Empirical Analysis of Changes in Human Creativity in People Who Work with Humanoid Robots and Their Avatars

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Abstract. This study presents results from an analysis of the relationship between humanoid robots and human creativity, which has not been demonstrated in the literature to date. To increase the academic rigor of our study, we adopted humanoid robots and their avatars in our experimental procedures. After participants engaged in experiments with humanoids and their avatars, we assessed the degree to which their levels of creativity changed. In experiments with 90 participants, we found that interactions with humanoid robots produced a statistically significant effect in increasing their creativity.

Keywords: Creativity, Creativity training, Human-robot interaction.

1 Introduction

In our competitive modern society, creativity has become an increasingly important factor in innovative development for individuals and society. For example, many researchers have shown that creative individuals were reported to be more productive and satisfied with their occupations [1]. Also, creativity within organizational and professional domains has been a popular subject of inquiry for managers and researchers. According to the research of Littleton et al., creativity enables workers to be more flexible and entrepreneurial within their organizations [2]. Thus, the presence and performance of creative people is essential to every organization, whether in the public or private sector, because their ability to invent, dream, problem solve, craft, and correspond in fresh, new ways is vital to organizational success [3]. Therefore, it is expected that enhancing an individual's creativity will enhance the performance of groups and organizations. If so, how can we improve individual creativity?

Training is one of the most common methods used to enhance creativity [4]. Creativity training tasks are based on the belief that creativity requires an environment that encourages risk taking and self-initiated projects and offers help and time for develop-

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ing ideas and individual effort. Previous studies have suggested several methods for enhancing creativity, among which are those intended especially for concrete problem-solving situations, including: brainstorming [5], verbal check-lists [6], picture stimulation and mind mapping [7]. Higgins [8] has also provided many methods to enhance creative problem solving. The purpose of many of these techniques is to generate ideas by using different types of games or tasks in order to suppress the common tendency to criticize or reject ideas.

Since evidence of the importance of creativity was first reported by researchers, many programs have been developed that use creativity training tasks to enhance individual creativity. Several researchers have reported the effectiveness of robot-mediated training in enhancing individual creativity, as well as the advantages of using robots in education [9, 10, 11, 12, 13]. According to Hwang and Lee [14], a dinosaur shaped robot had no significant effect on creativity enhancement, but the robot's avatar enhanced subjects' creativity. Likewise, in mediated creativity training, the level of creativity was found to be influenced by the type of mediator.

According to the research by Amabile [15], one more consideration in mediator-based creativity training is the fact that the presence of others can affect creativity. When the 'presence of others' is a mediator in the form of a robot, this can affect an individual's creativity. As Zhuo [16] reported, individuals who have high levels of creativity will be discouraged when they are with someone who is monitoring them, while the opposite occurs in the case of a person with low levels of creativity. Therefore, research should be conducted to understand the effects of the mediator's presence.

Until now, we have investigated the importance of individual creativity, tasks to improve creativity, mediator-based creativity training and the effect of another's presence on creativity. In this paper, we investigated the effects of the presence of a humanoid robot and its avatar on individual creativity in the performance of a task. The hypotheses developed in this research are:

- Hypothesis 1: A humanoid robot will enhance subjects' creativity in task performance.
- Hypothesis 2: A humanoid avatar will enhance subjects' creativity in task performance.
- Hypothesis 3: Enhanced creative task performance will differ between the humanoid and its avatar.
- Hypothesis 4: Highly creative people will be discouraged when they are with the robot or the avatar.
- Hypothesis 5: People with low creativity will be encouraged when they are with the robot or the avatar.

2 Literature Review

Creativity. Hennessey & Amabile [17] stated that: "Creativity involves the development of a novel product, idea, or problem solution that is of value to the individual

and/or the larger social group". Creativity is also defined as the production of original, unexpected and useful work [18]. Following these definitions of creativity, it seems that creativity and creative skills have become regarded as highly important in almost every field of work and education, especially those fields focused on creativity enhancement.

It has been demonstrated that creativity can be enhanced, and training has been used to achieve this. According to meta-analyses, creativity training is generally effective. Many methods are used in the work and education fields, but before applying them, we need to know how creativity is enhanced.

Pioneers in creativity research have come to share similar views, that creativity requires certain components, one of which is intrinsic motivation [18, 19]. Intrinsic motivation is considered a well-established predictor of creativity [20], and is the extent to which an individual is interested in a task and engages in it for the sake of the task itself [21]. Therefore, in this research, we measured the results of training on creative task performance according to the degree of the subjects' intrinsic motivation. To control for differences in personal creativity, we measured subjects' creativity levels (high, low) before the experiment, then analyzed the effects of creativity training by changes in their post-experiment levels of creativity. We also assessed the effect on creativity of the type of mediator.

Mediator-Based Creativity Training. In this paper, we used two types of mediators (robot and avatar) in creativity training. Since technology was introduced into the field of education, robots have been adopted to promote individual creativity. Several previous studies have introduced robot- mediated creativity education and demonstrated its effectiveness. Research with the Thymo robot found that this robot partly fulfilled the goal of promoting creativity. Because of its flexible characteristics several other researchers have used Lego Mind Storms to investigate individual creativity [13, 14].

The majority of previous research has employed the concept of experimental learning, which is described as: "The process whereby knowledge is created through the transformation of experience" in [22]. Therefore, students were able to promote creativity while engaging in robot-related tasks.

This study builds on previous work, but we addressed several distinctive features by comparison to previous research. First, we used two types of mediators: a robot and the robot's avatar. We used avatars because they are well known mediators in education and creativity training and also because they have flexible characteristics. Thus, by using both robot and avatar mediators, we were able to investigate the effect of mediator type on creativity training; to focus on the effects of the presence of the two types of mediators, we chose to match the avatar's and robot's appearance. Finally, a control group that had no mediator was used to investigate the training effect itself.

3 Experiment

Participants. 94 student participants were recruited via online advertisements and 90 of those were accepted. There were 38 males and 52 females who ranged in age from 20-32 years (mean = 23.31, SD = 2.56).

All participants first completed the Epstein Creativity Competencies Inventory for Individuals (EEC-I) to measure self-assessed individual creativity. The EEC-I is composed of 28 Likert 5-scale items (lower is better), and we used the scores as a criterion to group the participants. First, we divided them into two groups based on their creativity scores (low, high). Second, we set three conditions (None-NAO-Avatar) in each group already divided according to creativity. Participants were placed in these three groups, with each group having similar creativity scores. Finally, we divided all participants into six groups on the basis of high and low creativity and the three experimental conditions.

Table 1. Participants Group

Participants groups	Experimental conditions		
	None	**NAO**	**Avatar**
High creativity score	14 participants Mean : 74.07 SD : 9.19	15 participants Mean : 74.47 SD : 8.65	15 participants Mean : 74.53 SD : 6.45
Low creativity score	16 participants Mean : 95.59 SD : 7.58	15 participants Mean : 95.8 SD : 7.20	15 participants Mean : 95.38 SD : 9.27

Measures. To verify the influence of another's presence on creative performance, we designed two tasks based on the Torrance Tests of Creative Thinking (TTCT) verbal task and Consensual Assessment Technique (CAT). TTCT is the most well-known and widely used test to measure creativity (Baer, 1993; Kim, 2006; Ferrando, 2006; Wechsler, 2002). TTCT has 4 indicators: fluency, flexibility, originality, and elaboration. CAT provides a method to judge the creative content of, for example, stories and poems. CAT is one of the most powerful tools in assessing creativity (Kaufman et al, 2006). We accepted and revised the TTCT and CAT to fit our purposes.

In the first task, we asked participants to create words by assembling letters in the Korean alphabet. A Korean word consists of a series of characters, and a single character is composed of assemblies of the Korean alphabet, which consists of 14 consonants and 10 vowels. We provided 14 basic alphabet cards to participants, and they created words by assembling these alphabets. The alphabet cards that we provided consisted of 8 single consonants and 6 single vowels that were surveyed as the most used alphabets by the National Institute of the Korean Language. These alphabets

could combine consonants with vowels to make a single character, and consonants with consonants or vowels with vowels to create double consonants or diphthongs. We applied three criteria from the TTCT to evaluate participants' performance on the alphabet assembling task.

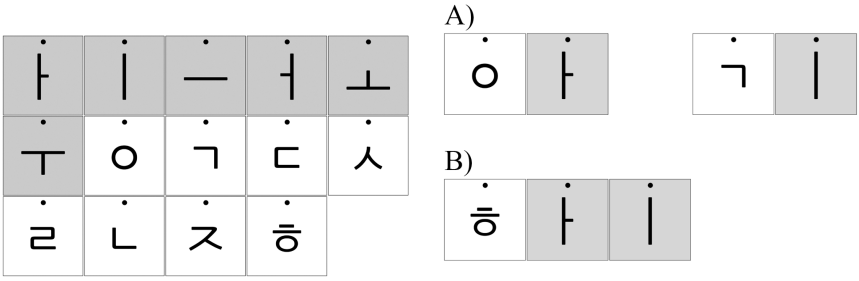

Fig. 1. Korean alphabet cards that used in word assembling task. Gray cards are vowels and white cards are consonants(Left), Example of assembled words. A) Baby, B) Sun. (Right)

- **Fluency** : Number of words participants created.
- **Originality** : The rarity of usage in words created.
- **Elaboratio**n : Number of alphabet cards used to create a single character.

We developed a program to analyze the results of the alphabet assembly task. Fluency was counted as the words that were assembled correctly. The National Institute of the Korean Language made a list of the frequency of word use, which we used to rate the originality of each word. As mentioned above, each alphabet could be combined in various ways. Thus, elaboration could be judged by counting the number of alphabet cards that were used to create a single character.

The second task was storytelling with the words created in the first task. The story-telling task is also used widely to measure creativity. The creative story products from the second task were evaluated by CAT using our revised TTCT criteria.

- **Fluency**: Number of characters in the story.
- **Originality**: Originality of the subject; creative usage of words.
- **Flexibility**: Number of words used in story that was created in first task.

The total number of words that was used in the stories represented fluency. Originality was rated by an expert who was a registered poet in a Korean writers' association. He rated the originality of the stories on a 100 point scale. We counted the number of words used in the story that were created in the first task and used that as our criterion of flexibility.

Finally, each task had three conditions, so a total of six criteria was used to measure creativity. We converted the results of all six indicators to a maximum 20 point score. The sum of the three criteria scores contained in each task represented the creative performance on that task. These two task performance scores were aggregated to assess comprehensive creative performance.

Fig. 2. Real robot NAO(Left), Avatar NAO(Right)

Procedure. Upon arrival, participants were ushered to separate rooms according to their experimental condition (None, NAO, Avatar). In the "None" control condition, there was only one participant in the room during the experiment. We introduced the minimum information necessary in order to conduct the experiment and stepped out of the room. In the NAO condition, participants conducted the experiment with an actual humanoid robot (NAO). In the Avatar condition, participants conducted the experiment with a virtual avatar on the screen. We used Webots for NAO that can also simulate NAO in a virtual environment. Thus, we could present the same appearance, behavior and feedback to participants between the two groups, NAO and Avatar.

- **None**: No feedback.
- **Nao**: Information and feedback about tasks from real robot NAO.
- **Avatar**: Information and feedback about tasks from virtual NAO Avatar.

Our ultimate goal was to find a way to enhance people's creative performance using a humanoid robot. Thus, we designed the behavior of and feedback from the NAO to enhance participants' creativity.

To begin, NAO said hello to the participant with an animated hand wave. When introducing the task, NAO usually gazed into the participant's eyes, sometimes nodding and shaking its head to indicate allowed and restricted actions. When each task began, NAO pointed its finger to the answer paper needed to conduct the tasks and explained how to use it. During the task, NAO gazed at the task field and gave feedback to the participants. First, NAO gave an example to which the participants could refer. Second, NAO gave a speech of encouragement about the participants' progress. Third, NAO counted the time remaining to increase motivation. For the first task, assembling the alphabet, 3 minutes were allowed, and for the second task, storytelling, 4 minutes were allowed.

4 Results

The analyses showed that the proposed hypotheses were supported in part. First, subjects who were in the NAO condition (m = 69.59, SD = 14.58) had significantly

higher average creativity scores than those in the 'None' control condition (m = 58.80, SD = 13.32: t = -3.008, p = 0.005). Therefore, hypothesis 1 was supported. The NAO avatar also enhanced subjects' creativity levels (m = 65.11, SD = 15.36), but was not significantly different from the 'None' condition (t = -1.69, p = 0.10); thus, hypothesis 2 was not supported. Finally, NAO enhanced subjects' creativity levels more than the NAO avatar, but again, there was no significant difference between the two (t = 1.06, p = 0.30), indicating that hypothesis 3 was not supported.

Further, the highly creative group showed no significant differences when they were exposed to the NAO vs. the avatar. However, the low creativity group was affected only by NAO (t = -2.71, p = 0.02). Therefore, hypothesis 4 was not supported and hypothesis 5 was partially supported. According to these results, many of the hypotheses were nonsignificant statistically; however, other factors need to be considered in the interpretation of our results.

Table 2. The average score of the creative task

Condition	Creativity level	Score			
		Task1	Task2	Total	
Alone	High	26.48	34.30	60.78	58.80
	Low	25.17	31.66	56.84	
With Nao	High	31.06	37.93	69.00	69.59
	Low	31.85	38.33	70.19	
With Nao avatar	High	32.88	32.75	65.62	65.11
	Low	33.40	31.20	64.60	

5 Conclusion and Future Work

The goal of this study was to investigate the effect of the presence of a humanoid robot and its avatar on individuals' creative task performance. Therefore, 5 hypotheses were proposed based on previous studies. We expected all of the hypotheses to be supported, but most were not. However, there are some points to consider.

First, the effect of the robot in creativity training was verified statistically, which is consistent with previous research. Second, people with low creativity were more motivated by the type of mediator than highly creativity people. From this result, we obtained the useful information that when conducting creativity training for those with low creativity, it is better to use a mediator that has a high presence.

In the future, we will focus on improving the tasks and measurements and use a larger sample size before conducting the experiment again.

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