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Effect of Suggestions from a Physically Present Robot on Creative Generation

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Abstract

This study experimentally investigated the effect of suggestions from a physically present robot on human creative generation. In the experiments, we used a creative task in which the participants were required to draw creatures living on a planet other than the Earth, and a physically present robot, which provided suggestions for creative drawing to the participants with speech sounds and physical movements. First, the results of the pilot experiment confirmed that drawing creativity was enhanced for the participants supported by a robot; however, they were unlikely to refer to the suggestions. Based on the results, two hypotheses were developed: the suggestions from a robot offered a variety of different perspectives and facilitated metacognition (Hypothesis 1), and the suggestions worked as distractions and suppressed fixated perspectives (Hypothesis 2). The experiment was conducted to investigate these hypotheses. As a result, Hypothesis 1 was supported. The results were discussed based on previous studies.

Keywords: Robot; Human-robot interaction; Creativity; Creative generation; Metacognition; Collaboration.

Introduction

Creative generation and collaboration

Creative generation is performed in various situations, such as engineers thinking of new information tools, novelists thinking of new stories, and chefs thinking of new recipes. Guilford (1979) showed that creative generation involved two types of thinking processes: divergent and convergent thinking. Divergent thinking is the process of generating multiple possible ideas. By contrast, convergent thinking is the process of examining the generated ideas to determine the best. The ideas would be refined by alternately repeating these two thinking processes. Also, Finke, Ward, and Smith (1992) developed the geneplore model of creative generation in which there are generative and exploratory phases. In the generative phase, abstract representations of ideas called preinventive forms are created. Following the generative phase, in the exploratory phase, the generated ideas are interpreted in a meaningful ways for specific purposes. The ideas become sophisticated as these two phases are repeated one after the other.

The scope of creative generation can be limited because people generate ideas based on existing representations of prior knowledge (Ward, 1994). Therefore, representational change, or re-representation, in divergent thinking or the generative phase is crucially important. It occurs when a representation described from a certain perspective is reinterpreted from a different perspective (Ward, Smith, & Finke, 1999).

In the field of cognitive science, many previous studies have shown that collaborative activities provide opportunities for people to develop new perspectives. For example, people reinterpret and deepen their knowledge by providing explanations about their knowledge and asking reflective questions to each other (Miyake, 1986). Also, in a collaborative problem solving situation, people develop abstract representation of the solution by alternately taking the roles of a task-doer, who externalizes their own ideas, and a task-monitor, who objectively reflects the others' ideas (Shirouzu, Miyake, & Masukawa, 2002). Moreover, people can acquire an integrated perspective of multiple viewpoints by taking a perspective from others that is incompatible with their own perspective (Hayashi, 2018). These previous studies show that it is important to interact with others to facilitate metacognition and form new perspectives that cannot be achieved alone.

Human-robot interaction

The development of technology has brought the prevalence of robots that support human physical and cognitive activities (e.g. Ros, Baroni, & Demiris, 2014; Saerbeck, Schut, Bartneck, & Janse, 2010). However, there are not many studies that experimentally investigated how robotic support influences human cognitive activities during human-robot interaction.

Leyzberg, Spaulding, Toneva, and Scassellati (2012) experimentally investigated how advice from a robot influenced human problem-solving performance with a nonogram puzzle. Their study compared the effects of advice from a physically present robot, a robot displayed on a screen, and only auditory sound. As a result, the participants supported by the physically present robot solved the puzzle faster than the participants supported by the displayed robot and auditory sound after receiving advice multiple times.

Moreover, a physically present robot gave better impressions to people than a virtually displayed robot or animated character. In particular, people felt the robot was more likable, helpful, enjoyable, trustworthy, creditable, and informative (Kidd & Breazeal, 2004; Powers, Kiesler, Fussell, & Torrey, 2007). Also, people became more compliant with a physically present robot than to a robot displayed on a screen (Bainbridge, Hart, Kim, & Scassellati, 2011). These effects were considered to occur because of the robot's physical presence (Powers et al., 2007). On the other hand, it was more difficult for people to recall suggestions from a physically present robot than suggestions from a robot displayed on a screen. Since people tended to allocate their attention to the presence of the robot, they were considered to allocate less attention to the contents of the suggestions and had difficulty recalling the suggestions (Powers et al., 2007). These previous studies showed that suggestions from a physically present robot provided different effects on people from those provided from a robot or animated character displayed on a screen and those in text or auditory sound.

Purpose of this study

The number of studies related to human-robot interaction has been increasing. However, there are still few studies that investigated human cognitive activities supported by a physically present robot. In particular, not much is known about how a robot could support human creativity. The focus of this study was on human creative generation and how suggestions from a robot influenced creativity.

Pilot experiment

The pilot experiment was conducted to confirm the effect of the suggestions from a physically present robot on creative generation and develop experimental hypotheses about the features of the suggestions.

Experimental task

The task used in the pilot experiment was a creative task used by Ward (1994). The participants were required to draw creatures living on a planet other than the Earth.

The participants draw creatures on a canvas displayed on a computer screen (Figure 1a) with a digital pen. The canvas was created with HTML5 Canvas and JavaScript. The participants could choose one of two colors, black and white, to draw a line by physically tapping one of the square boxes on the display. Also, they could change the line width and the level of the transparency by tapping and moving the slider bars before drawing the line. The software provided a redo button to redo drawing a line, a delete button to delete all the drawn lines on the canvas, and a submit button to save a drawn creature as a picture file and to delete the creature from the canvas.

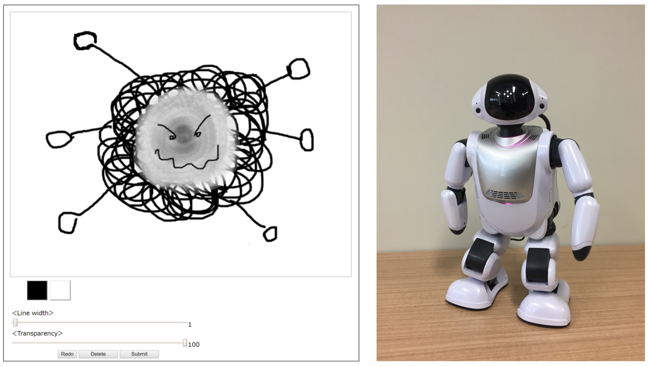
Method

Participants Thirty university students participated in the pilot experiment as volunteers.

Experimental design The experiment had a one-factor between participants design. The factor was the type of suggestions (no-, text-, and robot-suggestions).

In the robot-suggestion condition, the robot, Palmi by DMM.com LLC, was used (Figure 1b). The robot gave suggestions for creative drawing to the participants with speech sounds and the physical movements of moving the arms, legs, or head according to entered commands. Also, the no-suggestion condition was set up as a control condition in which the participants performed the task without suggestions.

Moreover, the text-suggestion condition was set up in which the participants were given the same suggestions as in the robot-suggestion condition. However, the suggestions were displayed in letters in the lower right corner of the display. Because text information allows people to carefully consider the meaning compared to auditory information (Blasio & Milani, 2008), the suggestions in text were presumed to be actively referenced and thus enhanced the creativity of the drawing.



(a) Canvas (b) Robot

Figure 1: (a) A canvas displayed on a computer screen and (b) the robot used in the experiments.

Suggestions For the robot- and text-suggestion conditions, 20 suggestions were created to encourage the participants to use metacognition and consider their ideas from a variety of different perspectives in divergent thinking or the generative phase. Some of the suggestions are shown in Table 1.

Procedure Ten participants were randomly assigned to each condition. First, the experimental task was explained to the participants. After the participants received the explanation of the drawing operations, they practiced drawing pictures for five minutes. Following the practice, in the robot-suggestion condition, the participants were told that the robot in front of them would give them suggestions for creative drawings during the task. Also, in the text-suggestion condition, the participants were told that the suggestions for creative drawings would be displayed on the screen during the task. After the explanation and instructions, the participants performed the task for 20 minutes. All participants were instructed to draw as many creative creatures as possible.

In the text- and robot-suggestion conditions, 10 suggestions were randomly selected from the 20 suggestions for each participant and given in randomized order every two minutes from the beginning of the task. The participants in these conditions were instructed to refer to the given suggestions as necessary.

After the task was finished under the robot- and the text-suggestion conditions, the participants rated to what degree the suggestions were referred to in order to draw creative creatures with a 5-point scale (1: not referred at all - 5: extremely referred).

Results

First, the average number of drawn creatures in each condition was 2.40 for robot-suggestion, 2.60 for no-suggestion, and 2.80 for text-suggestion conditions. A one-way analysis of variance (ANOVA) showed no significant differences in the number of drawn creatures between the three conditions ($F(2,27) = 0.53, p = .60$). The result showed that the participants drew creatures to the same extent in the three conditions.

Second, the creativity of the creatures was rated on originality using a 10-point scale (1: not original at all - 10: extremely original). Three independent raters who knew nothing about the experiment were trained and then rated the originality of all creatures in randomized order. The rated scores between the three raters were judged consistent ($\alpha = .69$).

Based on the originality scores for each drawn creature in the three conditions, a one-way ANOVA was performed (Figure 2). As a result, there was a significant main effect ($F(2,27) = 14.50, p < .001$). A multiple comparison test with Ryan's method revealed that the score was significantly higher in the robot- and text-suggestion conditions than in the no-suggestion condition ($t(48) = 3.68, p < .001$; $t(52) = 3.46, p < .001$). However, there was no significant difference between the robot- and text-suggestion conditions ($t(50) = 0.36, p = .72$).

Moreover, a t-test was performed to compare the reference ratings between the robot- and text-suggestion conditions (Figure 3). As a result, the rating was significantly lower in the robot-suggestion condition than in the text-suggestion condition ($t(18) = 3.82, p < .001$).

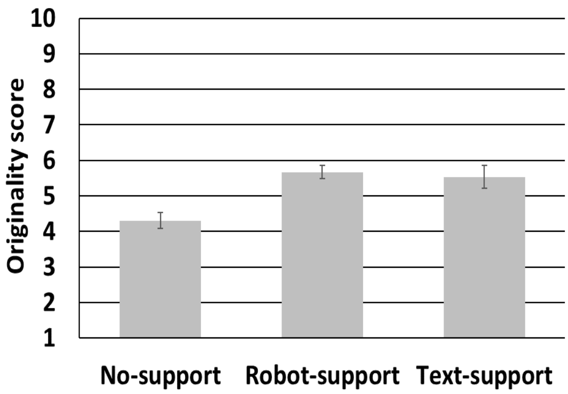


Figure 2: Average originality score in each condition in the pilot experiment. The error bars indicate the standard error.

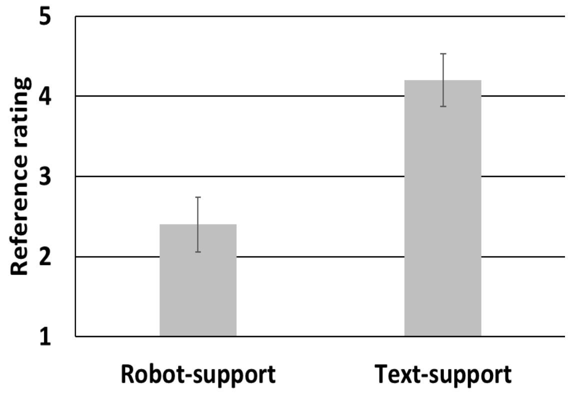


Figure 3: Average reference rating in each condition in the pilot experiment. The error bars indicate the standard error.

Discussion

First, the results confirmed that the suggestions from a robot enhanced the creativity of drawings. Second, the participants referred to the suggestions less frequently when given from the robot than when displayed in text. In addition, the suggestions in text were actively referred to and enhanced the creativity as predicted.

Although the participants were unlikely to refer to the suggestions from the robot over all, only some of the suggestions might be referred to and encouraged the participants to use metacognition and generate ideas from a variety of different perspectives. However, there is another possibility that the suggestions from the robot enhanced the creativity of drawings by causing irrelevant distractions.

Because the suggestions from the robot were less likely to be referred to, the suggestions might have tended to distract the participants from focusing on the task. In creative generation, irrelevant distractions can be beneficial in suppressing fixated perspectives and focusing on irrelevant information (Amer, Campbell, & Hasher, 2016; Dijksterhuis & Meurs, 2006). Therefore, the suggestions from the robot were assumed to work as irrelevant distractions and supported the participants in suppressing fixated perspectives and ideas. As a result, they might generate ideas from new perspectives and enhance the creativity of drawings.

In the following experiment, we conducted an experiment to investigate the features of the suggestions from a robot with considerations of facilitating metacognition and causing distractions.

Experiment

Method

Participants Sixty-seven university students participated in this experiment for course credit.

Experimental design The experiment had a one-factor between participants design. The factor was the frequency of the suggestions (high and low). The frequency of the suggestions was manipulated by the number of suggestions provided during the task. In the high-frequency condition, 12 suggestions were given every two minutes for 24 minutes. Conversely, in the low-frequency condition, six suggestions were given every four minutes for 24 minutes.

Suggestions and distractions In this experiment, two different situations were set up: the no-distraction and distraction situations. In the no-distraction situation, all suggestions provided during the task were related to drawing creative creatures (Table 1). They were selected from the suggestions used in the pilot experiment. Contrarily, the distraction situation was set up to provide apparent distractions, suggestions completely unrelated to drawing creative creatures, in order to enhance the effect of distractions (Table 2). In the distraction situation, half of the suggestions were selected from the list in Table 1, and the other half were selected from the list in Table 2. If the suggestions had prevented the participants from focusing on the task and enhanced creativity, the effect of distractions would have appeared prominently in the distraction situation.

Table 1: A list of suggestions

	Suggestions related to drawing creative creatures
1	Let's think about the shape of the creature.
2	Let's think about what kind of features the creature would have.
3	What kind of environment does the creature live in?
4	Let's think about what the creative creature would be.
5	Let's think about the movement of the creature.
6	Let's reconsider the idea.
7	Let's think about incidents that occur outside of Earth.
8	Let's think in a different way.
9	How about combining different ideas?
10	Let's think in different perspectives.
11	Let's think about something that could be referred to.
12	What kind of features would the creature have?

Table 2: A list of distractions

	Distractions
1	Look up to the ceiling and count 10 seconds as accurately as possible.
2	Close your eyes and count 10 seconds as accurately as possible.
3	Raise your feet and count 10 seconds as accurately as possible.
4	Let's do a mental calculation. What is eight plus six minus seven? (Silence for 3 seconds) The answer is seven.
5	Let's do a mental calculation. What is four plus nine minus five? (Silence for 3 seconds) The answer is eight.
6	Let's do a mental calculation. What is seven plus five minus nine? (Silence for 3 seconds) The answer is three.

Procedure The participants were randomly assigned to each condition in each situation. As a result, 16 participants were assigned to the low-frequency condition in the distraction situation and 17 participants were assigned to the other conditions. All the participants performed the task with the robot.

The task and the procedure were the same as in the pilot experiment. However, in this experiment, although the task display was the same as in the pilot experiment, an iPad by Apple Inc. was used to draw the creatures. Also, each task took 24 minutes. The suggestions or distractions were randomly chosen for each participant and given in randomized order.

After the task was finished, in addition to the reference rating, the participants in the distraction situation rated to what degree the suggestions and distractions were followed with a 5-point scale (1: not followed at all - 5: extremely followed).

Hypothesis

In this experiment, the following two hypotheses were examined in each of the no-distraction and distraction situations.

Hypothesis 1: The suggestions from a robot enhance creativity by facilitating metacognition.

Hypothesis 2: The suggestions from a robot enhance creativity by causing irrelevant distractions.

If Hypothesis 1 were confirmed, the participants would refer to the suggestions and generate creative ideas from the perspectives of the suggestions. There would be more opportunities for the participants to achieve helpful suggestions in the high-frequency condition than in the low-frequency condition. Therefore, in the both no-distraction and distraction situations, the participants in the high-frequency condition would refer to the suggestions more frequently and draw more creative creatures than those in the low-frequency condition.

Contrarily, if Hypothesis 2 were confirmed, the suggestions would distract the participants and enhance creativity; therefore, the suggestions would be unlikely to be referred to in order to draw creative creatures. There would be more opportunities for the participants to be distracted in the high-frequency condition than in the low-frequency condition. Thus, in the both no-distraction and distraction situations, the participants in the high-frequency condition would draw more creative creatures than those in the low-frequency condition; however, they would refer to the suggestions as frequently as those in the low-frequency condition.

Results

The average number of drawn creatures in the no-distraction situation was 9.29 for the high-frequency and 10.41 for the low-frequency condition. Also, the average number in the distraction situation was 6.94 for the high-frequency and 8.56 for the low-frequency condition. The results of t-tests showed that there was neither significant difference in the number of drawn creatures between the two conditions in the no-distraction situation ($t(32) = 0.98, p = .33$) nor in the distraction situation ($t(31) = 2.18, p = .05$). These results showed that the participants drew creatures to the same extent in the two conditions in each situation.

Also, the result of a t-test showed that there was no significant difference in the rating, what degree the suggestions and distractions were followed, between the high-frequency ($M = 4.05$) and low-frequency ($M = 3.88$) conditions in the distraction situation ($t(31) = 0.49, p = .63$). The result showed that the participants followed the suggestions and distractions to the same extent in the two conditions in the distraction situation.

For the analysis of the hypotheses, first, the originality of the creatures was rated in the same way as the pilot experiment. Three independent raters different from those in the pilot experiment were trained and then rated all creatures in randomized order. The rated scores between the three raters were judged consistent ($\alpha = .72$).

Next, the average originality score of each participant was calculated in each condition, and a t-test was performed on the score in each situation (Figure 4). The results revealed that in the no-distraction situation, the score was significantly higher in the high-frequency condition than those in the low-frequency condition ($t(32) = 3.62, p < .001$). In contrast, in the distraction situation, there was no significant difference between the two conditions ($t(31) = 0.07, p = .94$).

Moreover, a t-test was performed to compare the reference ratings between the two conditions in each situation (Figure 5). The results indicated that in the no-distraction situation, the rating was significantly higher in the high-frequency condition than in the low-frequency condition ($t(32) = 2.51, p < .05$). On the other hand, in the distraction situation, there was no significant difference between the two conditions ($t(31) = 0.09, p = .93$).

The results in the no-distraction situation supported Hypothesis 1. However, the results in the distraction situation did not support neither Hypothesis 1 nor 2.

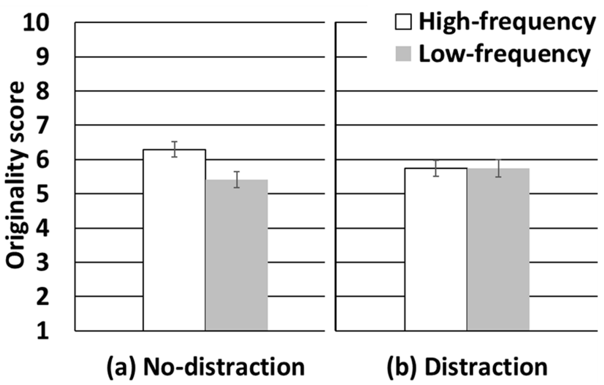


Figure 4: Average originality score of each condition in (a) no-distraction and (b) distraction situations. The error bars indicate the standard error.

Discussion

In the no-distraction situation, the participants in the high-frequency condition referred to the suggestions more frequently and created more original creatures than those in the low-frequency condition. This result supported Hypothesis 1, that is, the suggestions from the robot enhanced creativity by offering a variety of different perspectives to generate ideas and facilitate metacognition.

However, the effect of facilitating metacognition was not found in the distraction situation. This might be because the number of the suggestions related to drawing creative creatures was too small in the high-frequency condition, and therefore, there were not enough opportunities to facilitate metacognition. Also, the effect of causing distractions was not found in the distraction situation. Baird et al. (2012) showed that distractions which require light cognitive load enhance creative generation. In their experiment, the participants who performed the undemanding preceding task, which required cognitive load light enough to elicit mind wandering, enhanced creativity in the following creative task, the unusual uses task, more than those who performed the demanding preceding task, which required more cognitive load. The distractions provided in this study might be too demanding for the participants to enhance creativity.

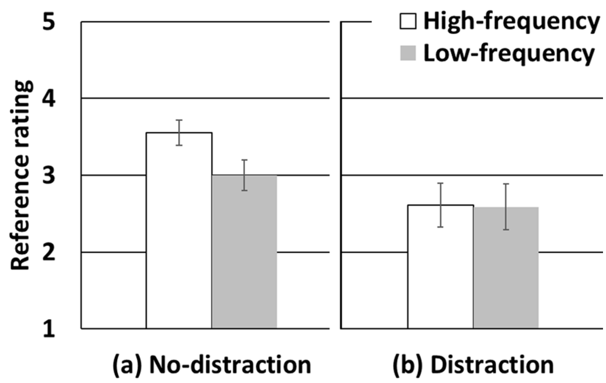


Figure 5: Average reference rating of each condition in (a) no-distraction and (b) distraction situations. The error bars indicate the standard error.

General discussion

Robots have been developed for a variety of applications. However, there have only been a few studies that investigated how a physically present robot could support human cognitive activities. This study focused on creative generation to investigate how suggestions from a robot would influence human creative generation. The results of the experiment revealed that the suggestions from a robot enhanced creative generation by offering a variety of different perspectives.

In human-human collaboration, representational change occurs when people reflect their own and the other's ideas or knowledge by asking, explaining, or externalizing (e.g. Miyake, 1986). The robot used in this study was not interactive; however, representational change might be caused by the suggestions in the same manner as in the previous studies of human-human collaboration. In particular, the participants were considered to refer to some of the suggestions from the robot and reflect their own ideas according to the suggestions.

Moreover, Okada and Ishibashi (2017) showed that in a creative drawing situation, new perspectives in drawing were acquired by copying and viewing other's unfamiliar artworks, and the creativity of drawings increased. However, in their experiment, a human verbal suggestion, which recommended creating original and creative drawings in different styles, did not enhance the creativity of drawings. In contrast to the previous study, in this study, the suggestions from a robot with speech sounds enhanced the creativity of drawings. Since the robot provided multiple different types of suggestions during the task, at least some of them were assumed to encourage the participants to consider their ideas from the viewpoints of the suggestions.

Furthermore, in the pilot experiment of this study, although the suggestions from the robot enhanced creativity, they were less referred to than suggestions in text form. In contrast, Leyzberg et al. (2012) showed that the advice from a physically present robot enhanced human problem solving performance and indicated a possibility that people might perceive the authority or social standing of a physically present robot and take their advice seriously.

This difference was assumed to happen because of the difference in the interactivity of the robots. In the previous study, the robot provided the advice according to the time required to solve the problem. On the other hand, in this study, the robot provided the suggestions without consideration of the participants. Thus, the participants in this study might not have perceived the sociality or interactivity of the robot to take the suggestions seriously as in the previous study. Another possibility related to the type of task was also considered. In the previous study, a well-defined problem, nonogram puzzle, was used as the task. Because there were clear solving strategies, the relevant advice about the strategies could be provided to participants. In contrast, in this study, an ill-defined problem, creative drawing, was used as the task. Since there were several possible and different perspectives to take for the creative drawings, there was a possibility that many of the suggestions from the robot did not match their ideas and likely were ignored during the task.

Finally, in this study, the suggestions from a robot were made to facilitate metacognition. However, the enhanced creativity observed in this study needs to be ensured as the result of facilitated metacognition. The results in this study could not deny the possibility that the suggestions facilitated other types of cognitive processes involved in creative generation and enhanced creativity. Therefore, in our future study, we will investigate how each suggestion from a robot influences cognitive process and creativity.

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