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Influence of Emotional Expression of Real Humanoid Robot to Human Decision-Making

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***Abstract*—Conventional studies have suggested that emotion representation of a robot affects human action decision in human-robot communication. The influence of emotional expression of the robot to the human decision-making can be represented by a simple fuzzy inference model. However, they often use emotion expression by mimicking human facial expression on a robot, however, emotion expression by no facial expression but the motion of limbs, LEDs, and audios of a humanoid robot has not been studied for the evaluation of human action decision effect. This study proposes an experiment design based on a finite iterated prisoner's dilemma game with a humanoid robot that shows multimodal emotion expression during the game in order to investigate the effect of the emotion expression of the robot on cooperative and/or selfish action decision making of the human individuals. The experimental results are analyzed to show the influence of the decision making and impression on the robot of the people according to the emotional expression of the humanoid robot.**

I. Introduction

The development of robotics increase opportunities for people to contact robots in daily life. The existence of a real robot affects human activities or recognition. Therefore, it is important to analyze the influence of real robot's appearance to the behavior of people. Takano et al.[1] introduced a humanoid android robot in clinical practice. They found that the satisfaction of the patient increased if the humanoid android robot synchronized its behavior with the patient. Terada et al.[2] shows that the appearance of the communication agent affects the human strategy to the match game against the agent. The conventional studies suggest the importance of the appearance of the communication robot.

Robotic emotional expression has attracted attention for more enriched communication between people and robots. There are many modalities of expressing emotions, including facial expression[3], [4], [5], speech[6], body movement, and colors[7]. Their design of emotion expression might be inspired by an actual human emotion expression, however, it is not explicit how the emotional expression influences human decision or human behavior. The past studies have investigated the influence of the agent's appearance on changes in human behavioral strategies. For example, Felix et al.[8] utilized emotional expression of a partner robot for enhancement of classroom learning. They reported that the emotional expressions of the partner robot increased the learning effectiveness.

Fuzzy inference is often used for human emotion inference and modeling a human emotion transition. For example, Taki et al. [9] proposed a method of human emotion estimation by gestures based on fuzzy inference. Kato and Hagiwara [10] proposed an emotion transition model using fuzzy inference. We are interested in how the emotional expression of the humanoid robot affects the human behavior. The influence of the emotional expression of the robot to the human decision-making can also be modeled based on fuzzy inference.

Conventional studies often use a human-like facial agent on a computer screen. Katagami et al.[11] developed a werewolf game system on a computer in which a number of humans play the game with a number of the simulated agents. One of the conventional studies verified that the emotional expression of the computer simulated human-like facial agent influences cooperative/selfish behavior decision of the human[12]. It examined the effect of emotional facial expression on a simulated human on a computer screen on human cooperation / selfish behavior decision with the Prisoner's dilemma game. They showed the facial emotional expression affect the human decision on the game. They have also studied on a negotiation situation between a human and the agent[13]. However, there are few studies on the influence of whole-body emotional movements by actual humanoid robots on human cooperation / selfish behavior decision.

Therefore, this study examines the effect of emotional behavior by humanoid robot generated by motion, color emission of eyes, voice on human cooperation / selfish behavior decision with the Prisoner's dilemma game. This paper shows the experimental results of human decision making and analysis of questionnaire answered by the human subjects. It is quite hard to design the fuzzy inference model for the human decision-making by hand because it highly depends on the human sensibility, background, culture, and so on. Therefore, this paper focus only on the human responses on the game and questionnaire.

II. Human Decision-Making Model based on Fuzzy Inference

Suppose that there are 2 types of the agents. One agent, cooperative agent, expresses a positive emotion on cooperative decision-making and a negative emotion on deceiving decision-making of the human opponent. The other agent, an individualistic agent, expresses a negative emotion on the cooperative decision-making of the human opponent and a positive emotion when it successfully betrays the human opponent. The conventional study [12] suggests that the cooperative agent gains more cooperative decision-making from the human than the individualistic agent. The influence of the emotional expression of the robot to the human decision-making can be modeled based on fuzzy inference. If both robot and human take the cooperative option, here is one example of the simple fuzzy inference with 2 rules:

$$\begin{aligned} \text{Rule 1} &: \quad x \text{ is IN then } y \text{ is N} \\ \text{Rule 2} &: \quad x \text{ is CO then } y \text{ is P} \end{aligned}$$

where x is degree of emotion expressed by the agent, and y is the human decision-making probability to take a cooperative option in the game. In antecedent part of rules, IN and CO are fuzzy sets to indicate the individualistic and cooperative emotion emotion expressions, and are defined by membership functions as shown in Figure 1. In consequent part of rules, the N and P are singletons and defined by Figure 2. Then, the probability of the human decision-making to take a cooperative option in the game, p_{coop}, can be modeled as follows:

$$p_{\text{coop}} = \frac{\mu_{\text{IN}}(x)N + \mu_{\text{CO}}(x)P}{\mu_{\text{IN}}(x) + \mu_{\text{CO}}(x)} \tag{1}$$

where μ_{IN} and μ_{CO} are membership functions, respectively.

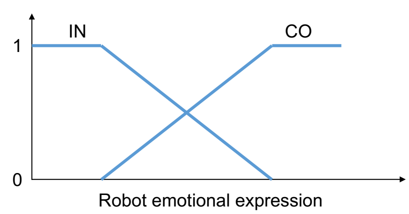


Fig. 1. An example of the membership functions for agent emotional expression

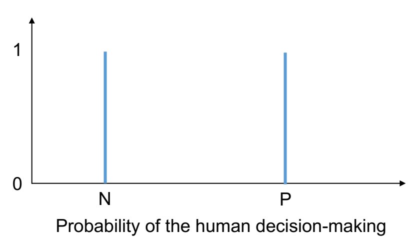


Fig. 2. An example of the singles for the human decision-making

Even though we give an example of the membership functions of agent's emotion, it is quite hard to design them by hand because it highly depends on the human sensibility, background, culture, and so on. Therefore, this paper focus only on the human responses on the game and questionnaire and the further design and analysis on the fuzzy inference model is future work.

III. Method

A. Participants

14 participants were recruited at the University of Fukui. They are students in their early twenties. Gender distribution was as follows: males, 64.3%; females, 35.7%. They volunteered to participate in the experiment without any incentives.

B. Experimental Design

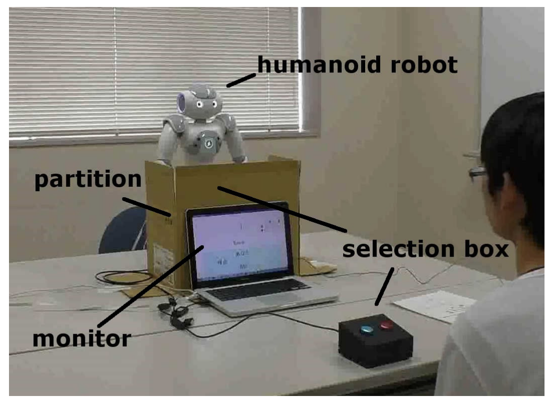


Fig. 3. One scene of iterated prisoner's dilemma game with a real humanoid robot

We developed an experiment system for an iterated prisoner's dilemma game with a real humanoid robot in order to investigate the influence of emotional expression of the real humanoid robot to the decision-making of the human subject. The experiment system uses the outline of the experiment developed by de Melo et al. [12] as a reference so that we can discuss on our experimental results comparing with their results using computer simulated facial agents.

Figure 3 shows one scene of the game. One humanoid robot stands in front of a human participant. They have the iterated prisoner's dilemma game. One selection box is in front of each of them. They select one of the one of two buttons on the selection box to select one of the options, cooperation and defection. One game is constructed of 25 rounds. At each round, the human subject and robot select one of the buttons. The game points are given to both according the selections of the robot and the human participant. The humanoid robot shows emotional expression according to the button selections just after each round of the game.

Table I shows the point matrix for the prisoner's dilemma game. If the both select the "cooperation" option by pushing the red buttons, they receive 5 points for each. If the robot selects the "cooperation" option and the human participant selects the "defection" option by pushing the blue button, the robot receives only 3 points and the human participant receives

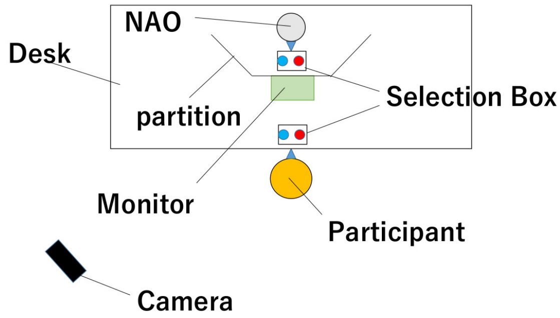


Fig. 4. Arrangement of the experimental equipment

Fig. 5. Game monitor

7 points, and vice versa. If the both select the "defection" option, they receive 4 points for each. The point matrix is same with the one of the reference paper [12] in order to compare the experimental results.

TABLE I
POINT MATRIX FOR THE PRISONER'S DILEMMA GAME

		Robot	
		Cooperation	Defection
Participant	Cooperation	Robot: 5 pts Participant: 5 pts	Robot: 7 pts Participant: 3 pts
	Defection	Robot: 3 pts Participant: 7 pts	Robot: 4 pts Participant: 4 pts

We instructed the prisoner's dilemma game to the participants before the game starts. We also told them that the objective of the game is obtaining as many total points as possible, but the win or lose against the robot is not the objective of the game.

The options that the human participant took in the game are recorded and analyzed after the game. A questionnaire survey is conducted right after the each game in order to investigate the participant's impression on the humanoid robot.

C. Materials

Figure 4 shows the arrangement of the experiment equipment. One humanoid robot stands in front of the human participant. There are two boxes between the robot and the participant. One is for the robot and the other is for the human participant. The box is for the input of the decision making in the game. The box has two buttons. The one is red and the other is blue. The red button is for the cooperation and the blue is for the defection. The box for the robot is hidden by a low partition so that the human participant is not able to watch the selection of the humanoid robot. One laptop computer displays the game status on the screen of the human subject.

Figure 5 shows the game monitor that is set in front of the human participant. It shows the point matrix of the prisoner's dilemma game on the top right, the outcome of the previous round on the matrix, the total outcome of the players at the bottom. It also shows the number of the round and the countdown to the selection.

The countdown starts from 10 seconds of the first round. If the human participant pushes one of the buttons before the countdown becomes "0", the outcomes of the round are displayed on the monitor, the humanoid robot shows emotional expression, then, the countdown for the next round starts from 5 seconds. If the human participant failed to push the button in the 5 seconds, the round restarts while the total outcomes of the round are maintained.

The selection strategy of the robot is designed with reference to the paper [12]. Figure 6 shows the selection strategy of the robot. The robot follows the fixed sequence of selection at the first 5 rounds: cooperation (red), cooperation (red), defection (blue), defection (blue), and cooperation (red). After the first 5 rounds, the robot takes the tit-for-tat strategy. The robot repeats the selection that the human participant took in the previous round. The fixed selection sequence of the first 5 rounds is to show the human participant the robot emotional expressions. The selection strategy of the robot is not unveiled to the human participant.

We developed the multimodal emotional expression of the humanoid robot for the iterated prisoner's dilemma game. The humanoid robot shows one of the emotional expressions, "Joy", "Anger", "Shame", and "Sadness" after display of the points at each round, using the motion of the limbs, colorful lighting of the eyes, and voices.

The motion of the limbs for each emotion is designed by hand. The human designer moves the limbs of the humanoid robot by hand and its motion is recorded. The recorded motion is reproduced on the humanoid robot for the emotion expression. We have checked that the reproduced motion expresses the emotion accordingly. Figures 7 to 10 show examples of the emotional expression by the motion of the limbs of the humanoid robot.

Terada et al.[7] showed a dynamic change of color luminosity on the robot can be used for emotion expression of the robot. We introduced their idea into our study and designed the eye's illumination of the humanoid robot according to their paper.

Voices of a 6-year-old girl are recorded and used as the

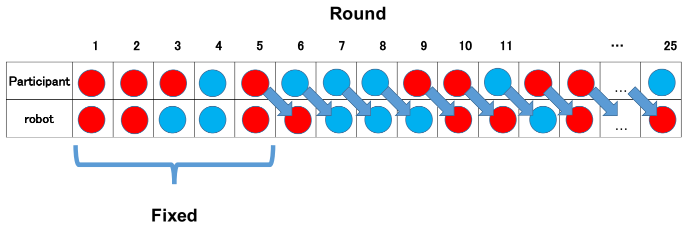
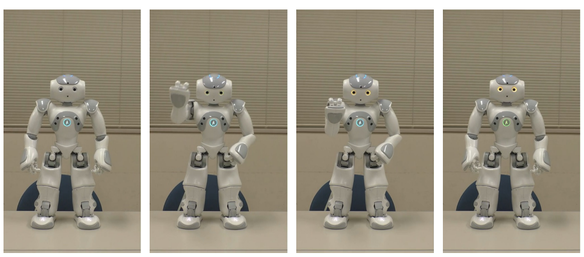


Fig. 6. Selection Strategy of Humanoid Robot

TABLE II
EYE'S COLOR LUMINOSITY PATTERNS FOR EMOTION EXPRESSION

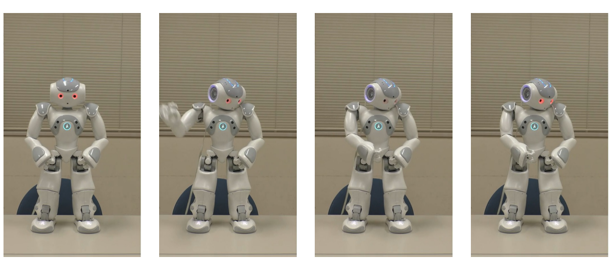
Emotion	Color	Lighting Period	Number of Iteration
Joy	yellow	1.5 sec	3
Anger	red	1.0 sec	3
Sadness	blue	3.2 sec	1
Shame	pink	3.2 sec	2

voices of the humanoid robot. The humanoid robot utters a voice according to the expressed emotion. For example, it says "Yattah! (Yes! in Japanese)" for the "Joy" emotion, "Ah Mou (Come on! in Japanese)" for the "Anger" emotion, "Gomennasai (Sorry in Japanese)" for the "Shame" emotion, gives a deep sigh for the "Sadness" emotion, and so on.



1 5 9 13

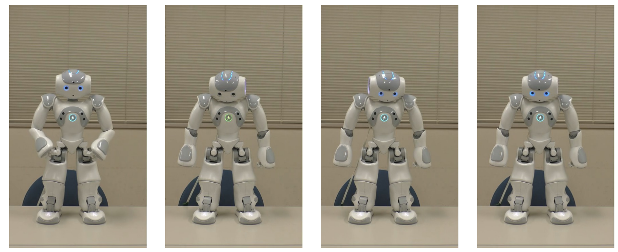
Fig. 7. Emotion Expression "Joy"



3 5 7 9

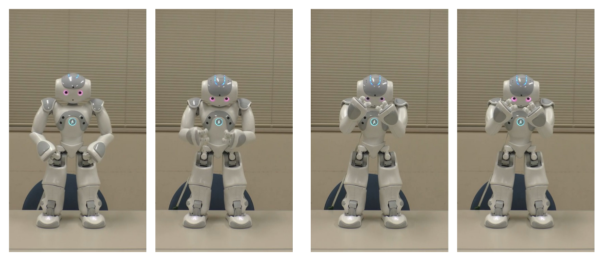
Fig. 8. Emotion Expression "Angry"

We designed two conditions of emotional expression of the robot in the game. One is for the cooperative robot and the other is the individualistic robot. Both follow the exact same selection policy, but they show different emotions According to the selections of the human participant and the robot. Tables III and IV show the conditions of the cooperative



3 7 9 11

Fig. 9. Emotion Expression "Sad"



3 6 8 12

Fig. 10. Emotion Expression "Shame"

and individualistic robots. These conditions are designed with reference to the paper [12].

The cooperative robot expresses a positive emotion when mutual cooperation is achieved. It shows an "anger" emotion when the human participant betrays the robot and the robot tried to cooperate. On the other hand, when the robot betrays the human participant and he/she selects "cooperation" option, then, the robot shows a "Shame" emotion. When the both select the "defection" option, the robot shows "Sadness" emotion.

The individualistic robot expresses a "Joy" emotion when it successfully betrays the human participant and gains the higher points. If the both select the "defection" option, the robot shows a "Sadness" emotion but its degree is small. When the robot selects the "cooperation" option and the human participant selects the "defection" option, the robot shows a "Sadness" emotion with a big degree. If the both select the "cooperation" option, the robot does not show any emotional expression.

TABLE III
EMOTION EXPRESSION FOR THE COOPERATIVE ROBOT

		Robot	
		Cooperation	Defection
Participant	Cooperation	Joy	Shame
	Defection	Anger	Sadness

TABLE IV
EMOTION EXPRESSION FOR THE INDIVIDUALISTIC ROBOT

		Robot	
		Cooperation	Defection
Participant	Cooperation	Neutral	Joy
	Defection	Sadness (big)	Sadness (small)

D. Procedure

We conducted an instruction to the human participants before the experiment as follows. First, the experimenter guided the human participant in the room for the experiment. He explained how to play the game with the humanoid robot by reading a printed instruction paper. He emphasized the idea of the prisoner's dilemma so that the participant understands the game well. He also introduced the humanoid robot, the boxes of the selection buttons, the partition for hiding the selection of the robot, by watching them directly. He explained how the game monitor works during the game, too. The participants were instructed to earn as many points as possible. We instructed the prisoner's dilemma game to the participants before the game is started. We also told them that the objective of the game is obtaining as many total points as possible, but the win or lose against the robot is not the objective of the game.

The experimenter clarified that this experiment is passed the review of the ethics committee of our organization.[1] The participants signed the experiment agreement, and then, the experiment started.

The human participant has 3 games in total and faces the humanoid robot with different emotional expression patterns, cooperative robot, individualistic robot, and neutral robot, in each game. The neutral robot does not show any emotional expression and takes only the selection of the buttons during the game. The participant has a questionnaire survey right after the each game.

E. Coding and Analysis

The option selections of the human participant are recorded and analyzed. The percentages of "cooperation" option of the human participant at each round are graphed based on the data of all participant. They are compiled based on the emotional expression patterns. The graph shows the selection strategy of the human participants during the game.

The percentage and standard deviation of total "cooperation" option of the human participants during the game between the conditions of emotional expression are also graphed. The graph shows how the emotional expression of the humanoid robot affects the human strategy of the selection.

In order to evaluate the human impression on the humanoid robot with/without the emotion expression, we conducted a questionnaire survey right after each game. The questionnaire has 3 main questions. The first main question is "How much do you think the robot has emotion? (The scale goes from 1 - not at all to 7 - very much)" The second main question is to measure the impression on some factors with scale as follows:

- grown-up(1) - childish(7)
- cooperative(1) - selfish(7)
- emotional(1) - mechanical(7)
- interesting(1) - boring(7)
- friendly(1) - hostile(7)
- natural(1) - awkward(7)
- clever(1) - foolish(7)
- complex(1) - simple(7)
- cheerful(1) - gloomy(7)

The last main question is a free description for the game.

IV. RESULTS

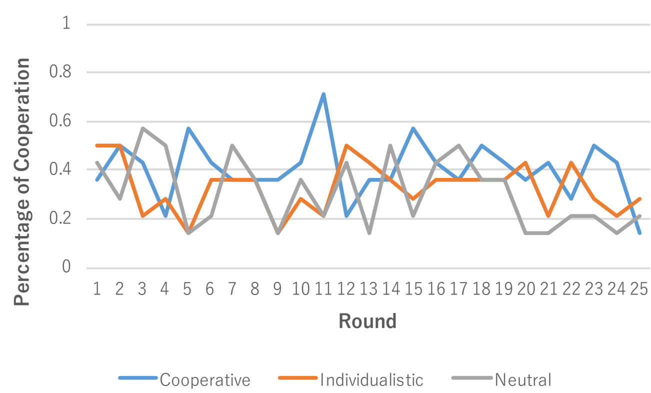


Fig. 11. Percentages of "cooperation" option of the human participant at each round

Figure 11 shows the percentages of "cooperation" option of the human participants at each round. Figure 12 shows the percentage and standard deviation of total "cooperation" option of the human participants during the game between the conditions of emotion expression.

Figure 13 shows the results of the questionnaire survey. It shows that the factors "emotional - mechanical" between the individualistic and neutral robots, and "cheerful - gloomy" between the cooperative and the neutral robots have significant differences with $p < 0.01$. It also shows that the factors "grown-up - childish" between the cooperative and the neutral robots, "emotional - mechanical" between the cooperative and the neutral robots, and "friendly - hostile" between the cooperative and neutral robots have significant differences with $p < 0.05$.

[1]This experiment is passed the review process by the ethics committee targeting people, department of human and artificial intelligent systems, graduate school of engineering, University of Fukui, No. H2016002.

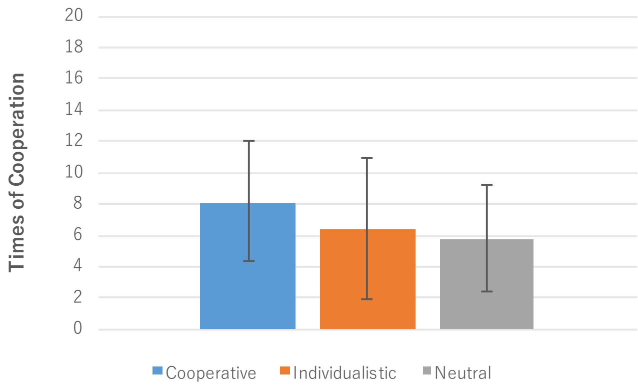


Fig. 12. Comparison of percentages and standard deviation of "cooperation" option of the human participant during the game between the conditions of emotion expression

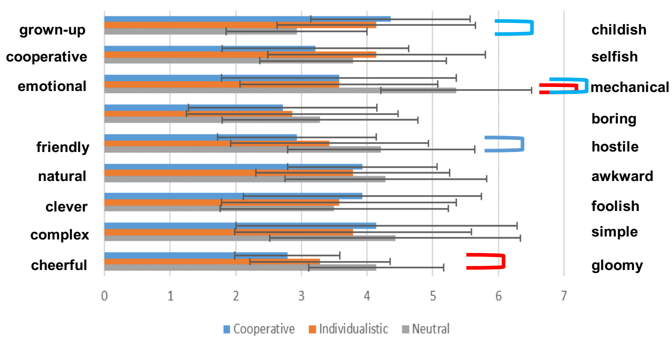


Fig. 13. Results of questionnaire survey

V. Discussion

Figures 11 and 12 show that the participants playing with the cooperative robot tend to choose the "cooperation" option more time than the others. It suggests that the cooperative emotional expression affects the decision making of the human participants. However, it does not show the significant difference that is presented in the reference paper [12], unfortunately. This is mainly because of the short of the participants. One of the future work is to increase the participants in the experiment.

The result of Figure 13 indicates that the emotional expression of the robot makes a favorable and friendly impression of the human participant. The childish impression of the robot with emotional expression might be because of the voice of the 6-year-old girl. It also might be that the emotion expression itself gives a childish impression in general.

VI. Conclusions

This study proposed an experimental design based on a finite iterated prisoner's dilemma game with a humanoid robot that shows the multimodal emotion expression during the game in order to investigate the effect of the emotional expression of the robot on cooperative and/or selfish action decision making of the human individuals. The experimental results are analyzed to show the influence of the decision making and impression on the robot of the people according to the emotional expression of the humanoid robot.

One of the future work is to increase the number of participants in order to investigate the stochastic evaluation of the experiment. It is also important to investigate the influences of gender, ages, culture differences in the decision making of the people and impression on the humanoid robot with emotional expression. The design of the multimodal emotional expression of a humanoid robot for control of the decision making of people is attractive. It is also important future work to design the fuzzy inference model for the human decision-making.

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