Changes of inferences caused by obtaining different perspectives: Analysis based on analogical reasoning

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Abstract

In this study, we aim to demonstrate the effect of obtaining perspectives for inference. As a start, we consider obtaining a specific perspective as an activity by identifying oneself with a role in a target situation. Such an activity can be understood based on the "CWSG" framework. According to CWSG, the probability of generating novel elements will increase in the fields where one self is connected. In order to examine this hypothesis, we conducted Experiment 1, in which subjects were presented with a situation where a student mistook a mathematical problem, and the subjects' perspectives were manipulated to become problem solver or tutor. However, in the result of Experiment 1, no effect was detected, perhaps because the subjects' experiences might have interfered with the activity of obtaining a perspective. Then we conducted Experiment 2, in which subjects who had different experiences from Experiment 1 participated. In the result of Experiment 2, we detected differences in generating novel elements between the experimental conditions. These results implied (1) the difference of perspectives leads to changes in the fields in which novel elements are generated, and (2) past experiences interfere with obtaining counter-perspectives.

Introduction

In this study, we aim to investigate changes in inference caused by obtaining different perspectives. As a start, we consider obtaining a specific perspective as an activity by identifying oneself with a role in a target situation. In other words, we suppose that obtaining a perspective is equal to thinking "If I were …". Such an activity may be understood based on the "CWSG' (Copying With Substation and Generation) framework, which is an algorithm of analogical inference, and explains the mechanism of inference using analogous representations (Holyoak, Melz & Novick, 1994). In past studies on analogical thinking, the term analogy has meant activities to match elements in a "source" representation, which is an exemplar in memory, to elements in the "target" representation. The term analogical inference has meant activities to construct new propositions based on the result of matching activities.

In the CWSG algorithm, correspondence between elements in the source and the target representations is searched first, and if the source representation includes elements that can not correspond to any element in the target representation, novel elements, not existing prior to the inference, will be generated in the target representation, novel elements, not existing prior to the inference, will be generated in the target representation. Holyoak et al. assumed that the generation of adequate elements is in need of a constraint called "pragmatic centrality", which activates fields of the target representation related to the goal and leads to the generation of novel elements only in the activated fields. We consider that obtaining a perspective is closely related to pragmatic centrality, and assume that the fields related to one's perspective are selectively activated, thus novel elements are frequently generated in those fields.

This idea is also confirmed by Goffman's social theory. Goffman stated that people in a specific social scene act as in social roles by following the scenarios attached to each role. Furthermore, he considered that their acts in a specific social role would lead to "the definition of the situation". For example, in every hospital, social roles such as doctor, nurse and patient exist in advance; thus each individual is forced to act in the social role assigned to him/her in the hospital. Accordingly, those actions define both officially and privately a situation in a hospital. Goffman referred to this performance activity as "the presentation of self". The idea of the presentation of self may be consistent with our above idea.

Task and design

Subjects were presented with the materials shown in Figure 1, which include a mathematical problem along with a correct and an incorrect solution of the problem. They were taken from Kougo's study, in which a student actually solved the problem and wrote the incorrect solution (Kougo, 1993).

Text of mathematical problem There is a rectangular parallelepiped container A. It is filled with water to a level 8 cm from the bottom. If a square pole B is inserted vertically into the container A, how many centimeters from the bottom will the water level reach?

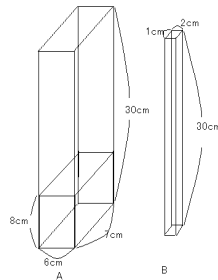| Correct solution	Incorrect solution
$6 \times 7 \times 8 = 336$	$1 \times 2 \times 8 = 16$
$6 \times 7 = 42$	$6 \times 7 = 42$
$1 \times 2 = 2$	$16 \div 42 = 0.38$
$42 - 2 = 40$	$8 + 0.38 = 8.38$
$336 \div 40 = 8.4$	

Figure 1: Task materials

Based on these materials, the subjects were asked to consider what kinds of causes underlay the mistake (Question1) and what kinds of plans were needed for overcoming these causes (Question 2).

The subjects answered these two questions based on two experimental conditions: the "solving condition" and the "tutoring condition".

In the solving condition, the subjects were instructed to identify themselves with a student who mistook the problem, as "If you mistook the problem in this way, then what kinds of causes do you think underlay the mistake? And what kinds of plans do you think are needed to overcome these causes?" On the other hand, the subjects participating in the tutoring condition were instructed to identify themselves with a tutor who teaches the student who mistook the problem, as "If you taught the student who mistook the problem in this way, what kinds of causes do you think underlay the student's mistake? And what kinds of plans do you think are needed to overcome these causes?

The question determining the way of relating the subjects' role to a context in the problem was different between the two conditions. In the instruction for the solving condition, the subjects acting as students were related to Question 1, because the student possessed the causes that led to mistaking the problem. In the instruction for the tutoring condition, the subjects acting as tutors were related to Question 2, because the tutor will propose and perform the plans. Therefore, we predicted that the subjects in the solving condition would generate more novel elements for Question 1, and those in the tutoring condition would generate more novel elements for Question 2.

Experiment 1

Method

Subject Twenty undergraduate and graduate students participated in this experiment. They were divided into a group of ten in the solving condition and a group of ten in the tutoring condition. All subjects in Experiment 1 satisfied the requirement of having experience in tutoring. The reason for setting this requirement is that it seemed easier to manipulate the solving and tutoring perspectives when using subjects who had experience in both solving and tutoring mathematical problems than when using those who had no experience in tutoring.

Procedure The subjects participated in the experiment individually. First, they were given a sheet of paper describing the title, the goal of the experiment, and explanations of the procedures. Then, the experimenter read out the text on the sheet to the subjects. The texts were different between the two experimental conditions. The title was written in the first line, such as "Investigation of monitoring activities in problem solving" for the solving condition and "Investigation of tutoring activities" for the tutoring condition. This means that the subjects in the solving condition were guided to identify themselves with the student in the target situation and to recall their own experiences from the viewpoint of a student (or a problem solver), while the subjects in the tutoring condition were guided to identify themselves with the role of a tutor in the target situation and to recall their own experiences of tutoring. The instructions about questions were the same between the two conditions, that is, (1) what kinds of causes do you think underlay the mistake? (2) what kinds of plans do you think are needed to overcome these causes?

After the above instructions, the subjects were given the materials. First, the mathematical problem was presented. The order of presenting the correct and incorrect solutions was different between the two conditions. In the solving condition, the correct solution was given after the incorrect solution. On the other hand, in the tutoring condition, the correct solution was given prior to the incorrect solution. This difference in presentation order was intended to provide a more naturalistic manipulation of perspectives. That is, we assume that the initial presentation of the incorrect solution might make the subjects behave as a problem solver whereas the initial presentation of the correct solution might make the subjects behave as a tutor.

After presenting the materials, subjects were again explicitly instructed to identify themselves with each roll and to recall each experience. Then, the subjects were given a sheet of paper to write their answers to the two questions, and they wrote the answers for about 20 minutes.

After completing their answers, the subjects were given a questionnaire in which they were asked about (1) their tutoring experiences and (2) ideas that came to mind during the task.

Analyses Each of the statements written in the subjects' answers was analyzed based on the two criteria shown below.

First, we judged question types for each statement. We defined statements about Question 1 as those related to previous states or past actions and statements
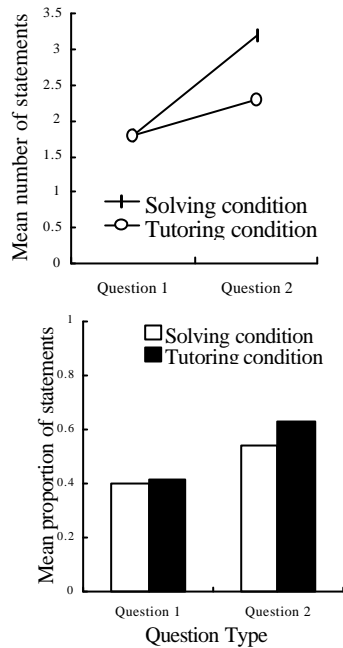
Figure 2: Results of Experiment 1

about Question 2 as those related to future actions. For example, statements such as "knew a formula" and "couldn't calculate it" are about Question 1, and statements such as "will learn it" and "should pay attention to it" are about Question 2. Statements that couldn't be categorized based on these definitions were excluded from analysis.

After the above procedure, each statement was categorized into one of two types: one containing novel elements and the other not containing these. Novel elements were defined as words neither involved in the instructions nor in the task materials. For example, a statement such as "He couldn't calculate the volume of the sinking pole" doesn't contain novel elements, because all words in the statement ("calculate", "sink", "pole" and "volume") appeared in the instructions or the task materials. On the other hand, a statement such as "He dwelled on a sinking pole" contains a novel element, because the word "dwell" doesn't correspond to any word in the instructions nor in the task materials.

Results

Quantitative indexes According to the above coding schema, two indexes related to novel elements were used. First, we counted the number of statements containing novel elements for each of the subjects and then calculated the mean score for each condition and each question type. Also, as a second index, we calculated the proportion of statements containing novel elements for each of the subjects and then calculated the mean proportion for each condition and each question type. We used the second index because there was a

possibility that the number of statements may reflect subjects' verbal fluency.

Figure 2 shows the results of Experiment 1. In contrast to the predication, Figure 2 indicates that in the solving condition as well as in the tutoring condition more novel elements were generated for Question 2 than for Question 1. In particular, the mean number of novel elements for Question 2 was larger in the solving condition than in the tutoring condition.

To confirm these patterns, mixed model analyses of variance (ANOVA) were computed. The dependent measures used were the number of statements and the proportion of statements. The independent variables were the question type (Question 1 vs. Question 2) as a within-subject factor and the experimental condition (tutoring condition vs. solving condition) as a between-subject factor.

In the analysis on the number of statements, only a main effect of the question type was significant [F (1, 39) = 5.92, $p < .05$]. Interaction between the question types and the conditions did not reach significance [F (1, 39) = 1.33, $ns.$].

The analysis using the proportion of statements confirmed a similar pattern. Interaction between the question type and the condition did not become significant [F (1, 39) = 0.50, $ns.$]; only a main effect of the question types was marginally significant [F (1, 39) = 3.74, $p < .10$].

Qualitative analysis The contents of novel elements were examined for future investigation. The number of novel elements for Question 1 was 37, and the number of novel elements for Question 2 was 55. We bundled novel elements containing the same words together. For example, multiple subjects wrote words such as "concentrated" or "fixated" for Question 1, and multiple subjects also wrote words such as "draw a diagram" or "think of examples" for Question 2. We counted the number of subjects who wrote each type of novel element. Table 2 shows the results. Among the categories shown in Table 2, there was no category indicating a significant difference between the two conditions.

Answers to the questionnaire The above analyses did not show differences of novel elements between the two conditions. What kinds of knowledge were used when performing the task? The questionnaire given to the subjects after performing the task contained the question, "While you performed the task, did you recall your experiences of tutoring?" For this question, the numbers of subjects who reported their recalled experiences in tutoring were almost the same between the two conditions: 10 individuals in the solving condition and 9 individuals in the tutoring condition. A more surprising pattern was detected in the answers to the question: "What kinds of knowledge came to mind when performing the task?" The numbers of subjects

Table 1: Categories of novel elements in Experiment 1

(a) Question 1

Categories	Solving condition	Tutoring condition
Fixating	1	1
Using a formula	1	2
Considering own experiences	1	2
Concentrating on	2	1
Not able to imagine	5	2

(b) Question 2

Categories	Solving condition	Tutoring condition
Drawing a diagram	6	5
Preparing an actual container	3	1
Considering examples	1	4
Solving other problems	2	1

who reported knowledge related to tutoring experiences were the same between the two conditions: 5 individuals in the solving condition and 5 individuals in the tutoring condition.

Discussion

Contrary to the prediction, the results of Experiment 1 did not show any difference in the answers between the two conditions. This result implies that perspectives obtained by the subjects performing the task were almost the same between the two conditions. In particular, the subjects in the solving condition might obtain a perspective of a tutor. This interpretation is consistent with subjects' verbally reported experiences. Despite the instruction that made the subjects obtain a perspective of a problem solver, why did they obtain a perspective of a tutor? Related to this question, two subjects in the solving condition reported as follows.

One subject said, "I recalled my student because I am now actually tutoring him. I was performing this task while considering it as if I were teaching the student in this task…" Another subject also said "I tried to consider it as if I mistook… but, somehow, I considered it as if I were teaching this student…"

These reports imply that the subjects' tutoring experiences had interfered with their ability to obtain perspectives as a problem solver. Perhaps strong experiences in everyday life might interfere with obtaining counter-perspectives. On the basis of this speculation, in the following Experiment 2, we chose subjects who had no tutoring experience and divided them into the two conditions that were the same as in Experiment 1. If a question type in which novel elements more frequently generated differs between the conditions in this setting, we verified the above hypothesis.

Experiment 2

Method

Subject Twenty-four undergraduate students who fulfilled a part of a class requirement participated in the experiment. Those who had no tutoring experience were chosen and divided into a group of 12 individuals in the solving condition and a group of 12 individuals in the tutoring condition.

Procedure The procedure for Experiment 2 was identical to that used in Experiment 1, with the exceptions in the instructions for the tutoring condition and the questionnaire for both of the two conditions. In Experiment 1, the subjects in the tutoring condition were instructed to recall their experiences in tutoring, but in Experiment 2, this instruction was excluded because the subjects in Experiment 2 had no experience in tutoring. For the same reason, the questionnaire in Experiment 2 was changed to one that asked (1) what did you think while solving the task? (2) what kinds of knowledge or experiences came to mind while solving the task?

Results

Quantitative indexes As in Experiment 1, two quantitative indexes (the number of statements and the proportions of statements containing novel elements) were used.

Figure 3 shows mean scores of the two indexes for each condition and each question type. According to Figure 3, we confirmed different patterns in both scores between the two conditions. In the solving condition, the scores in Question 1 seem higher than in Question 2, whereas in the tutoring condition the scores in Question 2 seem higher than in Question 1.

To confirm these patterns, two different 2 (question types) × 2 (conditions) mixed model ANOVAs were computed. As in Experiment 1, the dependent measures used were the number statements and the proportion of statements containing novel elements. Analysis of the number of statements revealed a significant effect of interaction between the conditions and the questions types [$F(1, 47) = 10.70, p < .01$]. Analysis of a simple main effect revealed that there was a differences between the two conditions in Question 2 [$F(1, 22) = 5.89, p < .05$], and that there was also a significant difference between the two question types in the tutoring condition [$F(1, 22 = 9.85, p < .01$). Analysis of the proportion of statements also revealed a significant interaction between the conditions and the question types [$F(1, 47) = 17.95, p < .01$]. Analysis of a simple main effect also revealed that there was a difference between the two conditions in Question 1 [$F(1, 22) = 6.14, p < .05$] and in Question 2 [$F(1, 22) = 5.08, p < .05$]. There was a marginal difference between the
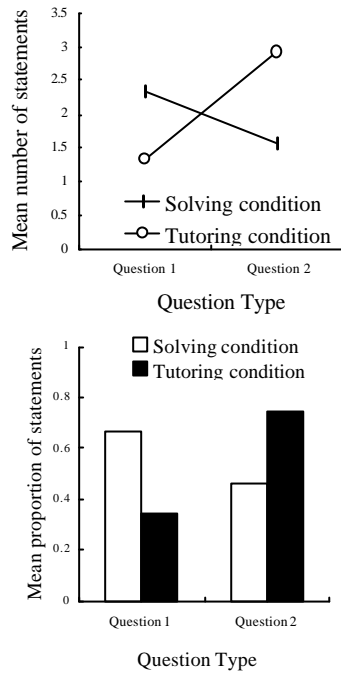
Figure 3: Results of Experiment 2

Table2: Categories of novel elements in Experiment 2

(a) Question 1

Categories	Solving condition	Tutoring condition
Not able to imagine	2	3
Forgetting carelessly	2	2
Jumping to conclusions	1	1
Fixating	2	0
Giving attention to a point	1	1
In one's mind	2	3

(b) Question 2

Categories	Solving condition	Tutoring condition
Preparing actual container	0	9
Explaining to other people	1	2
Reviewing	2	0
Solving other problems	2	3

two question types in the solving condition [$F (1, 22) = 4.13, p < .10$]. There was a significant difference between the two question types in the tutoring condition [$F (1, 22) = 15.67, p < .01$]. The above analyses show the quantitative effect of obtaining different perspectives on the generation of novel elements.

Qualitative analysis Contents of the novel elements were analyzed in the same way as in Experiment 1. The number of novel elements for Question 1 was 47, of which 20 novel elements were categorized into 6 types. The number of novel elements for Question 2 was 54, of which 19 novel elements were categorized into 4 types. Table 2 shows these categories and the numbers of subjects who wrote each of the elements involved in each of the categories. According to Table 2, there was a difference in the category "preparing an actual container" in Question 2 between the conditions ($p < .01$). Thus, this analysis confirmed a qualitative difference between the two conditions.

Answers to the questionnaire Subjects' reports on their use of experiences were analyzed. The number of subjects who reported their use of experiences was 6 in the tutoring condition and 10 in the solving condition. To examine the differences between the conditions, we categorized these experiences into two types. One type was related to experience in solving problem such as "I have solved similar problems". The other type was related to experience in receiving instructions such as " I have been taught". The number of subjects who reported an experience in solving a problem was 10 in

the solving condition and 2 in the tutoring condition. The number of subjects who reported an experience in being instructed was 3 in the solving condition and 4 in the tutoring condition.

These results confirmed that the experimental manipulation to make the subjects obtain different perspectives successfully caused them to recall different experiences. Almost all of the subjects who participated in the solving condition recalled experiences in solving a problem. On the other hand, in the tutoring condition, the number of subjects who recalled experiences of being instructed was greater than the number of subjects who recalled experiences of solving a problem.

Discussion

The results of Experiment 2 showed that the question types bringing about novel elements differed between the two conditions. That is, in the solving condition, the subjects more frequently generated novel elements for Question 1, and in the tutoring condition, the subjects more frequently generated novel elements for Question 2. These results are consistent with the idea that obtaining different perspectives causes changes in inference.

General Discussion

The results of the two experiments implied that (1) the differences in subjects' perspectives leads to changes of the fields of the representation in which novel elements are generated, and (2) past experiences interfere with obtaining counter-perspectives. In this section, we discuss the meanings and mechanisms of these implications.

The mechanism of obtaining perspectives

The results of Experiment 2 are consistent with the idea that obtaining different perspectives leads to changes in inference. In the terminology of the CWSG framework,

this result can be explained as follows: obtaining different perspectives leads to the changes of activated fields; therefore, novel elements were more frequently generated in those activated fields.

In particular, it is important that the interaction was detected in the analysis of the proportion of statements because this result means that obtaining perspectives does not increase every kind of statement but selectively increases the statements containing novel elements. In fact, analysis of the number of all statements did not detect interaction between the question type and the experimental condition [$F(1,47) = 0.43$ ns.]. We believe that our investigation based on the CWSG algorithm enabled us to confirm the effect of obtaining perspectives by virtue of using the indexes of novel elements.

Additionally, it is also important to compare the results of this study with those in the preceding studies on pragmatic centrality. For example, Liu, Pham and Holyoak (1997) investigated the changes in inference by pragmatic centrality. Liu's subjects performed an inference task in which they were asked forms of greeting in an unknown society. The subjects in some conditions were told that the difference of groups was important. While the subjects in other conditions were told that the difference of social status was important. Then, Liu et al. compared the answers of tasks between the conditions.

One of differences between our study and Liu's study lies in the way of experimental manipulation of pragmatic centrality. Compared with Liu's study, we manipulated the emphasized fields more implicitly. The subjects were not instructed which questions were more important but were told to identify themselves with one of the roles in the situation. This manipulation is consistent with Goffamn's idea claiming that acting in social roles leads to the definition of situations.
According to the above discussion, we believe that the results of this study do not simply replicate the effects of pragmatic centrality but also provide deeper explanations and new implications of the phenomenon dealt with in those studies. To expand the discussions of pragmatic centrality, it is important to have the viewpoint that obtaining different perspectives brings about changes in the emphasized fields.

The mechanism of interference caused by past experience

Contrary to the results of Experiment 2, the results of Experiment 1 showed neither quantitative nor qualitative differences between the two conditions. The distinction between the two experiments' results could be explained by the difference of experiences gained in subjects' everyday life. The subjects in Experiment 1 have experience in tutoring, but the subjects in Experiment 2 have no tutoring experience. Taking this difference into consideration, subjects' tutoring experiences in Experiment 1 might interfere with

obtaining perspectives as a problem solver (student). This interpretation is consistent with subjects' reported approaches to the task.

What kinds of mechanisms explain these effects of experience? Indurkhya (1997) provides a candidate explanation for answering this question. According to his theory, a target representation is constructed through the interaction between (1) the process in which the past experiences in the long-term memory are retrieved by the properties of target situations and (2) the process in which the structure of the long-term memory is projected on the target situation. In other words, the representations of situations are constructed through incremental interactions between the above two processes. Thus, the representations of situations are not determined in one decisive way but dynamically constructed through the interaction between past-experiences and one's perspective.

According to the above theory, the results of Experiment 2 can be explained as follows: the specificity of the target situation containing a mathematical problem causes the subjects to retrieve their tutoring experiences, and then the tutoring experiences interfere with obtaining perspectives as a problem solver. We believe that this interpretation seems plausible; however, the generality of this explanation is still unclear. To what extent does the mechanism function in various research domains? This question should be investigated in the future.

References

Goffman,E.(1959).*The presentation of self in everyday life*, Doubleday Company.

Indurkhya, B. (1998). On creation of features and change of representation. *Bulletin of the Japanese Cognitive Society*, 5 (2), 43 –56.

Holyoak, K. J., Novick, L. R. & Melz, E R. (1994). Component processes in analogical transfer: Mapping, pattern completion and adaptation. In K. J. Holyoak & J. A. Barnden (Eds.), *Advances in Connectionist and Neural computation Theory, Vol2: Analogical connections*, 113 –180.Norwood New,NJ:Ablex.

Reiko Kougo(1993). Taiseki wo motomeru mondai heno ninti kaunsering: judou kara noudou he [The cognitive counseling about the problem asked volume: passive to active]. Itikawa. Siniti(Eds.), *Gakushu wo sasaeru ninti kaunseringu: sinrigaku to kyouiku no aratana setten* [*Cognitive Counseling that sustain leraning: Contact point between psychology and education*],361 –369. buren syupppan.

Liu,J.H., Pham,L.B. & Holyoak,K.J.(1997). Adjusting social inferences in familiar and unfamiliar domains: the generality of response of situational pragmatics. *International Journal of Psychology*, 32 (2), 73 –91.