asked to summarize briefly the main points of the story by stating the general's goal, dilemma, and solution. An example of a description at this level is, "The general's goal was to overthrow the dictator with his army. His entire army couldn't go down one road. So he split his army and had them arrive at the fortress at the same time, thereby overthrowing the dictator." The Abstract condition focused on the abstract structure, or relations among the goal, dilemma, and solution, rather than specific objects or actions. Subjects in this condition were asked to abstract the principle underlying the story by stating the goal, dilemma, and solution in a way that would reflect a more general solution. An example of a description at this level is, "An individual wants to overcome a central target with a strong force, but this force can't be applied on one path. So the force is split into smaller lower intensities which converge at the target and overcome it."

The descriptions of the base story were scored on a scale of 1-4, with 1 being the most descriptive and 4 being the most abstract. Levels 1-3 consisted of the Detail, Gist, and Abstract levels, respectively. However, it was found necessary to include a fourth level because some subjects in the Abstract condition produced protocols so abstract as to be vacuous. This level of description was termed Meta level. An example is, "The general had a goal which he could not achieve directly so he came up with an ingenious solution." Scoring was conducted by two independent coders with a reliability of 98%.

Results and Discussion

The mean levels of abstraction of the descriptions of the base story for the three groups were analyzed with a one-way analysis of variance (ANOVA). A planned trend comparison confirmed a linear trend of increasing abstraction across the three groups [$F(1,87) = 356.30$, $p < .001$]. Within groups, however, the level of description did not always match the assigned condition. In the Detail condition, 40% of the subjects gave Gist descriptions. In the Abstract condition, 50% of them were too abstract, giving descriptions at the Meta level. Therefore, the protocols were regrouped by actual level of description instead of by their assigned condition. The solutions to the radiation problem were scored on a scale of 1-3. A score of 1 reflected unrelated solutions, a score of 2 reflected partial answers (such as first intensifying and then lowering the radiation), and a score of 3 reflected the convergence (transfer) solution. A one-way ANOVA across the actual levels of description showed the differences in the transfer scores to be significant [$F(3,85) = 11.22$, $p < .001$]. The 21 subjects who described the story at the Detail level had a mean transfer score of 1.5; only 3 of these subjects gave the convergence solution. The 45 subjects who used the Gist level had a mean transfer score of 2.0, and 15 gave the convergence solution. The 8 subjects who used the Abstract level had a mean transfer score of 3.0; all of them gave the convergence answer. Finally, the 15 subjects who used the Meta level had a mean transfer score of 1.3; only 1 of these subjects transferred. Thus, there was a curvilinear relationship between actual level of description and transfer. This relationship is shown in Figure 1.

Only 11 (40%) of the 27 subjects who gave the correct solution were reminded of the General story while they were working on the transfer problem. Eight of the 11 were those who had produced the Abstract level of description. Another 8 subjects said they were aware of the story, but that they were reminded only at the Meta level of similarity; none of these subjects transferred. Thus, being reminded of the base story at an Abstract level of description was invariably associated with transfer, but more subjects transferred without awareness, at least by their retrospective accounts.

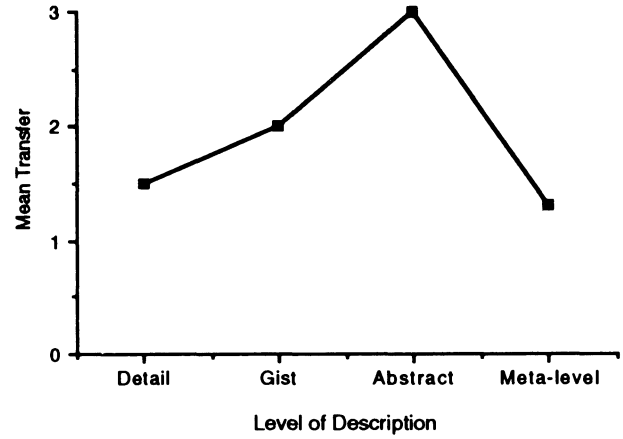

Figure 1. Mean transfer scores in Experiment 1 as a function of level of description of the base story.

The results of Experiment 1 support the hypothesis that analogical transfer is affected by the way in which the base domain is encoded. Subjects who described the base story at the Abstract level always transferred. However, subjects who gave Gist descriptions transferred more often than subjects who gave Detailed descriptions (or overly abstract Meta-level descriptions), suggesting that even a concrete version of the schema can be of use. Because the number of subjects who gave Abstract descriptions was small, a second experiment was conducted, in which subjects were given training to ensure that they described the base story at the desired levels.

EXPERIMENT 2

Method

A new set of 72 undergraduate subjects were randomly assigned to one of four experimental conditions of 18 subjects each: No training (control), Gist training, Abstract training, and Meta-level training. Subjects in the training conditions were taught to describe stories at one of the three levels of abstraction (Gist, Abstract, or Meta level, as described in Experiment 1). They were first given an example of the desired level of abstraction, using a short version of Cinderella. Then they wrote descriptions of two other stories, correcting their descriptions under the direction of the experimenter until they reached the desired level of abstraction. Then they wrote their descriptions of the General story. All subjects achieved the desired level. After this training phase, the subjects solved two of the distractor problems used in Experiment 1, followed by Duncker's (1945) radiation problem. Finally, they were asked whether or not they had been reminded of the base story while working on the radiation problem. Subjects in the control condition received the same treatment, except that they were given no training.

Results

Solution scores were analyzed on the scale of 1-3, described in Experiment 1. These scores were analyzed by

a one-way ANOVA [$F(3,68) = 2.81, p < .05$]. The control group showed a lower level of transfer ($M=1.7$) than all of the experimental groups combined ($M=2.2$; $p < .05$). A trend analysis of the three training conditions showed a curvilinear trend with increasing levels of abstraction [$F(1,52) = 4.08, p < .05$]. Subjects in the Gist condition ($M=2.1$) performed worse than those in the Abstract condition ($M=2.5$). Subjects in the Meta-level condition ($M=2.0$) were slightly worse than subjects in the Gist condition. Thus, the curvilinear relationship shown in Figure 1 between level of abstraction and transfer was replicated.

As in Experiment 1, the subjects' overall level of awareness of the base story while solving the transfer problem was low, with only 38% of the 24 who transferred being reminded. As in Experiment 1, however, those who were aware of the abstract schema all transferred. Nevertheless, even in the Abstract condition, 8 of the 11 subjects who transferred said they were not reminded of the base story.

GENERAL DISCUSSION

The two experiments presented here show that encoding information at either a Gist or an Abstract level facilitates transfer from a single exemplar of a base domain to a target domain. These two levels of encoding are each characterized by a version of the underlying schema of the base domain exemplar. The curvilinear relationship found between level of abstraction and transfer supports this hypothesis: when the schema is not included in an encoding, as in the Detailed and Meta-level encodings, transfer occurs less often.

Traditionally, an important aspect of the transfer process has been thought to be noticing and retrieving the base domain (e.g., Gentner, 1989; Ross, 1989). It has been the assumption of many, including ourselves, that analogical reasoning relies on explicit memory, that is, on conscious reminding of the base domain. However, most of the subjects in the present experiments who transferred did so without apparent conscious reminding. It may be that transfer requires only an implicit process of activation. On the other hand, subjects who were aware of the abstract schematic similarity of the base and target stories always transferred. This suggests an advantage for awareness not of the base domain per se but of its underlying schema. It may be that once an abstract schema such as convergence is represented, it can be activated independently of the base domain from which it was derived. Because of its abstract nature, activation of the schema would not necessarily remind subjects of the base domain itself. Further work, including that on on-line judgments of awareness, will be needed to determine if analogical transfer can take place without any activation of a concrete base domain.

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(Manuscript received June 17, 1993.)