Training for Facilitating Spontaneous Analogical Transfer

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Received December 7, 1999; final version accepted May 11, 2000

Two experiments were conducted to investigate the availability of training for solving a problem spontaneously by analogy where necessary and what kinds of requirements should be fulfilled in order to realize such training. In Experiment 1, the repetition of analogical transfer and the tasks for abstraction were examined and the significant effect of repetition were found. Experiment 2, revising the experimental design and developing some new tasks for enhancing training, was carried out to reexamine the repetition method, focusing on the effect of mapping processing and the solving problem alone. The results showed the repetition training with noticing the structural correspondence between the source and the target have some effects. These findings are discussed in terms of the recent studies of analogical transfer.

KEYWORDS: spontaneous analogical transfer, training, problem solving

Introduction

Everyday life is filled with problems that need solutions. Although many of such problems are familiar to us and can be easily dealt with through already acquired solution procedures as in the case of routine problems, we sometimes face unfamiliar and unanticipated problem for which we have no previously learned solution procedure. In such situations, there is a need to identify the problem and describe the given state, goal state, and allowable operators before devising a possible solution. When we cope with such “ill-defined” problems (Kehney, 1986), we are apt to make the most use of previous experience and knowledge.

One heuristic response is to retrieve a problem similar to the problem at hand from memory and apply that problem’s solution procedure to solve the immediate problem (Polya, 1957). If the problem is solved in this way, it is said that analogical transfer has occurred. When the problem that a solver endeavors to solve (called the target) is similar to the problem that the solver previously experienced (called the source) by virtue of an identical causal structure, those are called analogs of each other.

The ability to use analogy is a fundamental cognitive aspect of humanity. Even children show excellent analogical thinking (Holyoak and Thagard, 1995). But, on the other hand, adults often find it hard to make use of analogy, even when a known analog would be helpful. Gick and Holyoak (1980), using Duncker’s (1945) “Radiation problem” as a target problem, found that subjects rarely spontaneously transferred principles acquired from an analog story to their target (A “story” means a description which contains both problem sentences and its solution, while a “problem” contains only problem sentences). So we pose the question, is it possible to train people to solve problems spontaneously by analogy when necessary? What kinds of requirements are necessary for such training? The purpose of this study is to answer these questions.

A number of studies have demonstrated that the rate of analogical transfer can be affected or facilitated by some factors. These factors include, similarity between the source analog and the target (Holyoak and Koh, 1987; Francis and Wickens, 1996), giving explicit instructions or a hint to use a prior analog (Gick and Holyoak, 1980; Roth and Kennedy, 1990), providing multiple source analogs (Gick and Holyoak, 1983; Catrambone and Holyoak, 1989; but see Spencer and Weisberg, 1986 for negative results), extensive comparison among source analogs (Catrambone and Holyoak, 1989), problem-oriented training (Needham and Begg, 1991). These findings suggest that recognizing two problems as the potential source and the target, and the formation of generalized rules or schemata by induction or abstraction from comparison between the source and the target, may play an important role in spontaneous analogical transfer.

However, most of the studies described above aimed at investigating how a specific solution can be transferred effectively to the target problem. They were not concerned with improving generic skills for facilitating spontaneous analogical transfer. Therefore, it is not clear that the subjects in those experiments would solve novel problems in like ways spontaneously. On the other hand, some studies are concerned with ways to teach or give instruction for improving students’ analogical reasoning skills (e.g. Robin and Mayer, 1993). But in these studies, the tasks usually used were verbal analogical reasoning tasks such as TREE:FOREST::ROOM: (house), which are not ill-defined problems. Therefore we had to devise a new experimental paradigm to achieve our purpose.

Overview of the Experiments

The training procedure we devised aimed to have people repeatedly experience analogical transfer in solving problems. Therefore subjects were given and solved several source-target problem pairs. All of problems presented in experiments were ill-defined problems in the form of sentence problems and collected from divergent domains. The effect of training was estimated by the rate of analogical transfer from prior potentially helpful source to the target problem without any hint when novel potential source-target pair was presented.

Further, to enhance training, we provided additional tasks in which subjects processed source information and/or source-target relationships. Previous studies suggest that analogical transfer can occur when contextual differences between the source and the target can be overcome by detecting common principles in both the source and the target problems, at an appropriate level of abstraction (e.g. Catrambone and Holyoak, 1989). We introduced two types of task which would lead subjects to get such abstract relations between the source and the target, and examined the net effectiveness of those tasks.

The main purpose of Experiment 1 was to check whether the repetition of the experience of using analogical transfers can have the effect to enhance subject's performance in solving problems by analogy, or not. As a secondary purpose, we investigate the effect of tasks which insisted on subjects understanding problems at a higher level of abstraction. In results, the effect of repetitive experience of analogical transfer was found, but not the effect of abstraction tasks.

Experiment 2 was, through investigating where the effect of repetitive experience shown in Experiment 1 originated, to explore requirements necessary for effective training. Some factors related to ways to experience source-target pairs in training were examined. Those included the effects of different ways of problem presentation and the effect of solving problems alone. As an additional task to enhance training, a task focusing on the mapping process in analogy was prepared.

In general discussion, we will rearrange findings found in two experiments and point out some requirements necessary for effective training for facilitating spontaneous analogical transfer.

Experiment 1

To check the effect of repetitive experience of using analogical transfer, we compared the experimental groups in which subjects had repeatedly experienced analogical transfer across divergent domains with a control group in which subjects were offered no such experience. When novel potential source-target pairs were presented to these groups, we expected subjects in the former groups to show a higher rate of analogical transfer from potentially helpful prior sources to the target problem without any hint than subjects in the control group.

Secondly, to investigate the effect of tasks of understanding problems at a higher level of abstraction, we divided the experimental group into three groups and gave each group one of three kinds of tasks. In the "Diagram group", subjects read a story and drew a simple diagram representing the gist of the story. In the "Summary group", subjects read and summarized the story. In "Recall group", subjects read and recalled the story by filling in blanks on recall test sheets. We expected that the first two tasks would afford an opportunity to the subjects to enhance their ability to abstract principles from materials and also to repeat the analogical problem-solving experience. The third task would only afford an opportunity to repeat the problem-solving experience by virtue of analogical transfer.

Method

Subjects

Eighty volunteer students from an introductory psychology class at Tohoku University participated in the experiment. The subjects were divided equally at random into four groups described above. Eleven other subjects were disqualified, because they had prior experience with some target problems used in the experiment.

Tasks and Materials

The titles and the sources of problems used in the experiment are shown Table 1.

In the "training phase", subjects except in control group read and solved multiple source and target problems, while they carried out one of three abstraction tasks (Diagram, Summary, or Recall task) in a specified way described above before attempting to solve target problems. As abstraction tasks, three story-problem sets were prepared. Each set contained two stories and one target problem. Of the two story-problem sets, one set contained one story which was analogous to the target problem (source story) and the other was irrelevant (filler story). The other set had two filler stories. The order of presentation of the three story-problem set was counter-balanced across subjects.

Table 1. Problems/Stories used in Experiments and their sources.

Experiment 1	
Training phase	
Set A Source:	Birthday party story (Gick and Holyoak, 1983)
Target:	Hammock problem (Gick and Holyoak, 1983)
Filler:	Chef story (original)
Set B Source:	Lumber story (original)
Target:	Yacht problem (original)
Filler:	Tennis ball story (original)
Set C Target:	Railroad Model problem (original)
Filler:	The Identical Twins story (Gick and Holyoak, 1980)
Filler:	The Wine Merchant story (Gick and Holyoak, 1980)
Test phase	
Test source:	the General story (Gick and Holyoak, 1980)
Test target:	Radiation problem (Duncker, 1945)
Experiment 2	
Test	
Source:	the General problem/story (Gick and Holyoak, 1980)
Target:	Radiation problem (Duncker, 1945)
Filler:	Chain problem/story (Bransford and Stein, 1984)
Training phase	
Source:	Birthday party problem/story (Gick and Holyoak, 1983)
Target:	Hammock problem (Gick and Holyoak, 1983)
Source:	Trains and a Bird problem/story (Bransford and Stein, 1984)
Target:	Stock Value problem (original)
Source:	Get the jewels problem/story (Nakayama, et al., 1988)
Target:	Railroad Model problem (original)
Fillers:	Clever Brothers (Nakayama, et al., 1988)
	Yacht problem (original)

In the “test phase”, the potential source story was a “convergence solution” version of the General story and the target problem was the Radiation problem.

Procedure

The subjects participated in the experiment individually or in small groups. Each of them received a booklet containing all relevant materials and instructions.

The overall sequence of tasks presented in Experiment 1 is indicated in Figure 1. The experiment had two phases. In the training phase, subjects in experimental groups first read the first story (3 minutes) and performed an abstraction task (5 minutes) according to the assigned group (Diagram, Summary, or Recall). They then read the second story (3 minutes) and performed the abstraction task (5 minutes) in the same way. Subsequently, they solved a problem (5 minutes). No instructions were given to refer back to previous stories. After writing down possible solutions, they read an example of correct solution (1 minute). With a 5-minutes recess, the subjects repeated this sequence three times.

In the following “test phase”, all subjects firstly read a source story (3 minutes) and subsequent to reading a 3-minutes filler story, attempted to solve the target problem.

Lastly, they answered two questions; Did you know the General story or the Radiation problem? Was the General story helpful in solving the Radiation problem?

Results and Discussion

Rates of Subjects Producing Correct Solution to Three Target Problems in the Training Phase

Subjects’ answers were evaluated by two scorers who were blind as to the subject’s group. In order to be counted as a correct solution, a subject’s solution to each target problem must have explicitly mentioned the components which had been defined by the experimenter before running the experiment.

Table 2 shows the number of subjects producing correct solutions to each target problem in each group. A Chi-square (χ^2) test showed no significant difference among the groups for each problem. That is, the different abstraction training tasks did not produce a visible effect on the solutions of the target problem.

Table 3 presents the results of Type II Quantification Method using “correctness of answers” as an external criterion, and “problem”, “order of presentation”, and “training group” as explanatory variables. Although the correlation ratio indicates that these explanatory variables can not sufficiently explain the pattern of answers, several tendencies are suggested from “values of range” and “partial correlation coefficient”. First, the variation in difficulty across the problems appears to have a strong affect on our results. Problem C appears to

Fig. 1 The sequence of tasks in Experiment 1.

have been more difficult than the other problems. This was the problem which had no corresponding source analog, and so could not be solved by virtue of analogical transfer. This could be weak evidence supporting the possibility that subjects solve problems by analogy. Also, the order of presentation appears to have had some influence. The later a problem was presented, the easier it was solved. This indicates that subjects may have learnt something from the repetition.

Table 2. The number of subjects producing correct solution to each target problem in each groups.

Group	N	problem A	problem B	problem C
Diagram	20	16	16	8
Summary	20	17	14	10
Recall	20	13	13	10

Table 3. An Analysis of factors affecting solution to the target problem by Type II Quantification Method.

item	category	category quantity	range (partial correlation coefficient)
problem	A	-0.769	
	B	-0.431	1.969
	C	1.200	(0.287)
order of presentation	1st	0.697	
	2nd	-0.256	1.139
	3rd	-0.442	(0.171)
condition	Diagram	-0.106	
	Summary	-0.212	0.531
	Recall	0.319	(0.080)
external criteria (correctness of solution)	correct incorrect	$\eta^2 = 0.108$	

Rates of Subjects Producing Convergence Solution to Radiation Problem in Test Phase

Subjects' answers to the Radiation problem were scored for inclusion of the convergence solution. To be scored as a convergence solution, an answer had explicitly to include the following two components: "rays applied to the tumor from several directions" and "applied simultaneously". All other answers were labeled as nonconvergence solutions.

As can be seen from Figure 2, subjects in the three trained groups produced convergence solutions significantly more frequently than subjects in the control group (Fisher's exact method; $p < 0.05$). The General story (potential source analog) and the Radiation problem (target) in the test phase were presented to all the subjects in the same way, irrespective of any preceding operation. Moreover, unlike the previous studies, subjects in the trained groups had not received any additional instruction or undergone any other operation concerning the convergence solution. In addition, all subjects who produced a convergence solution reported that the General story was helpful in solving the Radiation problem. Taking all this into consideration, the results suggest that subjects who had experienced repeated training for analogical transfer had become more capable of spontaneous transfer of previous information to problems for which it would be useful.

Fig. 2 The rate of subjects producing correct solution for Radiation problem for the four groups in Experiment 1.

On the other hand, no significant difference, of any type, was revealed across the three trained groups ($\chi^2 = 0.99$, n.s.). This result may indicate that training in the understanding of problems at an abstract level did not improve the ability to produce analogical transfer. Another possibility is that the diagram and gist tasks had some effect, but that the recall task had the same effect (see Needham and Begg, 1991). Subjects who engaged in the recall task may have been able to abstract the gist spontaneously from source stories contrary to our expectations.

Experiment 2

Experiment 2 was designed to investigate where the effect of repetitive experience of analogical transfer revealed in Experiment 1 originated, and to explore requirements for effective training to improve a subject's analogical problem-solving skills. In order to achieve this, we revised several of our procedures and introduced new variables.

Revision of Experimental Procedures to Confirm the Repetition Effect

The results of Experiment 1 suggest that subjects who had repeatedly experienced training for analogical transfer came spontaneously to transfer previous information to problems where it would be useful. However there were some extraneous factors which could make another explanations of the results possible.

First, subjects in the three trained groups in Experiment 1 performed the reading of a problem-solving story six times in total and solved problems by themselves three times, while subjects in the control group had no such experience. It could be that the superiority of the training groups over the control group in performance on the following problem-solving may have been caused by the circumstances whereby the subjects in the trained groups became more familiar with the experimental environment or tasks. In Experiment 2, we included a control group that received the same number of problem-solving experiences as the training groups, but received no analogical source-target pair, so as to check this possibility.

Second, both in training phase and in the test phase of Experiment 1, each source analog was presented immediately before the target problem. Consequently, subjects may have developed and executed the simple strategy of always applying to the target problem the solution that was immediately before studied. So, in Experiment 2, source-target pairs in the training phase were not always presented successively, and the source in the test pair was presented as far from the target as possible.

Third, although some of the result in Experiment 1 suggest that subjects tried to make use of analogy for solving target problems, we did not directly check whether they actually solved each target problem by analogy. We needed to confirm that repetition of analogical transfer had undoubtedly occurred in the training phase. But this confirmation is not easy to obtain. If the subjects are asked whether they used analogy every time they solved the target problem, it would be virtually equivalent to an explicit instruction "make use of analogy!". In the second experiment, we asked subjects how they solved the problem after each solution. By examining their answers, we could estimate whether they made use of analogy for each target problem.

The Task Focusing on the Mapping Process in Analogy

In Experiment 1, we prepared training tasks in which subjects practiced abstracting principles from materials, to have subjects notice the similarity between the source and the target at the structural level. But the effect of those tasks was not clear. In Experiment 2, we investigate the effectiveness of a training task in which subjects practiced comparing explicitly abstract elements between source and target. We reasoned that retrieving the most appropriate source analog and noticing the similarity between the target and the source must be accomplished by repeating the mapping, that is the comparison between the target and a potential source analog, while changing a potential source analog or switching the level on which the mapping between them is carried out.

Effect of Solving Problems Alone

In Experiment 1, the source was presented in the form of a story, that is, a description containing a problem and a ready-made solution. But subjects may comprehend the causal structure of a problem more deeply if they solve the problem by themselves rather than when they receive it as a story. Accordingly, they can readily choose an appropriate level of comparison between the source and the target, and analogical transfer may occur easily. Therefore, in Experiment 2, not only targets but sources were also presented in the form of a problem to be solved by the subjects, except for one group which was included in order to confirm the effect.

Solving Test Target Problem with and without Hint

In Experiment 2, all subjects solved the test target problem firstly without hint or instruction “refer to the General problem”, and next solved with hint. Catrambone and Holyoak (1989) hypothesized that transfer before a hint indicates subjects’ ability to spontaneously notice and apply the analogy, whereas transfer after a hint indicates subjects’ ability to apply the analogy once its relevance has been suggested. Therefore it was expected that, by comparing performance on pre-hint trial to that on post-hint trials in each groups, we could clarify what effect the treatment conditions had.

Method

Subjects

Eighty-five volunteer students from an introductory psychology class at Tohoku University participated in the experiment. Roughly equal numbers of subjects were assigned to each of four groups as described below. Ten other subjects were disqualified because they had prior experience with the Radiation problem.

Tasks and Materials

The titles of problems used in Experiment 2 are shown in Table 1. Subjects in the “S-T pair mapping group” solved, in the training phase, six problems which were three source-target analog pairs, and after solving each target problem, they were given the mapping task. In this task, subjects received a sheet on which elements in the source problem were written at a structural level, and had to describe the elements in the target problem corresponding to the source problem. The “S-T pair group” was identical with the S-T pair mapping group, except that it did not include the mapping task. Subjects in the Non-pair group solved six problems which were irrelevant to each other. Subjects in the Story group were given source problems in the form of a story. Procedures in this group were similar to the procedures used in Experiment 1. In all groups, subjects answered the question: “what information did you use for solving the problem” after solving each target problem (after the mapping task in the Mapping group), and then an example of the correct solution was given. The order of presentation of the three source-target pairs was counterbalanced across the subjects.

All materials (instructions, problems, stories, questionnaires for the mapping task, hints, and so on) were printed in a booklet.

Procedure

Subjects participated in the experiment in small groups. Each subject received the booklet, and worked according to the experimenter’s time-keeping signals.

The overall sequence of tasks presented in Experiment 2 is indicated in Figure 3. The time allowed to subject was 5 minutes for solving each problem, and 3 minutes for reading each story in the Story group.

At first subjects were given two problems (or stories), one of which was the General problem. Then in the training phase, subjects solved problems and tasks according to the assigned group. They were not told of the relationship between the target problems and other problems.

Following the training phase, all subjects solved the test target problem without receiving hint. After that, they were given the hint “refer to the General problem” and were asked to solve the Radiation problem again.

Throughout the experiment, subjects were not allowed to review previous pages of their booklet.

Results and Discussion

Subjects’ answers to the Radiation problem were scored as a correct solution both when the answer meet the criterion already described in Experiment 1 and when produced by referring to the General problem. Whether or not subjects referred to the General problem was judged from the content of the answer to the question: What information did you use for solving the problem.

As can be seen in the left hand side of Figure 4, rates of subjects producing a correct solution to the Radiation problem in pre-hint trials were significantly different across the four treatment groups ($\chi^2 = 17.82$, $df = 3$, $p < .01$). Comparisons between individual groups were performed in order to examine the effect of each experimental treatment.

Effect of Repeating Analogical Transfer

To examine the effect of repeating the analogical transfer, we can compare the rate in the S-T pair group with

Fig. 3 The sequence of tasks in Experiment 2 (S-T mapping group).

that in the Non-pair group. In these two groups, the number of problems subjects solved were the same, and only subjects in the S-T pair condition could utilize a source problem to solve a target problem in the training phase. However, the difference in the rate between the two groups did not reach statistical significance (Fisher's exact method; $p > .10$). This finding may suggest that the mere repetition of problem-solving by analogy is not enough to enhance analogical transfer in later problem-solving.

Effect of the Mapping Training

By comparing the rate of subjects producing the correct solution to the Radiation problem in the S-T mapping group with the S-T pair group, we can examine the net effect of the mapping training. Because these two conditions were different from each other only in that the S-T mapping group included the mapping training tasks. The rate in the S-T mapping group was higher than the rate in the S-T pair group ($.05 < p < .10$). This

Fig. 4 The rate of subjects producing correct solution for Radiation problem on pre-hint and post-hint trial for the four groups in Experiment 2.

result indicates that repetition of the mapping training had some effect on improving a subject's skill at solving a problem by analogy. Repeating analogy experiences while noticing the structural correspondence between the source and the target appear to enhance the utilization of analogy in later problem-solving.

Pre-hint vs. Post-hint Trial

So what process was improved by the training? A clue to this question can be obtained by comparing between pre-hint and post-hint trials. As can be seen in the right hand side of Figure 4, there was no clear difference among groups in the rate of subjects producing the convergence solution to the Radiation problem after receiving the hint to refer to the General problem ($\chi^2 = 5.85$, $df = 3$, $p > .10$). That is, the advantage of S-T mapping over S-T pair in the pre-hint trial disappeared in post-hint trial. Referring to Catrambone and Holyoak's (1989) discrimination described above, this may suggest that training had the same effect as giving the hint did, improving the effect on the process retrieving the appropriate source analog.

Effect of Solving Problems Alone

To examine the effect of solving problems alone, the rate of subjects producing the correct solution to the Radiation problem in the S-T pair group with the Story group was compared. Contrary to our expectations, the rate in the Story group was higher than that in the S-T pair group ($p < .01$). This finding indicates that when we solve potential source problems by ourselves, it does not necessarily follow that we can successfully solve by analogy the same type of problem when we come up against it later. Rather, the practice of examining worked-out problems as source analogs before solving target problems can provide a basis for producing analogical transfer.

However, we must take into consideration the possible effect of extraneous factors specific to the present experimental procedure. First, the interval between the test source and the test target problem (c.f. Figure 3) in the Story group was about 30 minutes shorter than the S-T pair group, because we allowed subjects to spend more time to solve a problem than to read a story. Second, only in the Story group, each source was presented in the form of a story while each target was in the form of a problem. So, subjects in this condition might possibly have come to expect that the problem relevant to the story which they were reading at that time might be given later, after they had experienced a source story-target problem pair in the training phase. On the other hand, subjects in the S-T pair group might have tried to solve each source problem without trying to relate them to other problems. As a result, subjects in the Story group may have developed a different strategy for processing the source in the training phase from other subjects.

General Discussion

The aims of the present study were to pursue the possibility of training people to solve problems spontaneously by analogy when needed, and to clarify the requirements for realizing such training. In Experiment 1, we

found that subjects who had repeatedly experienced analogical transfer with tasks for understanding problems at a higher level of abstraction were more proficient in using potentially helpful source analogs to solve new target problem than untrained subjects. This finding suggested the possibility of successful training, although it was not clear where the effect originated, the repetition of analogical transfer or the tasks for abstraction. Results in Experiment 2 indicated: (a) the mere repetition of problem-solving by analogy is not enough for enhancing analogical transfer in later problem-solving, (b) the repetition of mapping training has some effect, and repetitive experiences of analogy when the subject notices the structural correspondence between the source and the target will enhance utilization of analogy in later problem-solving, (c) direct experience of solving the source problems independently is not crucial. What do these findings tell us?

First, as is clearly shown in Experiment 2, the mere repetition of problem-solving by analogy is not sufficient to enhance analogical transfer in later problem-solving. The positive results found in Experiment 1 may be due to the fact that two factors, the repetition of problem-solving by analogy and the effect of additional tasks, were not separated. We often use analogy to solve an immediate problem (Holyoak and Saggard, 1995), but the unintentional accumulation of these experiences does not lead to any improvement of analogical problem-solving skills.

On the other hand, the repetition of analogical problem-solving “with” tasks which entails processes essential to the use of analogy was effective.

In Experiment 1, the task was focussed on abstracting principles from materials, and subjects in the Recall group showed the same performance as subjects in the Diagram group and in the Summary group. This should be interpreted as evidence that subjects could abstract the gist spontaneously from source stories. Needham and Begg (1991), comparing the effect of memory-oriented and problem-oriented training, revealed that memory-oriented processing is a reasonably good training procedure, although problem-oriented training is much more effective. As Guindon and Kintsch (1984) said, we must be ready to take verbal materials not as superficial expressions but according to their deeper meaning. Looking at this from the opposite viewpoint, subjects in the Diagram and the Summary group performed the tasks at the same level as the Recall group. That is, to force subjects into abstracting materials had no such a remarkable effect.

In Experiment 2, the training task which focussed on mapping process had some effect. Even when problems were from different domains, subjects who repeatedly processed problems while noticing the structural correspondence between the source and the target could use source information to solve a novel problem spontaneously. Further, it was suggested that this effect was caused by improving the subprocess in which the appropriate source analog was retrieved. But, the question of why the mapping training improved the retrieval process remains open.

In Experiment 2, subjects in the Story group attained the best performance of all the groups, being better even than those subjects who actually solved source problems. Although the several effects of extraneous factors specific to the present procedures may be reflected in the results, there seems to be an important factor of some sort, inherent in these methods for processing source problems. Stories used in the present study are equivalent to worked-out examples in studies on the use of them in the teaching of mathematical problem solving (see Mayer and Wittrock, 1996 for review). Some studies have revealed that practice in examining worked-out examples is more effective than practice in actually solving example problems (Cooper and Sweller, 1987; Robins and Mayer, 1993). Catrambone and Holyoak (1989) also claim that direct problem-solving experience, though it may be helpful, is not crucial. Robins and Mayer (1993) explain that activity such as solving exercises may divert the learner’s attention toward nonproductive processing. We expected that the presentation of a source in story form would lead subjects to process passively, while solving the source problems by themselves would lead to active processing, resulting in deeper comprehension of the problems. This may be the case. But subjects who actually solved source problems may also be highly cognitively loaded, and would indicate a possible tendency to grasp each of solution separately, with the result that they found analogical relations between the source problem and the target problem hard to notice. On the other hand, reading a story may have required less cognitive resources to grasp and memorize its structure (the gist of the problem and the solution) and this new knowledge may be easily used as a source during later problem solving. From these considerations, it can be concluded that subjects need not necessarily solve source problems alone in order to enhance the skill of analogical transfer.

In summary, we could show the availability of and some conditions necessary for training for the enhancement of spontaneous analogical transfer. It is important to examine repeatedly appropriate work-out examples while noticing the structural correspondence between the source and the target. It is not necessary that problems be solved without aid. Future research is needed to assess the durability of the training effect, and whether the effect of the training can be expected even when the target problem is similar, not isomorphic like as the present study, to the source problem (Terao, Kusumi, and Ichikawa, 1997).

Acknowledgment

This research was supported by the Japan Atomic Energy Research Institute. We thank Dr. Fumiya Tanabe for helpful suggestions. A report was given on Experiment 1 at the 62nd annual meeting of the Japanese Psycho-

logical Association, Tokyo, 1998 and Experiment 2 at the 63rd annual meeting of the Japanese Psychological Association, Nagoya, September, 1999.

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