

The effects of representing source analogies as identical on facilitating spontaneous analogical transfer.

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This study used an entrance examination problem to investigate how the similarity of source analogies lead subjects to spontaneously solve the target problem with structures that included many identical analogies. Experiment 1 used university students and student nurses. This study was designed to clarify how keywords of source analogies and associate words were plotted to solve the target problem. Results indicated student nurses could solve the target after a hint representing the keywords of well structured source analogies as identical before hint, but for university students. Experiment 2 used university students was designed to clarify whether training to represent source analogies as identical world facilitate the successful analogical transfer or not. The results showed that the training group showed significantly higher frequencies of transfer than the control group (only a hint group), whereas the frequencies of successful achievers did not surpass those of non-achievers. These results suggest that this training increase the number of achievers, but its progress was not remarkable. These results were discussed from not only the significance of representing source analogies as identical but also the significance of meaning to solve the target problem.

Keywords: analogical transfer, representation, source analogy, identical

When we are confronted with a novel problem, we solve it by drawing an analogy that we can understand better. This process of reasoning is named analogical transfer, and it is a part of our intellectual repertoire. Holyoak (1985) has postulated that analogical transfer is achieved through four basic steps : (1) constructing a mental representation of the source and target; (2) selecting the source as a potentially relevant analogy to the target ; (3) mapping the components of the source and target ; and (4) extending the map to generate a solution to the target. Gick and Holyoak (1980, 1983) used the well-known radiation problem as the target problem and the fire problem or the fortress problem as the analogous problems.

The radiation problem was originated at Duncker (1945) : “You have a patient with an inoperable stomach tumor. There are some rays that, at sufficient intensity, destroy healthy tissue. How can you free the patient of the tumor without destroying the healthy tissue surrounding it ?” The fire problem was one where ray was replaced by water and the general by soldiers (person).

They asked participants to solve the target problem after giving the solution of the

analogy problem and after giving the hint of its structural correspondence to the target. They hypothesized that this procedure would result in a convergent schema. Gick and Holyoak (1980) were primarily interested in investigating whether a hint to utilize prior experiences helped the participants to solve the target problem. Gick and Holyoak (1980) and Anzai (1985) concluded that the rate of transfer decreased unless a hint was given.

Following these pioneering studies based on the pragmatic approach, a number of investigations have relied on a variety of instructions to make the participants aware of the correspondence between the analogy and the target problem. They have also attempted to elucidate the type of instructions that help to map the analogy to the target problem (Yamasaki, 1992; Yuzawa, 1988). These investigations have focused on steps (3) and (4) of the steps discussed above.

However, the original meaning of analogical transfer refers to spontaneously noticing the correspondence between the source and target problems and the resulting transformation of a well-structured source problem into an unstructured target problem. Therefore, the transfer depended on the represented structures of the two problems, especially that of the source analogies. Identical representations of structures between the source and target problems were considered to increase the possibility of noticing the correspondences between the two. Thus, for understanding spontaneous transfer, it is critical that processes in levels (1) and (2) indicated above should be clarified, as opposed to processes in levels (3) and (4). The way source analogies are pre-represented in memory has not been explored in previous studies about representations of analogy structures.

There are problems in using the radiation problem. First, it may be too abstract for novice participants to notice the correspondence to source analogies. As Beveridge & Parkins (1987) have pointed out, solving this problem was difficult because participants could not be convinced that several weak rays have a summative effect. They substituted a filter for the rays and obtained a higher rate of analogical transfer than that obtained by Gick and Holyoak (1980).

Secondly, no analogies to the radiation problem other than the fire and fortress problem have been found. The analogies used in Gick and Holyoak (1980, 1983) were developed by the experimenters without confirming whether naive participants could make the same analogies by themselves, or whether they were familiar with those analogies. Therefore, it is not clear whether the participants were satisfied with the solution to the radiation problem. Gick and Holyoak (1983) did examine whether induced schema influenced the transfer or not. However, it is difficult to determine that the schema was represented in memory.

Clearly, the radiation problem and the procedures used in Gick & Holyoak (1980, 1983) are not adequate to examine spontaneous analogical transfer. Gick and Holyoak (1980) used the procedure described above to teach the analogical correspondences to participants who were unaware of the structures underlying the transfer. Therefore, it is not clear whether learning the analogy could be effective in finding solutions to other

target problem.

Remarkably, Gick and Holyoak (1980) reported that several participants did succeed in the analogical transfer without the hint about the problem. It was considered that these participants had structural representation of the source analogy to notice its correspondences to the target problem. Gick and Holyoak (1980) suggested that the transfer was facilitated by induced schema. However, the schema was introduced to the participants by the experimenter. Nevertheless, Gick and Holyoak (1980) postulated that participants activated the schema that they had in advance. Therefore, it is not clear how these analogies worked to solve the target problems.

Contrary to the position of Gick & Holyoak (1980), spontaneous transfer should have occurred even if subjects were not given the solution to the target or given the hint of the correspondence between analogy and target.

Spontaneous analogical transfer could not be examined in such problems as the radiation problem where the solution is to recognize summative effect by several weak rays. We need another well constructed problem. Therefore a noodle problem related to functional fixedness has been developed (Tanabe, 1993). The solution of the noodle problem is as follows : "Once a strategy is used continuously over a long period, we find it difficult to do change strategies. The noodle problem seems to be familiar to participants and seems to facilitate spontaneous transfer because it has plain surface traits and has several identical analogies found by Tanabe (1993) using university student participants. There are six source analogies to this problem : stream of water, footpath in the bush, wheel-mark on a muddy road, gullet, railway line, and automation. Tanabe (1993) found the first three analogies well structural analogies and the later three as partially structured analogies.

The purpose of this study is twofold : (1) Verify whether participants who achieve analogical transfer represent the well structured analogies as identical in comparison to participants who fail to achieve the transfer : and (2) Verify whether training in representing well-constructed analogies as identical did facilitate successful analogical transfer.

Before conducting the main study, we conducted two preliminary experiments. The first study was to identify the associated words with analogical keywords. The other study was to compare the satisfaction degree of the noodle problem's solution with that of radiation problem's solution.

Preliminary Study 1

The purpose of preliminary study 1 was to identify associative words to be used in the main studies.

Method

Participants and Procedures

College students served as participants (n=90). They were asked to associate one analogous word corresponding to each keyword.

Results

The associative words that were obtained were divided into several categories. Among these, one word that did not share the same meaning, but with a high associative value to the keyword was selected as associative words for each analogy. These were correspondingly: fishing, insect, dust, internal organ, closing, and large enterprises.

Preliminary Study 2

The purpose of preliminary Study 2 was to estimate and compare the degree of satisfaction with solutions to the noodle problem with those to the radiation problem.

Method

Participants

College students ($n = 37$) participated in the study.

Procedures

The participants were asked to estimate the degree of satisfaction that they felt about solutions to both radiation and noodle problems.

Results

The degree of satisfaction about solutions to the noodle problem (mean = 5.770) was significantly higher than that (mean = 4.865) to the radiation problem ($t = 2.332$, $df = 36$, $P < 0.05$) suggesting that participants were more convinced that the solution to the noodle problem was correct, in comparison to the solution to the radiation problem.

Experiment 1

Experiment 1 was conducted to examine structural changes in source analogies of the noodle problem during transfer. Multi-dimensional scaling (MDS) analysis was applied to the semantic similarity matrix of every pair of analogy keywords and associate words to estimate the structures of analogies.

Method

Participants

We intended to use two groups. University students ($n = 88$) and student nurses ($n = 43$) participated in the study. The two groups were expected to show different ways in utilizing knowledge for their lives.

Procedure

The participants were presented with the noodle problem and were asked to solve it within five minutes.

The content of the noodle problem is as follows : A head of an enterprise wants to screen out non creative candidate at the job interview. He devises a unique test to identify non creative people by giving a meal of noodles and some pepper to every candidate and instructing them to eat whenever they wanted. He observes how each candidate eats : if they put pepper into the soup before tasting the soup and if they ate the noodles without first tasting the soup. He decides to screen out the candidates who ate the noodles without tasting the soup as non creative, because their behavior is

stereotypical. This schema which would interfere with a creative solution emerging is: “Once we repeatedly engage in a particular problem solving strategy, it is easier to continue using it rather than try a different strategy”.

Every analogy keyword described above was related to this schema. Consequently, a sheet of paper listed with every pairing between analogical keywords and associative words was given to the participants and they were asked to evaluate the semantic similarity of each pair of words (Table 1).

Table 1 Keyword used in each analogy and its associative word.

	keyword of analogy (○)		its associative word (●)
1	stream of river (川の流れ)	1'	fishing (魚釣り)
2	footpath in the bush (林の人道)	2'	insect (昆虫)
3	wheel-mark on a muddy road (泥道の車輪跡)	3'	dust (砂ぼこり)
4	gullet (食道)	4'	internal organ (内臓)
5	railway line (電車のレール)	5'	closing (踏み切り)
6	automation (オートメーション)	6'	large enterprises (大企業)

() shows the Japanese keyword used in experiment.

After completing this task, the participants were again presented with the noodle problem but now with the hint : “Once we get accustomed to a habit, we find it difficult to get rid of it,” in order to activate the analogical transfer. The concept of “habit” was considered to be identical to “the fixed way.” Participants were asked to solve the problem in five minutes. Then, they were given the same sheet of paper with the analogical key words and were asked to evaluate it again.

Results and discussion

Participants were divided into three groups by analogical transfer based on their responses both before and after receiving the hint condition. The participants who could not solve the noodle problem before and after being given the hint were named Group 1 (47 university students and 31 nurses). Those who solved it after the hint were named Group 2 (10 university students and 4 student’s nurses). Those who could solve it before the hint were named Group 3 (31 university students and 7 student’s nurses).

The average semantic similarities of each pair were calculated as a similarity matrix for each group both for before and after hint conditions. When the scores of university students and student nurses were combined, the results were not significant. Thus, the

average semantic similarities for university students and student nurses were analyzed separately. This was justified on the basis of difference in their specialized fields.

MDS was applied to each matrix both for university students and student nurses. Significant differences were found only for student nurses. Results for the student nurses, semantic distances for Group 2 showed a different pattern from those of other groups, both before and after the hint condition. Whereas, with the university students there were no significant differences among the three groups for the two conditions.

The MDS results, that is, semantic distance among analogy keywords and associate words for student nurses were plotted in Figures 1, 2, and 3 for both the before and after hint condition for each group. Moreover, the semantic distance among analogy keywords and associate words for university students were plotted in Figures 4, 5, and 6 for both the before and after hint condition for each group.

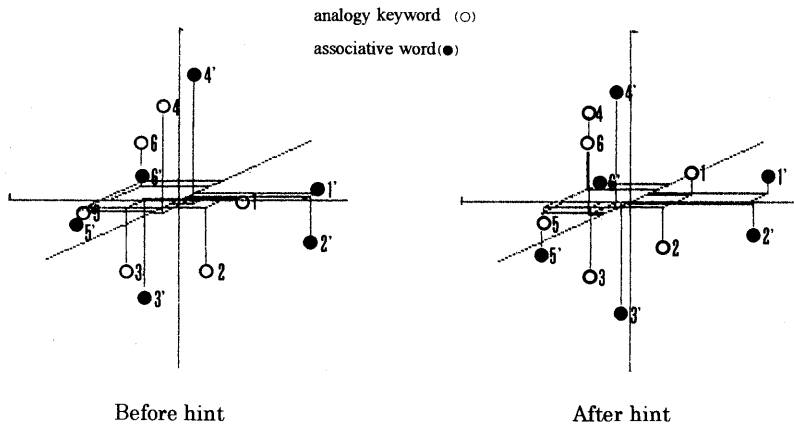


Figure 1 Analogy keywords and associative words plotted before and after hint conditions for student's nurses Group 1.

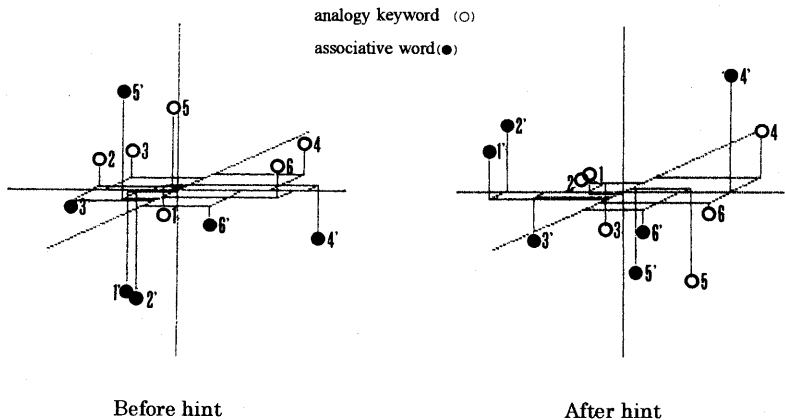


Figure 2 Analogy keywords and associative words plotted before and after hint conditions for student's nurses Group 2.

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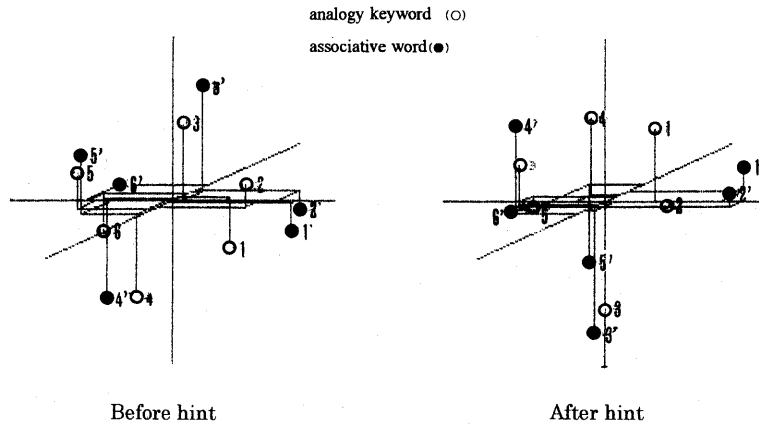


Figure 3 Analogy keywords and associative words plotted before and after hint conditions for student's nurses Group 3.

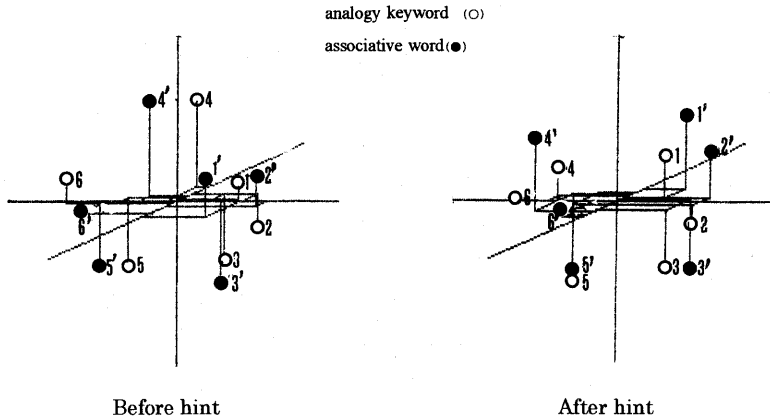


Figure 4 Analogy keywords and associative words plotted before and after hint conditions for university students Group 1.

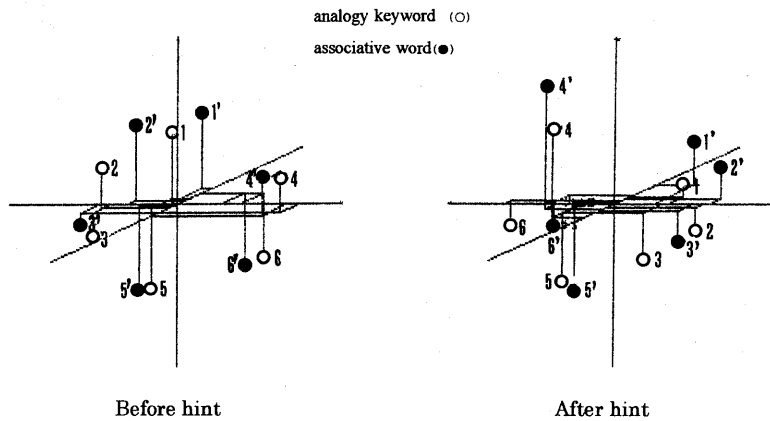


Figure 5 Analogy keywords and associative words plotted before and after hint conditions for university students Group 2.

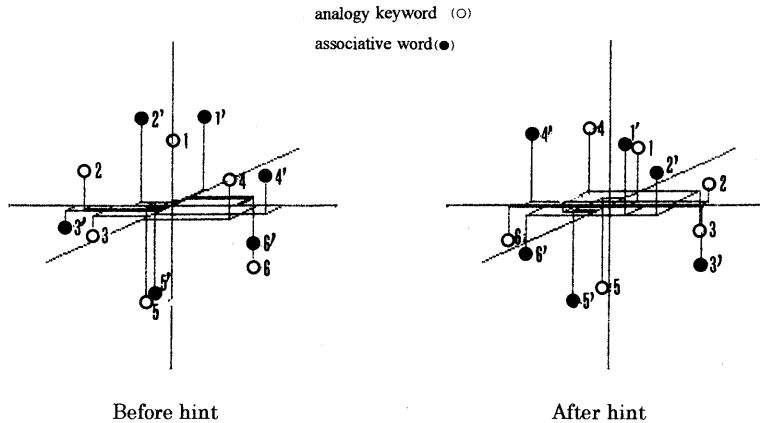


Figure 6 Analogy keywords and associative words plotted before and after hint conditions for university students Group 3.

It can be seen from the figures for student nurses in Group 2 (Figure 2) that in the before condition, the left direction of the horizontal dimension is interpreted as “naturally deeply traced rout” and the right one is interpreted as “artificial circuited rout”. Furthermore, in the after condition the upper direction of the vertical dimension is interpreted as “natural material”, the down one is interpreted as “artificial material”. The well-structured analogy keywords approached closely to each other in the after condition.

A one way analysis of variance (ANOVA) performed on the data for the before hint condition indicated that there were differences among the three groups ($F(2, 40) = 3.000$, $P < .10$). Duncan’s multiple comparison tests showed that the plot for “Foot path in a bush” analogy and “wheel mark on a muddy road” analogy of Group 2 to be different from that of other groups.

Cluster analyses were also applied to the matrix to confirm the visual results of MDS. For the before hint condition, “a stream of water” analogy and “foot path in a bush” analogy in Group 2 formed a sub cluster that excluded their associative words. Contrary to this, in Group 1 and 3, analogy keywords and their associative words formed a sub cluster. The results for both the before and after hint conditions were same for each group. These cluster results support the MDS results and suggest that representing source analogies as identical to a target problem was related to the successful transfer in Group 2.

The participants of Group 2 had an identical structure about analogies before the hint. For Group 3, well structured analogies for both the before and after hint conditions were not plotted closely because this group had already solved the target, and it was considered that they did not need analogies to solve the target.

However, only four participants in the Group 2 student nurses attained spontaneous analogical transfer. Even though only a few participants attained spontaneous transfer in the Gick and Holyoak’s study (1980), it may be desirable to reexamine the effects of source analogies by training participants to represent the well structured analogies as

identical.

Experiment 2

Experiment 1 examined how the source analogies were represented to facilitate spontaneous analogical transfer; and it was found that participants who could achieve the transfer represented source analogies as identical before given a hint and represented them more identical after given a hint., even though the number of such participants was only four.

Therefore, a training program representing analogies as identical was developed and the effect of this training on spontaneous transfer was examined. The training was to judge whether every pair among analogy sentences and destructive sentences obtained in Tanabe (1993) had the same meaning or not.

It was hypothesized that participants who received this training would achieve transfer more frequently than participants who did not. It was also hypothesized that participants who were successful in achieving transfer would complete the training more rapidly than those who failed. The later hypothesis was verified by two methods : (1) By the number of sessions taken until they could correctly respond to all pairs, and (2) by the reaction time (RT) needed to judge whether the pair was same or different.

Method

Participants

Participants were University students. There were 61 in the experimental group and 89 in the control group.

Procedure

The experiments consisted of two parts. In the first part, all participants were presented with the noodle problem and they were asked to solve it within five minutes. The second part of the experiment was conducted one week later for the experimental group. They were randomly presented with every pair of sentences with in the three well-structured analogies used in Experiment 1 . These were identical to the solution of the noodle problem. The two sentences which were not related to that solution were used as the destructive sentences. All the above sentences were obtained in Tanabe (1993). Also, a sentence which showed that solution was used as the hint analogy. These sentences in Japanese were shown on a computer display (NEC FA) at random. The program was written in BASIC. Participants were asked to decide as quickly as possible whether the pairs had the same meaning or not.

The well-structured analogy sentences used were as follows: "Once water flows, water digs the soil, next water flows along that line." (The title of this analogy is "a stream of water after rain." The title is the same for the analogy below.) "When someone passes in the bush, a path emerges, and the next person also passes along that path. "Foot path in a bush", "Once a motorbike runs on a muddy road, a track emerges, the next one also runs along that track." ("Wheel marks on a muddy road.")

The two destructive sentences were as follows : "People who belong to large enter-

prises can work without fearing failures.” (“Workers in large enterprises”) “Language brings changes in the mind from the outside” (“Change of mind by language”) The hint sentence was, “when someone repeatedly does things in a certain way and a habit is formed, then they behave that way automatically.” All sentences used in experiment 2 are shown in Table 2 (both in English and in Japanese).

Table 2 The well- structured analogy sentences, the destructive sentences and the hint sentence which were used in the experiment 2.

The title of the sentences	The title of the sentences Its contents (in English)	The title of the sentences Its contents (in Japanese)
The well-structured analogy sentences	stream of water after rain Once water flows, water digs the soil, next water flows along that line.	大雨の後の水の流れ いったん水が流れると流れの筋ができ、後の水の流れもその筋に沿う
	Foot path in a bush When someone passes in the bush, a path emerges, and the next person also passes along that path.	林の中にできた人の道 誰かが山を通ると人の道ができ、後の人もその道しか通らない
	Wheel marks on muddy road Once a motorbike runs on a muddy road, a track emerges, the next one also runs along that track	泥道の車輪の跡を通る後の車 泥道を誰かがバイクで通ると、泥にタイヤの跡ができ、後に通る人はその跡にそって走る
The destructive sentences	Workers in large enterprises People who belong to large enterprises can work without fearing failures.	大企業の中で働く従業員 大企業というバックアップがあれば従業員は安心して働ける
	Change of mind by the language Language brings changes in the mind from the outside	言葉使いから直す心の更正 言葉という外面から徐々に内面を変えていく
The hint sentence	habit formed by behaving the same way when someone repeatedly does things in a certain way and a habit is formed, then they behave that way automatically.	繰り返すと形成される習慣 何度もその行動をとっていると習慣になってしまい、つい同じ行動を取ってしまう

The computer immediately indicated the correctness of the answer with an illustration of its construction, whenever the participants responded.

The construction of the well-constructed sentences consisted of three parts : “once someone passes in the bush,” “a path emerges,” “the next person also goes along that

path.” After every response, feedback information about which part was same or different was given. A sample of feedback information was shown in Figure 7.

いったん水が流れると 流れの筋ができ 後の水の流れもその筋にそう。
 誰かが山を通ると 人の道ができ 後の人もその道しか通らない。

あなたは似ていると評定しました。

あっています。3つも似ている部分が有ります。従ってよく似ていると言えるでしょう。

理解できたら、何か文字を入力してください。

load " auto go to list run save " key print edit . cont

Figure 7 A sample of feedback information shown on computer display.

This training was completed when participants could correctly respond to all pairs, or up to 4 sessions. A computer recorded the results of the judgments and RT. After completing the training, or after four repetitions were completed, the participants were presented with the noodle problem and were asked to solve it again within five minutes.

Participants in the control group were presented with the noodle problem after a hint was given: The hint was, “When someone repeatedly does things in a certain way and a habit is formed, then they behave that way automatically.” Then all participants were asked to solve the problem again in five minutes.

Results and Discussion

The participants were divided into three groups as in Experiment 1. As shown in Table 3, the numbers of participants in Groups 1, 2, and 3 were 35, 12 and 14 respectively in the experimental group, and 61, 5 and 23 respectively in the control group.

Table 3 Participants in each experimental and control group.

	G 1	G 2	G 3	Total
Experimental Group	35 (57.3)	12 (19.7)	14 (23.0)	61
Control Group	61 (68.5)	5 (5.6)	23 (25.8)	89
Total	96	17	37	150

A chi-square test was applied to the two groups. The results indicated a significant difference between the groups ($\chi^2 = 7.135$, $df = 2$, $p < .05$). According to the results of standardized residual differences, the number of participants in the Group 2 of the

experimental group was larger than that in control group. However, this difference was not significant. These results showed that training facilitated spontaneous transfer.

The number of successful participants in each session is shown in Table 4. The participants of Group 3 completed the training until the third session, however 8 in group 1 could not complete the training even after 4 sessions.

Table 4 The number of successful participants in each session for each group.

		Session			Rests	Total
		1	2	3		
Group	G 1	4 (11.5)	13 (37.1)	10 (28.6)	8 (22.9)	35
	G 2	2 (16.7)	7 (58.3)	1 (8.3)	2 (16.7)	12
	G 3	2 (14.3)	8 (57.1)	4 (28.6)	0 (0.0)	14
Total		8	28	15	10	61

A chi-square test was conducted on the numbers of participants in the two groups for the first and second sessions. The results were not significant. However, the number of successful participants in Group 2 and Group 3 appear to be similar and did increase in the second session.

Next, a one-way ANOVA was conducted on the RT among the three groups in first and second sessions. In the first session, as shown in Figure 8, the RT for “stream of water after rain”–“habits formed” pair showed marginally significant difference ($F(2, 56) = 2.437, p < .10$), the Group 3 ($M = 3.071, SD = 1.592$) did judge this pair faster than Group 1 ($M = 6.441, SD = 5.383$). Also, as shown in Figure 9, the RT for “stream of water after rain”–“foot path in a bush” pair in Group 2 and 3 showed a marginally significant difference ($F(2, 56) = 2.336, p < .15$). Group 2 ($M = 4.636, SD = 2.663$) and Group 3 ($M = 4.571, SD = 2.901$) appear to judge this pair faster than Group 1 ($M = 7.147, SD = 2.901$). In the second session, as shown in Figure 10, the RT of “foot path in

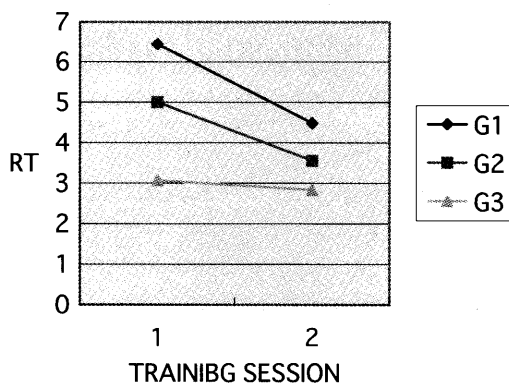


Figure 8 RT for judging the relation between “stream of water after rain”–“habits formed by behaving the same way” in each group during first session.

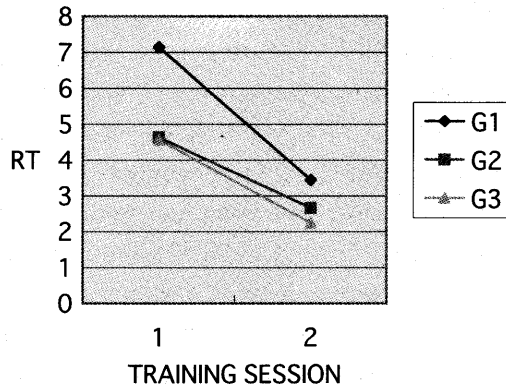


Figure 9 RT for judging the relation between “stream of water after rain” – “foot path in a bush” in each group during first session.

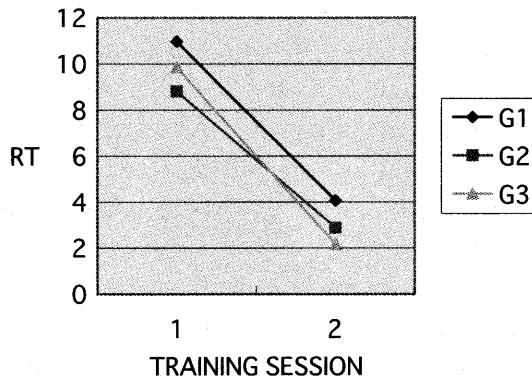


Figure 10 RT for judging the relation between “foot path in a bush” – “workers in large enterprises” in each group during second session.

a bush”-“workers in large enterprises” pair showed significant differences. Groups ($F(2, 47) = 4.817, p = 0.012$), Group 2 ($M = 2.889, SD = 1.269$) and Group 3 ($M = 2.167, SD = 1.030$) appear to judge this pair faster than Group 1 ($M = 4.069, SD = 2.170$).

These results suggest that, over the training sessions, participants in Group 2 and 3 noticed the identical structures among well-structured analogies compared with participants of Group 1.

General discussion

Experiment 1 investigated whether spontaneous transfer occurred when the hint about correspondence between the analogy and the target problem were not given to the participants. Results indicate that some of Group 2 student nurses, (although only four), represented well-structured analogies as identical. MDS results also indicate that well structured analogies were closely plotted to each other and far from their associative words. The left direction of the horizontal dimension formed by well-structured analogies was interpreted as “natural deeply traced route” and the right direction

that was formed by partially structured analogies was interpreted as “artificial circuited rout”. These results agree with the contention that refraining from overemphasizing irrelevant cues, as well as recognizing relevant cues, were crucial conditions for insight (Schooler, Fallshore, & Fiore, 1994). The results also suggest that the identical constructions of analogies in memory generate further spontaneous transfer.

The hypothesis that training to represent analogies as identical increases spontaneous transfer was partly supported. The training facilitated spontaneous transfer as suggested by the increased frequencies in Group 2 of the experimental group compared to the control group. Moreover, even in the first training session, members of Group 2 and 3 were inclined to be aware of the similarity among the well-structured analogies faster than Group 1. These results indicate that training by itself facilitated analogical transfer. However, the number of successful transfer of Group 2 did not surpass that of Group 3 even after training.

In conclusion, representing analogies as identical suggests this may be a crucial condition for spontaneous transfer. However, the number of participants who can successfully achieve transfer is as low as ten percent of the total number. The training facilitated spontaneous transfer as shown in Group 2, but it was not a remarkable increase. It is possible that the training aimed at representing analogies as identical does not manifest as transfer facilitation unless the participants themselves are aware of the importance of solving the target problem.

This study aimed at only representing source analogies as identical. It did not aim to make the participants aware of the correspondence to the target problem. Considering the comparatively low number in Group 2, the training was not effective by itself, without giving the goals of the problem to the participants. Considering the significant results associated with the student nurses in Experiment 1, it appears necessary to make participants face a critical situation in which they have to solve the problem and have to be aware of the goals of the problem. Suzuki (1996) reported that participants saw problems differently according to the goal of the problem. This study did not include an operation to make participants notice the goal of the problem, and did not conduct such training. In the future it would be necessary to compare the results of students with that of student nurses in such a study.

It is not clear from this study whether analogical transfer was a function of the training. Considering that Group 2 and 3 participants completed this training faster than those in Group 1, there is potentially an effective training advantage in facilitating analogical transfer. It is suggested that the effect of training on analogical transfer should be investigated further.

The representing source analogies as identical are related to the concept of affordance proposed by Gibson (1977) and Ad-hoc category proposed by Barsalou (1983) that implicit traits in the environment could be accumulated after long period of interaction with it. The successful achievers seem to have affordance in advance.

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