Verbalization Toward Others Facilitates Insight Problem Solving

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Abstract

We examined the effect of verbalization on problem solving using mathematical insight and non-insight problems. A total of 321 participants were randomly assigned to one of three conditions (verbalization toward self, verbalization toward others or control). A one-minute problem solving phase was followed by a one-minute verbalization phase; afterward, the participants were asked to work on the same problem again for two minutes. Each participant worked on three insight and non-insight problems each. A generalized linear mixed model analysis showed that the solution rate was significantly higher in the verbalization toward others condition than the other two conditions. There was no interaction with the problem type. When examining the effect of verbalization on insight problem solving, the type of insight problem (verbal, spatial or mathematical) and the verbalization addressee (self or others) should be considered.

Keywords: insight problem solving; verbalization; mathematical problem; business-as-usual view; special process view

Introduction

The present study examined the effect of verbalizing one's thoughts (i.e., verbalization) on problem solving. Furthermore, we aimed to determine whether the effect of verbalization differs between insight and non-insight problems and whether the verbalization addressee (self or others) plays a role. This section is structured as follows: i) a review of previous studies investigating the effect of verbalization on insight problem solving is presented, ii) the relevance of considering both the verbalization addressee and the problem type is highlighted and iii) the purpose of this study is clarified.

Effects of Verbalization on Insight Problem Solving

Insight problem solving is considered a creative process. There has been a debate about the special process and business-as-usual views of insight problem solving. The former assumes that insight problem solving processes are implicit, difficult to verbalize, and different from non-insight problem solving. Conversely, the latter assumes that the processes used in non-insight problem solving are also involved in insight problem solving. However, both these views remain controversial and non-conclusive.

Verbalization is the process of putting into words the thoughts that occur during problem solving. Verbalization encourages analytical approaches and plans to solving problems. As a result, verbalization is considered to facilitate ordinary problem solving. Predictions of the effects of verbalization on insight problem solving depend on which view is considered. Specifically, the special process view holds that verbalization disrupts only insight problem solving. In contrast, the business-as-usual view holds that verbalization does not disrupt insight nor non-insight problem solving or facilitate them.

Previous studies have examined whether verbalization disrupts insight problem solving (Ball et al., 2015; Fleck & Weisberg, 2004; Gilhooly, Fioratou, & Henretty, 2010; Schooler, Ohlsson, & Brooks, 1993). Schooler et al. (1993) used verbal and visuospatial tasks to examine the effects of retrospective verbalization (Experiments 1 and 2), wherein participants reflected on how they approached the problem and concurrent verbalization (Experiments 3 and 4), which occurred during problem solving. The results showed that both retrospective and concurrent verbalizations disrupt insight problem solving. This phenomenon is referred to as the verbal overshadowing effect. As this effect was not observed for non-insight problems, it is considered to be evidence of the special process view of insight problem solving. Ball et al. (2015) examined the effects of concurrent verbalization on insight problem solving using a visuospatial task. Comparisons were made regarding the solution rates up to half of the time limit, and a verbal shadowing effect was observed.

However, some findings support the business-as-usual view that verbalization does not disrupt insight problem solving. Fleck and Weisberg (2004) examined the effect of concurrent verbalization on insight problem solving using the candle problem, and found no difference between the think-aloud and silent conditions.

The debate remains unresolved owing to mixed results. It is necessary to conduct more studies on the effects of verbalization on insight problem solving and consider

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variables that moderate the effect of verbalization on insight problem solving.

Verbal Addressee as a Moderator

The first moderator to be considered is the verbalization addressee (i.e., to whom one's thoughts are verbalized). Previous studies on the effects of verbalization on insight problem solving have focused on individual situations; however, verbalization occurs in both individual and group situations. Several studies have examined whether the effect of verbalization on insight problem solving differs according to social conditions, whether alone or in a group. Sio, Kotovsky, and Cagan (2018) used the Remote Associates Test to examine the effects of concurrent verbalization on insight problem solving. They compared the performance in three conditions: silent individual, think-aloud individual and think-aloud group. The results showed that the performance in both think-aloud conditions was worse than that in the silent condition. They concluded that verbalizing one's thoughts impairs insight problem solving.

In our pilot study, we investigated the effects of retrospective verbalization on insight problems using a T-puzzle. We compared the solution rates of the puzzle between the verbalization toward self condition, the verbalization toward others condition and the control condition. The results showed no differences between the two verbalization conditions, and the solution rate was higher in the control than the verbalization conditions. Based on this, there is no difference in the effects on insight problem solving between verbalization toward self and verbalization toward others.

Problem Type as a Moderator

The second moderator to be considered is the problem type. Verbalization may also affect insight problem solving differently depending on the problem type. Dow and Mayer (2004) identified the following three types of insight problems: verbal, visual and mathematical. It is necessary to consider whether these findings can be generalized to other types of problems.

The effects of verbalization may differ according to the type of problem. Gilhooly et al. (2010) added verbal problems to those used by Schooler et al. (1993) to examine the effects of concurrent verbalization on problem solving. They set up a concurrent verbalization condition in which participants thought aloud while working on the problem, and a silent condition in which they worked on the problem silently. They examined the effects of insight versus non-insight and visuospatial versus verbal. The results showed no difference in solution rates between conditions, regardless of an insight or a non-insight problem. Therefore, no evidence is available that verbalization uniquely affects insight problem solving. By contrast, the disruptive effect of verbalization was greater for visuospatial problems than for insight problems. These results suggest that the verbal overshadowing effect demonstrated by Schooler et al. (1993) is more likely to occur when solving problems involving visuospatial materials than insight problems.

While verbal insight problem solving requires reinterpreting the meaning of words, visuospatial insight problem solving requires reinterpreting visuospatial material. By contrast, mathematical insight problem solving requires reinterpreting the manipulation of numerical values. As the search for word meanings involves associative processes, it is difficult to verbalize the process and interpretation of visuospatial materials. By contrast, it is relatively easy to verbalize the manipulation of numerical values. Thus, verbalization may not be disrupted and can facilitate mathematical insight problem solving. To the best of our knowledge, no existing study has examined the effects of verbalization using mathematical problems.

The Present Study

The present study aims to clarify the effects of retrospective verbalization on mathematical problem solving, while considering the verbalization addressee (self or others). We addressed this question by comparing the solution rates in experimental and control conditions. The first experimental condition involved verbalization toward self condition, and participants were asked to verbalize what they had thought about toward themselves during the previous problem solving phase. The second experimental condition involved verbalization toward others; participants were asked to verbalize their thoughts during the previous problem solving phase toward other participants. The only difference between the two conditions was the verbalization addressees. In the control condition, participants were not asked to verbalize their thoughts during problem solving but to verbalize daily tasks irrelevant to problem solving. Based on previous studies, we predicted no difference between the verbalization toward self and verbalization toward others and that the solution rates in the verbalization toward self and verbalization toward others conditions would be as high as or higher than those in the control condition.

Method

Participants

A total of 498 native Japanese speakers accessed the survey site from Lancers, an online Japanese work portal; however, only 322 completed the experiment. One participant did not consent to the use of their data; therefore, we used the data of 321 participants (137 women and 194 men, M_{age} = 42.3, SD = 10.2). Participants were paid 400 yen for their participation in the study.

Design

A 3 (verbalization: verbalization toward self/verbalization toward others/control) × 2 (problem type: insight/non-insight) mixed design was used. Verbalization was a between-participant variable, and problem type was a within-participant variable.

Table 1: Problem descriptions and answers

<table>
<tr><th>Session</th><th>Type</th><th>Description and answer</th></tr>
<tr><td>Practice</td><td>Non-insight</td><td>Equations: Solve for Y. Find the exact number that the variable Y equals by using only the necessary equations from the set of equations below.
3Z * 3 = 27, 2C-9 = Z, P-C = 2D, 5Z - 11 = M, 2X =56 + A, 8M -C =Y, 3Y + 14 = X

<u>A. Y = 26</u></td></tr>
<tr><td>Main</td><td>Insight</td><td>Ocean: At noon a ship's porthole is 4 m above the waterline. The tide rises at 1 m/h. How long will it take the water to reach the porthole?
<u>A. The water cannot reach the porthole.</u>

Barrels: If John can drink one barrel of water in 6 days and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together?
<u>A. 4 days</u>

Flashlight: A flashlight and a battery cost $11 in total. The flashlight costs $10 more than the battery. How much does the flashlight cost?
<u>A. $10.5</u></td></tr>
<tr><td></td><td>Non-insight</td><td>Water jug: Given four containers of different capacities–99, 14, 25, and 11 liters–obtain exactly 86 liters of water,
<u>A. 25*3 + 11 = 86</u>

Supply: Larry (age 35), his wife June (age 34), and his son Kenny (age 15) are going on a three-month camping trip in Alaska. Larry has heard stories of people getting snowed in during camping trips and not having enough food to survive. He wanted to be sure to send enough supplies to the cabin before he left on the trip. Larry got a list of the amount of supplies needed per day by people of different age groups. In total, exactly how many pounds of food supplies will his family need per day?
<table><tr><th></th><th colspan="4">Amount Needed per Day (in Pounds)</th></tr><tr><th>Age and Gender</th><th>Bread</th><th>Vegetables</th><th>Meat</th><th>Water</th></tr><tr><td>Male child</td><td>0.9</td><td>1.0</td><td>1.2</td><td>1.9</td></tr><tr><td>Female senior citizen</td><td>4.3</td><td>3.2</td><td>3.6</td><td>6.5</td></tr><tr><td>Male baby</td><td>0.5</td><td>0.8</td><td>0.4</td><td>1.0</td></tr><tr><td>Male teen</td><td>2.5</td><td>3.0</td><td>3.5</td><td>4.2</td></tr><tr><td>Female teen</td><td>2.5</td><td>3.5</td><td>3.0</td><td>4.4</td></tr><tr><td>Female adult</td><td>4.0</td><td>3.7</td><td>3.5</td><td>5.5</td></tr><tr><td>Male senior citizen</td><td>4.4</td><td>4.5</td><td>2.0</td><td>6.7</td></tr><tr><td>Female baby</td><td>0.5</td><td>0.8</td><td>0.6</td><td>1.1</td></tr><tr><td>Male adult</td><td>3.5</td><td>4.0</td><td>3.3</td><td>6.0</td></tr><tr><td>Female child</td><td>0.9</td><td>1.4</td><td>1.0</td><td>2.0</td></tr></table>
<u>A. 46.7</u>
.
Cash: Bob left home with an ATM card, a credit card, a checkbook, and $70 in his wallet. Below is a list of the purchases that he made during the day. How much money did Bob have in his wallet at the end of the day?
<table><tr><th>Location</th><th>Type of Purchase</th><th>Amount ($)</th><th>Tax ($)</th><th>Tip ($)</th></tr><tr><td>Corner Diner</td><td>Credit</td><td>15.72</td><td>1.26</td><td>2.50</td></tr><tr><td>Quick Mart</td><td>Credit</td><td>9.75</td><td>0.78</td><td>*</td></tr><tr><td>Rapid Transit</td><td>Cash</td><td>1.50</td><td>*</td><td>*</td></tr><tr><td>Sports Inc.</td><td>Check</td><td>75.00</td><td>6.00</td><td>*</td></tr><tr><td>Fast Food Hut</td><td>Cash</td><td>8.72</td><td>0.69</td><td>*</td></tr><tr><td>Movie Plaza</td><td>Credit</td><td>11.00</td><td>*</td><td>*</td></tr><tr><td>Movie Concession</td><td>Cash</td><td>15.20</td><td>1.22</td><td>*</td></tr><tr><td>Rapid Transit</td><td>Cash</td><td>1.50</td><td>*</td><td>*</td></tr><tr><td>Mickey's Pub</td><td>Credit</td><td>22.50</td><td>1.80</td><td>4.50</td></tr></table>
<u>A. $41.17</u></td></tr>
</table>

Materials

A non-insight problem, *Equations* (Ash & Wiley, 2008), was used in the practice session. The following three insight and non-insight problems were used for the main session: *Ocean* (Gilhooly et al., 2010), *Barrels* (Chuderski & Jastrzebski, 2018) and *Flashlight* (Chuderski & Jastrzebski, 2018) for insight problems and *Water jug* (Karimi et al., 2007), *Supply*

(Ash & Wiley, 2008) and *Cash* (Ash & Wiley, 2008) for non-insight problems. Table 1 presents the problem descriptions and answers.

Procedure

The experiments were conducted online. The participants were randomly assigned to one of three conditions (verbalization toward self, verbalization toward others or control). A total of 166 participants were assigned to each condition, but only 99 in the verbalization toward self condition, 99 in the verbalization toward others condition and 123 in the control condition completed the experiment.

Participants completed the practice and main sessions. The same procedure was used in both sessions, but the number of trials was different; that is, the practice session comprised one trial and the main session comprised six trials. A trial consisted of the following three phases: pre-verbalization solving, verbalization and post-verbalization solving.

Participants were asked to solve a problem in one minute during the pre-verbalization phase, which was followed by a one-minute verbalization phase. In this phase, the participants were asked to verbalize their thoughts according to specific instructions for each condition. Participants in the verbalization toward self condition were instructed to write down their thoughts about solving the problem by addressing themselves in the first minute. The instructions were as follows: "Recall what you were thinking about to solve the problem. Recall strategies, rules and a series of actions. Describe these in as much detail as possible so that you can understand them."

In the verbalization toward others condition, participants were asked to write down their thoughts by addressing other participants during the first minute of problem solving. The instructions are as follows: "Recall what you thought about to solve the problem. Recall strategies, rules and a series of actions. Describe these in as much detail as possible so that the other participants can understand them."

In the control condition, participants were asked to write the procedures of a daily chore irrelevant to the problem. The daily tasks were to make a rice ball, transfer money from an automated teller machine, make curry, eat dinner at a restaurant, do laundry, play rock paper scissors and play baseball. The instructions were as follows: "Recall [one of the daily tasks mentioned above]. Recall strategies, rules and a series of actions. Describe these in as much detail as possible so that other participants can understand them."

After the verbalization phase, participants were asked to solve the problem again within two minutes and then answer whether they had seen the problem before the experiment. In the main session, the order of the six problems was randomized.

After the main session, participants were asked to indicate to whom they addressed their verbalization and what they wrote in the verbalization phase and to provide demographic information (gender, age and education level). After the purpose of the experiment was explained in detail, consent was obtained from participants to use their data for the study.

Results

We checked whether participants followed the verbalization instructions in two ways. First, we examined the recognized addressees and the content of the verbalization based on the questions. Data were excluded from analysis if the participants did not choose an option appropriate for their condition. Second, we examined whether participants wrote anything during the verbalization phase. Data were excluded from the analyses if the participants did not write anything during at least one of the six trials. Based on the responses to the problem experience questions, we ensured that none of the participants had experienced any problems prior to the experiment. Fifty-three participants in the verbalization

Table 2: Solution rate for each problem in each condition

		Verbalization toward self (N = 46)	Verbalization toward others (N = 59)	Control (N = 73)
Insight	Ocean	0.30	0.49	0.38
	Barrels	0.52	0.56	0.42
	Flashlight	0.43	0.49	0.38
Non-insight	Water jug	0.46	0.53	0.40
	Supply	0.46	0.46	0.51
	Cash	0.28	0.39	0.29

toward self condition, 40 in the verbalization toward others condition and 50 in the control condition were excluded from the analysis. Table 2 presents the solution rate for each problem in each condition.

We performed analyses with a generalized linear mixed model (GLMM) using the lme4 package (Bates, 2005). We saw that a model that included the main effect of verbalization toward other conditions provided a significantly improved fit over a model containing only the main effect of the verbalization toward self condition. Neither the main effect of problem type nor any interaction provided a better fit. Thus, the model containing the fixed effects of the verbalization toward self and verbalization toward others conditions (but no interaction) plus participant and item random intercepts for the condition seems to be the most complex model justified by the data. The analysis of this model indicated that the solution rate was higher in the verbalization toward others condition than in the other two conditions (estimate = 0.40, SE = 0.19, z =2.11, $p < .05$).

Discussion

W examined the effect of verbalization on problem solving using mathematical insight and non-insight problems. We predicted no difference between verbalization toward self and verbalization toward others, but the analysis using GLMM showed that the solution rate was significantly higher in the verbalization toward others condition than other conditions. There was no interaction with the problem type. The results support the business-as-usual view of insight problem solving. In addition, unlike in previous studies that used verbal and visuospatial insight problems, verbalization toward others facilitated insight problem solving.

Why Did Verbalization Toward Others Facilitate Problem Solving?

The results of the present study are novel in two respects. First, the effect was observed only in verbalization toward others. Second, a facilitative—rather than a disruptive—effect, was observed. Regarding the first point, the manipulation of verbalization may be related to the results. Specifically, in Sio et al. (2018), in addition to verbalizing their thoughts, the group condition involved listening to others' verbalization and obtaining their responses. Additional processes may compensate for the differences between group and individual conditions. In our pilot study, although the processes of listening to others' verbalization and receiving responses from others were excluded, the purpose of verbalization was different. Specifically, the participants in the verbalization toward self condition were asked to verbalize with the following instruction: 'Write a record to yourself of how you tried to solve the problem', and those in the verbalization toward others condition were asked to verbalize as follows: 'Write instructions for other participants on how to solve the problem'. This additional difference may affect the effects of verbalization on insight problem solving.

The type of insight problem may be related to the results. Verbal insight problem solving requires reinterpreting the meaning of words, visuospatial insight problem solving requires reinterpreting visuospatial materials, and mathematical insight problem solving requires reinterpreting the manipulation of numerical values. As the search for word meanings involves associative processes, it is difficult to verbalize the process and the interpretation of visuospatial materials. By contrast, it is relatively easy to verbalize the manipulation of numerical values. Thus, the effects of verbalization on insight problem solving may depend on the ease of verbalization.

Future Directions

The effects of verbalization may vary depending on the stage of insight problem solving. Specifically, the greater the degree of involvement in the explicit process, the more likely that the facilitative effects of verbalization will emerge. Hélie and Sun (2010) proposed the explicit-implicit interaction theory. This theory suggests that insight problem solving involves explicit and implicit knowledge, which have different characteristics. Explicit knowledge is consciously accessible, easily verbalized and highly flexible but requires cognitive resources; this knowledge is expressed in a rule-based way. By contrast, implicit knowledge is difficult to access consciously and verbalize, does not require cognitive resources and is expressed on an associative basis. In most problems, we assumed that explicit and implicit processing involve these two types of knowledge simultaneously. There is a bottom-up influence—wherein implicit knowledge influences explicit knowledge—and, conversely, a top-down influence—wherein explicit knowledge influences implicit knowledge. Thus, the explicit and implicit processes are believed to proceed by influencing each other in both directions, leading to a final solution. Based on this theory, insight problem solving can be viewed as follows: first, the preparation stage mainly involves explicit processing, and a controlled search is conducted. However, in many cases, this search is unsuccessful, leading to an impasse. Implicit processing is mainly involved in the subsequent incubation stage, which is eliminated from the problem. At this stage, the degree of confidence in the solution is explored. Insight occurs when the confidence in the solution being explored exceeds a certain threshold. A strong emotional experience of inspiration, termed the 'aha experience', is caused by the integration of implicit and explicit knowledge. Explicit processing is predominantly involved in the final verification phase. If the solution is incorrect, the knowledge state is modified, and the process is repeated back to the preparation stage.

Studies on the relationship between working memory capacity and insight problem solving have also suggested that the effects of verbalization on insight problem solving vary depending on the stage. Ash and Wiley (2006) examined the relationship between working memory capacity and problem solving using visuospatial insight problems. They examined the relationship at different stages of problem solving by

manipulating the number of possible incorrect moves in the early stages of problem solving. When the number of possible incorrect moves is small, the search is terminated prematurely and an impasse is reached. Therefore, the success or failure of the solution depends on whether the reconstruction can be performed correctly. However, if there are many possible wrong moves, the search is not terminated early, and it takes a long time to reach an impasse. Therefore, in addition to whether proper reconstruction can be performed after an impasse, whether an impasse is reached affects the success or failure of the solution. As a result, the larger the working memory capacity, the better the solution performance when the number of possible false moves in the early stages of problem solving is large. By contrast, this relationship was not observed when working memory capacity was small. These results suggest that the relationship between working memory and problem solving differs depending on the stage of problem solving, with working memory being relevant in the exploration stage but not the reconstruction stage. Lv (2015) also showed that executive and inhibitory functions were positively associated with the exploratory and reconstructive stages of working memory function.

Limitations of This Study

Although we obtained novel results, the present study has some limitations. First, a large amount of data were excluded. As this experiment was conducted online, many people who accessed the study dropped out. As participants were randomly assigned at the time of obtaining consent, the amount of data varied owing to dropouts. Considerable data were also excluded from the analysis based on the post-main session questions and checks based on the presence or absence of verbalization. In particular, many participants who verbalized toward others in the verbalization toward self condition were excluded. Therefore, it is necessary to emphasise the addressee of verbalization.

Second, only native Japanese speakers were included in the study. The effects of verbalization may differ depending on the language used. The same procedure can be used to examine the influence of a native language by studying another language (e.g., English).

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