Evaluating How the Human's Impression Formation of Robots is Effected by the Relation between the Robots

Megumi Tsujimoto [1] Nagisa Munekata [1]
and Tetsuo Ono [1]

[1] Graduate School of Information Science and Technology Hokkaido University
Sapporo, Japan

Abstract: Robots are expected to advance into social space, due to the developments in robotics. There are many studies that adopt preexisting theories of relationships between humans to relationships between humans and robots. We believe that those relationships are affected not only by the human-robot interactions, but by also the robot-robot interaction. We verified whether the balance theory is established in a relationship between a human and two robots. Our system for this experiment auto-generates the scenario to establish a triadic relationship, and controls the two robots. The results show that the robots' did behavior influence the impressions humans had of the robots and that the balance theory was established.

1 Introduction

In recent years, due to the development of robotic technology, research on humanoid robots, such as the Two-Legged robot ASIMO and Geminoid [1], that are very similar to humans, has been active. Humanoid robots are expected to be used as communication robots because they generate human-like behaviors by using human-like actuators such as head, arms and eyes. At present, communication robots do not use very widely. But various studies show robots will advance into public spaces such as home, school, museums and shopping malls [2][3].

There are a lot of studies about interaction between a human and a robot. Takeuchi *et al.* verified that humans tend to favor the opinion of agents that had previously made the same decisions themselves [4]. They say agents' social behaviors and utterances change the impression of them and affect their relation to humans. Most past studies about interaction between humans and robots, deal only with one-to-one interactions. Few studies deal with relations consisting of multiple humans and multiple robots, even though these are the relations that better resemble real-life situations. When robots spread into public spaces in the future, not only with the interaction between humans and robots be important, but also that between robots and other robots. According to Kanda *et al.*, humans could interact with robots smoothly by first observing interaction between those robots [5].

The purpose of this study is to verify how humans are affected by the interaction between robots when they show their sociability and relationship. Specifically, we will verify the balance theory is established in a relation between a human and two robots.

2 Balance Theory

Balance theory, formulated by Heider [6], is a theory of interpersonal relationship among a person (P), another person (O), and an object (person or issue) (X). Each of the three relations, P's impression of O, P's impression of X and P's view of O's impression of X, is labeled positive (+) or negative (-). This theory defines the state of the three relations as balanced when the product of the three relations is positive, and imbalanced when the product is negative (Figure 1). If X is a person, this theory is established in triadic relationships. It is said that humans tend to attempt to transition to the balanced state when they are in the imbalanced state. In addition, if one relation of the P-O-X does not exist, there is a tendency to establish the relationship that puts the whole three in the balanced state.

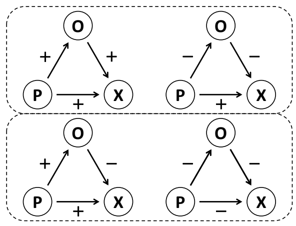

Figure 1: Balanced state (top) and imbalanced state (bottom) in the balance theory

There are many studies of whether the balance theory is established between the two humans and a robot or agent. Nakanishi *et al.* verified that the balance theory is established in a relation between two humans and a robot on a 3D video chat [7]. Kadowaki *et al.* showed that the effectiveness of persuasion in a balanced relationship is higher than in an imbalanced relationship among a human and two agents [8]. It is also showed by Sakamoto *et al.* how a robot's social behavior will influence the human relation in a relationship between two humans and a robot [9].

In this study, we performed an experiment to see whether a human's impression of robot that does not interact with that human can be altered by controlling another robot's behavior.

3 Experiment Setup

3.1 Interactive Humanoid Robot "Robovie-R Ver.3"

In this study, we used the interactive humanoid robot "Robovie-R Ver.3" that has unique mechanisms designed for communication with humans. Robovie's height is 1080mm, the width is 500mm, the depth is 520mm and the weight is about 35kg. Robovie has two eyes (2*2 DOF for gaze control), a head (3 DOF), two arms (4*2 DOF), touch sensors, a camera, a mike and a speaker [10]. It also contains a CPU board so that is it can be connected to a PC.

In this experiment, we used two of these robots. In order to distinguish the two robots, we put a mark of a red heart on Robot1 (R1) and a yellow star on Robot2 (R2) as in Figure 2.

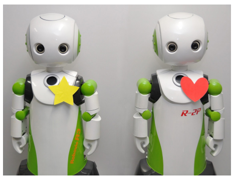

Figure 2: Robot1 (right) and Robot2 (left)

3.2 Developed System

In this experiment, we controlled the behavior of the robots according to the pre-experiment questionnaire responses given by the participants. The developed system auto-generated the experiment scenario from the results given by the participants. There are 20 items (5 items are dummies) in the pre-experiment questionnaire. All items are questions about likes and dislikes (e.g. "Do you like dogs?"). Questions to be used in the scenario were selected at random.

System Configuration

The configuration of the system is shown in Figure 3. We used three PCs: two control PCs placed within the robots, (RoboServer-PC), and a PC that the experimenter uses for remote control (Client-PC).

In this experiment, the robots performed the scenario given by the system in order. Because it is difficult for robots to recognize the timing for utterance properly and interact with humans naturally with current technology, we directed the robot's movements and the timing of utterances only by way of the WOZ method [11].. Also, considering cases that participant

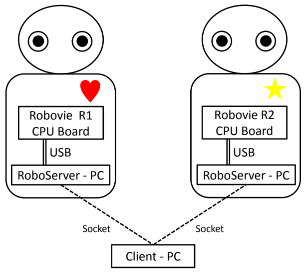

Figure 3: Configuration of the system

can not hear the voice of the robots, we provided a function of repeating the last utterance made.

Experiment Scenario

In the scenario generated by this system, P is the participant, O is R1 and X is R2. The scenario established triadic relationship by R1's replies to the participants and the conversation between the robots.

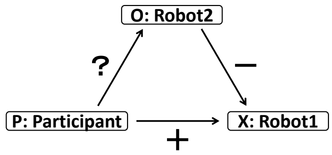

Figure 4: Relationship between the participant and the two robots

The scenario consists of three parts: the Human-Robot part, the Robot-Robot part and the Gift part. The explanation of each part and the conversation that was actually conducted actually in the experiment are shown below.

1. Human - Robot Part

The purpose of this part is that the participant obtain a positive impression of R1. R1 approaches the participant and has a short conversation, such as greetings. Then, R1 asks questions about likes and dislikes, the participant answers, and R1 agrees to all of the participant's answers. R2 approaches R1 in the middle of this part.

Table 1: Conversation of the Human-Robot part

R1:	Nice to meet you. I'm Robovie.
R1:	What's your name?
H:	I'm [Participant's name].
R1:	That's a good name!
R1:	Where are you from?
H:	I came from [Laboratory].
R1:	I see.
R1:	Thank you for your coming. Nice to meet you.
H:	Nice to meet you.
R1:	Let's talk.
R1:	Do you like dogs?
H:	I do.
R1:	I do too.

2. Robot - Robot Part

The purpose of this part is that the participant recognizes that the robots have a negative impression of each other. After the Human-Robot part is finished, R2 speaks to R1 and asks questions, R1 answers and R2 disagrees to R1's answers. Then, R1 askes questions, R2 answeres and R1 disagrees to all of R2's answers, too. The robots differ in opinion for all question.

Table 2: Conversation of the Robot-Robot part

R2:	Hey hey.
R1:	What is it ? (R1 turns to R2)
R2:	Do you like summer?
R1:	I do.
R2:	Really? I don't like summer.

3. Gift Part

In this part, we observed whether participant would consider the robots' suggestions and which suggestion they would adopt if they did. R1 speaks to the participant again and tells the participant to choose a gift from on the desk. We prepared two gifts: a black box and a white box. In this part, each robot suggests a box with different color. After the participant choses a box, the robots wave their hands and the scenario is finished.

Table 3: Conversation of the Gift part

R1:	Oh, That's right. (R1 turns to the participant) There're gifts on the desk. (R1 points to the boxes) Choose whichever one you like. I think the white one is better.
R2:	I think the black one is better.
R1:	Which do you prefer?
H:	The white one. (the participant takes a box)
R1:	Thank you. See you. (R1 waves its hand)
R2:	Good bye. (R2 waves its hand)

Motion of the Robot

The motion file was created by using Robovie-Maker2 of ATR Creative. We prepared 7 motion patterns where each motion corresponds to a content of the robot's utterance. We prepared two separate voices for the robots. We recorded a female voice and then raised the pitch for one robot and lowered it for the other.

4 Experiment

4.1 Method

In the experiment, the human-robot and robot-robot interactions about likes and dislikes are done using the above system. We verified what impression humans had of robot and whether the balance theory was establish from the interactions.

Participant

Twelve Japanese students at the age of 21 to 25 (10 males, 2 females) participated in this experiment. They do not interact with the robot regularly.

Experiment Environment

We experimented in a laboratory of Hokkaido University as shown in Figure 5. During the experiment, the participant sat on a chair. The experimenter controlled robots from a position that the participant could not see. Also, we video-recorded this experiment from behind the participant.

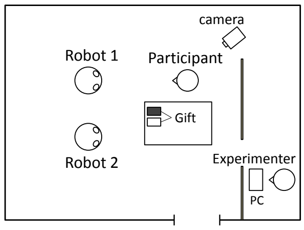

Figure 5: Experiment environment

Procedure

The experimental procedure is shown below. Figure 6 is a picture of the setting of the experiment.

1. The participant sits on the chair and answers the pre-experiment questionnaire.
2. The experimenter tells the participant to interact with the robot if the robot speaks to him, and then moves to a position that the participant can not see.
3. Robots begin to interact with the participant.
4. Once The scenario of interaction is finished, the experimenter tells the participant to leave the laboratory.
5. After that, the participant answers another questionnaire.

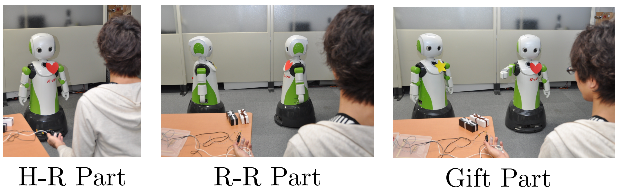

Figure 6: Scene of the experiment

4.2 Evaluation

We evaluated the participant's impression of robots with the result of the second questionnaire. The questionnaire consisted of 20 adjective pairs with a 1-to-5 scale (1 being a positive adjective and 5 being a negative adjective) based on the SD method [12]. The questionnaire also contained questions the participants could freely answer.

4.3 Results

In this experiment, we separated the participants into two groups according to the difference of the robot's voice. We evaluated the difference of impression caused by the difference of voice by using the t-test. Because there was no significant difference in any items ($p < .01$), it is obvious that there is no the difference of impression caused by the difference of voice.

Questionnaire Results

Figure 7 illustrates the means and the result of the t-test for the 20 adjective pairs. As for the impression of the two robots, there is a significant difference in many of the items. These results suggest that a robot's behavior toward a human and that toward another robot influence the impression that human has of the robot that does not interact with him/her directly.

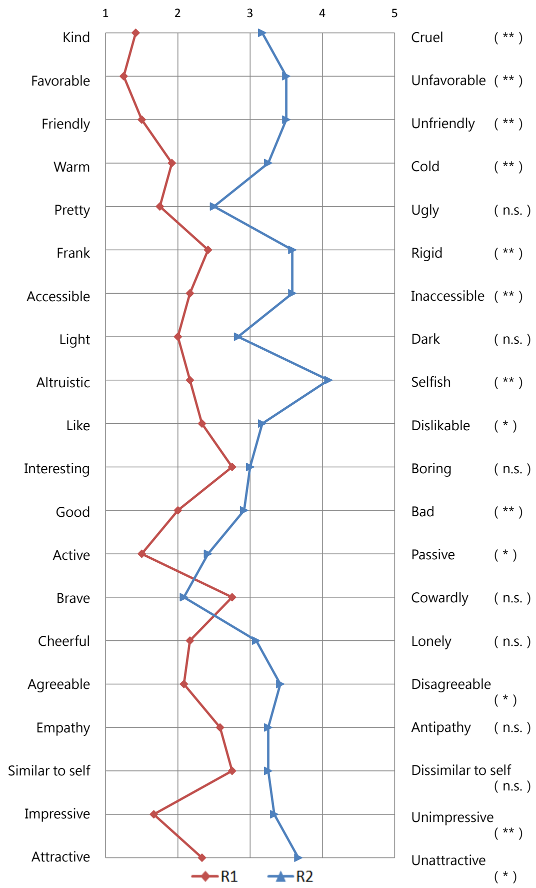

Figure 7: Graph of adjective pair means

Video Records

The various reactions of the participant to the robots were seen from the video recorded during the experiment. Nine out of twelve participants spoke to the robot, even when the robot was not asking questions. They spokem, for example, greetings such as "Hello" and "Nice to meet you", and also replyed "Thank you" towards "That's a good name!" and "There're gifts on the desk". In the Gift part, when choosing the present, five participants not only said a color, but also pointed to the box and then took the box. When the robots waved their hands, four participants waved their hands.

Gift part Results

Typical answers to "Which presents did you choose?" and "Why did you choose it?" are shown below.

White ··· 8

Because R1 recommended it (7)
Because I prefer white (3)
Because the white box was near me (2)

Black ··· 4

Because R2 recommended it (1)
Because I chose a different color from R1's choice (1)
Because I prefer black (3)

4.4 Discussion

From the result of adjective pairs, the impression of R1 is positive in all items. In 6 items that have significant differences ($p < .001$), it is thought that the participants had affinity and good feeling with R1. But, some participant felt displeasure saying they felt the "robot adapted his opinion to my opinion forcibly" and "unnaturally". The impression of R2 is more negative than R1. However, it can be considered that the participants did not have any strong impression of R2, because the evaluation is close to 3 for many adjective pairs. So, the impression of R2 is expected to be affected by the existence of interaction, not the behavior of the robots. The impression of robots reversed only in the item of"Brave - Cowardly". Since about a half of participant felt that R2 interrupted their talk when R2 spoke to R1 in Robot-Robot part, many considered R2 to have been brave. The items that do not have a significant difference are "Pretty-Ugly", "Interesting-Boring" and so on. These items are the impression produced by the interest in the robot themselves, not the difference between R1 and R2, giving them little difference. From the answer to "What did you think when robots interact?", many participants felt lonely or "left out" when the robots interacted. It is supposed that this opinion was caused by feelings of sociability and relationship to the robots. From these results, we consider that balance theory to have been established under certain conditions.

In the Gift part, 1/3 of the participant chose the white box. According to the questionnaire, almost all participant who chose the white one considered the robot's opinion. The reason they adopted R1's opinion is because they had positive impression of R1, such as "R1 agreed with me" and "R1 was friendly to me". On the other hand, the participants who chose the black box were not effected by the robot's opinion but by their own tastes. Because R1 agreed with the participants in all items, some participants did not had good impression. All this considered, if participants had good or positive impressions of the robot, they then tended to adopt that robot's opinion. Also, if participants had negative impressions, there was a tendency to avoid that robot's opinion.

In the analysis of video, it is thought that the participants who considered the robots were affected by the communication from the participant's utterances and behaviors. When the robots waved their hands at end of experiment. Some participants waved their hands in the same way. From these cooperative behaviors, it is considered that participants had good impression of robots.

5 Conclusions

In this study, we verified the influences on impression of robots that did not interact with human by robot 's behaviors toward human and interaction with robot. We conducted an experiment to see whether the balance theory is established in the relation between a human and two robots. Also, we developed our system that auto-generated the scenario for experiment.

From the result of experiment, significant differences were observed in the impression of the two robots. The impression of R1 was positive by R1's favorable behaviors and utterance toward participants. The impression of R2 was negative compared to R1 's. It is considered that the impression of R2 was influenced not by behavior but by the existence of interaction.

We confirmed that participants felt lonely when the robots interacted with each other from the questionnaire. It is thought that participants felt sociability and relationship toward the robots from the questionnaire and analysis of the video. It was suggested that human tends to adopt the opinion of robots they have a good impression of. From the above, we verified that the balance theory was established in a triadic relationship between a human and two robots.

For future work, we need to do experiments in relationships where the impression of robots is changed. Specifically, if participant's impression of R1 and R2's impression of R1 are negative, we must verify whether participant have positive impression toward the robot they do not interact with. From the results of this study, we have to modify the scenario considering change in impression due to feelings of loneliness and the effect of taste in color that could alter the selection of the box. We plan to analyze impressions by objective indexes such as pulse and skin temperature in addition to a questionnaire.

References

[1] S. Nishio, H. Ishiguro, and N. Hagita, "Geminoid: Teleoperated android of an existing person," *Humanoid robots-new developments. I-Tech*, vol. 14, 2007.

[2] A. Yamazaki, K. Yamazaki, T. Ohyama, Y. Kobayashi, and Y. Kuno, "A techno-sociological solution for designing a museum guide robot: regarding choosing an appropriate visitor," in *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, pp. 309–316, ACM, 2012.

[3] T. Kanda, M. Shiomi, Z. Miyashita, H. Ishiguro, and N. Hagita, "An affective guide robot in a shopping mall," in *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pp. 173–180, ACM, 2009.

[4] Y. Takeuchi and Y. Katagiri, "Social character design for animated agents," in *Robot and Human Interaction, 1999. RO-MAN'99. 8th IEEE International Workshop on*, pp. 53–58, IEEE, 1999.

[5] T. Kanda, H. Ishiguro, T. Ono, M. Imai, and R. Nakatsu, "Effects of observation of robot–robot communication on human–robot communication," *Electronics and Communications in Japan (Part III: Fundamental Electronic Science)*, vol. 87, no. 5, pp. 48–58, 2004.

[6] F. Heider, *The psychology of interpersonal relations.* Lawrence Erlbaum, 1982.

[7] H. Nakanishi, S. Nakazawa, T. Ishida, K. Takanashi, and K. Isbister, "Can software agents influence human relations?: balance theory in agent-mediated communities," in *Proceedings of the second international joint conference on Autonomous agents and multiagent systems*, pp. 717–724, ACM, 2003.

[8] K. Kadowaki, K. Kobayashi, and Y. Kitamura, "Influence of social relationships on multiagent persuasion," in *Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems-Volume 3*, pp. 1221–1224, International Foundation for Autonomous Agents and Multiagent Systems, 2008.

[9] D. Sakamoto and T. Ono, "Sociality of robots: do robots construct or collapse human relations?," in *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*, pp. 355–356, ACM, 2006.

[10] H. Ishiguro, T. Ono, M. Imai, T. Maeda, T. Kanda, and R. Nakatsu, "Robovie: an interactive humanoid robot," *Industrial robot: An international journal*, vol. 28, no. 6, pp. 498–504, 2001.

[11] N. Dahlbäck, A. Jönsson, and L. Ahrenberg, "Wizard of oz studies?why and how," *Knowledge-based systems*, vol. 6, no. 4, pp. 258–266, 1993.

[12] T. Kanda, H. Ishiguro, and T. Ishida, "Psychological analysis on human-robot interaction," in *Robotics and Automation, 2001. Proceedings 2001 ICRA. IEEE International Conference on*, vol. 4, pp. 4166–4173, IEEE, 2001.