

Effects of Interaction and Appearance on Subjective Impression of Robots

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Abstract—Human-interactive robots are assessed according to various factors, such as behavior, appearance, and quality of interaction. In the present study, we investigated the hypothesis that impressions of an unattractive robot will be improved by emotional interaction with physical touch with the robot. An experiment with human subjects confirmed that the evaluations of the intimacy factor of unattractive robots were improved after two minutes of physical and emotional interaction with such robots.

I. INTRODUCTION

The design of the appearance and behavior of the robot that will interact with human beings poses an important problem. Humans perceive information on visual appearance quickly, and this leads to prejudice before interaction. When humans evaluate each other, the attractiveness of one's appearance is evaluated as a high ability. Crime perpetrated on an individual is reduced if attractiveness of appearance is higher, even in cases where a person must be evaluated without reference to their appearance, such as in judging a crime [1]. Additionally, the appearance of a robot is a clue to the function of the robot. The appearance of animal robots such as PARO (a seal-like robot) and AIBO (a dog-like robot) are indicators that its behavior will be friendly, like the animals they resemble. In addition, predicted interactions are changed by the degree of similarity of the appearance to an animal or human. For example, vertically linked spheres are regarded as Keepon's (a small robot designed to study social development) head and body. The head of Keepon has small eyes and mouth for communication [2]. Telenoid is a neutral design that can look like a child, man, or woman, and has been designed so that it is gradually simplified toward the periphery and around the eye, which is important for interaction [3].

On the other hand, behavior is also perceived from visual information, as much as appearance is, but it requires time to understand a robot's behavior. However, behavior and interactions change the evaluation of a robot. For example, J. Goetz has shown that when evaluating robot interaction, contents of the interaction changed the impressions of the

robot and the length of time the participant cooperated with the robot [4].

The difference in the behavior that the participants expected from the appearance of the robot and the actual behavior is called the adaptation gap. Komatu's pioneering study [5] on the adaptation gap showed that the adaptation gap is correlated with the final evaluation of the robot. Komatu asked participants to collaborate on a treasure-hunting task with a robot. The robot advised the participants on the location of the hidden treasure. Komatu compared the ability to correctly advise, which is predicted from appearance and the actual ability to provide correct information. As a result, when the ability to provide correct advice that is predicted from appearance was higher than the actual ability, a negative adaptation gap occurred, which impacted the final evaluation of the impression given by the robot. Furthermore, a negative adaptation gap did not encourage a participant to continue to interact with the robot. Conversely, when the actual ability was higher than the ability predicted from appearance, a positive adaptation gap occurred, which improved the final evaluation of the impression of the robot. In addition, the positive adaptation gap caused the participant to continue to interact with the robot. However, although Komatu's study focused on appearance and predicted function from appearance, the changes that emotional interaction give to the impression of a robot having a clearly negative appearance was not made a focus. In addition, the emotional relationship between human and robot was not mentioned, because the robot's behavior was intended to assist participants in goal-oriented tasks. In this study, we conducted experiments to investigate whether interaction could have the effect of improving a first negative impression of appearance. We used an attractive robot for creating a first impression.

II. PARTICIPANTS AND METHOD

A. Participants

The experiment was targeted at 42 males; all of whom were Gifu University students, aged 21.48 years old on average ($SD = 2.18$). The experiment was conducted using a two-factor mixed design for appearance (covered (Fig.1)/naked (Fig.2), among participants) and the interaction factor (Before/After, per participant). We divided 21 participants in the experiment using a good-looking robot (Covered). The remaining 21 participants were divided using an unattractive robot (Naked).

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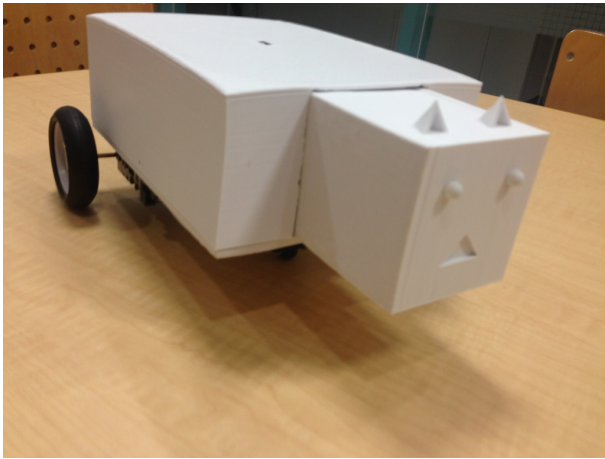


Fig. 1. The Robot Used by Covered-level

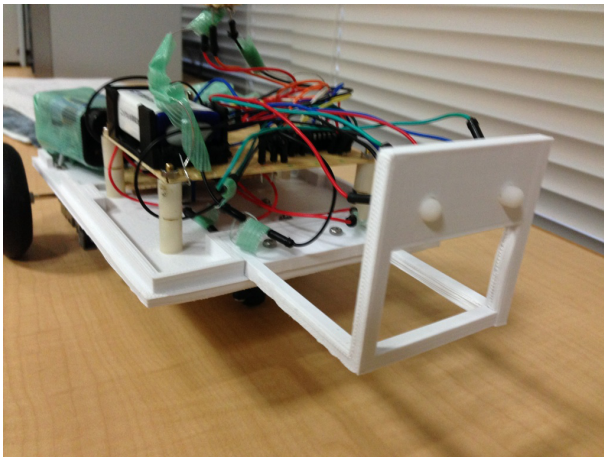


Fig. 2. The Robot Used by Naked-level

B. Experimental Equipment

We defined the robot with an exterior (Fig.1) as an attractive robot, and we defined the robot with no exterior (Fig.2) an unattractive robot. The reasons for defining the robot with an exterior as attractive were that the presence of a head mimicking an animal's face, with mouth, eyes, and ears, and its easy manipulability provided by the cover on the body. The reasons for defining the robot with no exterior as unattractive were that its rickety appearance gives a negative impression that it is built negligently, due to the exposed circuits and sensors and its unkept wiring fixed by tape.

- **The covered Robot**

Fig.1 shows the covered robot. The following are the dimensions of the robot: height 150mm, width 128mm, length 240mm. The exterior was designed using SOLIDWORKS 2013, and it was made from laminated pvc 0.2 mm using Replicator 2X and ABS resin. An infrared sensor makes it possible to determine whether a participant touches or strokes a robot. The robot equipped with two full color LEDs. A built-in microcomputer (AVR168P-20PU) monitors the LEDs and is able to control the robot's behavior.

- **The naked Robot**

Fig.2 shows the naked robot. This robot is the same as the covered robot, but has had its cover removed, as well as the L-shaped parts on the head. The functionality of this robot is same as that of the covered robot's.

- **Robot Behavior**

The robot has three levels of behavioral openness that alter depending on number of times it is stroked by the participants. When the robot is stroked between zero and five times, the robot watches the participants. When the number of times stroked is more than six but less than nine, the robot is hesitant in moving toward the participants. When the stroked number of times is more than ten times, the robot gets attached to participant.

The decision as to whether the robot was stroked is made as follows. First, the participant is asked to stroke an infrared sensor that is installed in the top portion of the robot. When infrared sensor perceives the participant's hand, an infrared sensor sends a signal to the microcomputer. The microcomputer thus receives a signal. This constitutes "stroking" and decides whether the robot has been stroked. There are three stages of robot behavior, which represents the robot's emotion through the following actions. The behavior that represents vigilance is when the light of the eyes turn red, and the robot retreats about 210mm. The behavior that represents hesitation is when the light of the eyes turns yellow, and the robot retreats about 150mm. The behavior that represents joy is when the light of the eyes turn green, and it proceeds through an arc angle of about 120 degrees, with a left and right radius of 65mm and makes a clockwise rotation of a half in place.

TABLE I

BEFORE QUESTIONNAIRES

Number	Content
1	Familiarity
2	Familiar
3	Friendliness
4	Appearance is good
5	Emotionality
6	Look like creature
7	Loveliness
8	Smartness
9	Beauty
10	Originality
11	Handiness
12	Glitz
13	Poorness
14	Fascination
15	Grace
16	Solemn
17	Sophistication
18	Robustness
19	Brittleness
20	Hugeness
21	Do you want to play with robot?

TABLE II
AFTER QUESTIONNAIRES

Number	Content
The question contents to question number 1-20 are same as a questionnaire before an experiment.	
21	Behavior is peculiar
22	Behavior is smooth
23	Behavior is slow
24	The tone when a robot moves, is noisy.
25	Behavior is cute
26	Eye color of robot has changed
27	There is meaning in the color of the eyes
28	(If you chose the 5-7 in the question 27 Please answer)Do you think that there is any meaning in the color of the eyes
29	There is meaning in behavior
30	(If you chose the 5-7 in the question 29 Please answer)Do you think that there is any meaning in the behavior
31	Time to interaction with robot is short
32	Would you like to interaction with a robot more?
33	Do you have knowledge about the robot making?

C. Experiment Environment

The experiment was conducted on a desk with a height of 695mm, a depth of 890mm, and a length of 890mm.

D. Experimental Procedure

STEP1 : Before Questionnaires

Participant responds to a questionnaire on his impression of robot's appearance preceding the interaction.

STEP2 : Interaction with Robot(interaction session)

Participant interacts with robot. Participant strokes the robot and observes the robot for two minutes.

STEP3 : After Questionnaires

Participant responds to a questionnaire on his impression of the robot after the interaction.

E. Measuring Method

We measured the impression of the robots using before-and-after questionnaires. The questionnaires given before consist of 21 items. The questionnaires given after consist of 33 items, including 20 items from the questionnaires given before. The method of evaluation of the questionnaires' contents was performed using seven-point Likert scales to assess the impressions of the robots. The evaluations consisted of seven-point Likert scale questions (1 = "definitely no" to 7 = "definitely yes"). Table I shows the questionnaire taken before the interaction, and table II shows the questionnaire taken after the interaction. Only questions number 28 and 30

of the questionnaire taken after demand a description from the participants.

We refer to the following literature to measure reliance, affinity, and animal-like through questionnaire. Refer to [6] for the inspiration for items such as questions number five, six, and 7, which measure the presence of emotion and creature. Refer to [7] for items such as questions number 11 and 21, which measure anxiety and expectation, respectively.

III. RESULT

TABLE III
RESULT OF ONLY THE QUESTIONNAIRE AFTER AN EXPERIMENT

Number	Covered level		Naked level	
	M	SD	M	SD
21	5.05	1.13	4.76	1.38
22	4.10	1.38	4.43	1.13
23	3.43	1.05	3.24	1.19
24	4.62	1.50	4.24	1.51
25	3.67	1.21	3.67	1.21
26	6.33	0.99	5.76	1.23
27	5.43	1.09	5.19	1.10
29	5.29	1.08	4.62	1.09
31	3.43	1.18	4.00	0.98
32	4.24	1.31	4.14	1.21
33	3.14	1.78	3.38	1.68

A. Manipulation Check

We analyzed the distinction among the answers to questions number three, "Friendliness," four, "Appearance is good," 11, "Handiness," 17, "Sophistication," 18, "Robustness," and 19, "Brittleness" between the covered and naked robots using a one-way ANOVA for verifying that the presence of the exterior increases relative merits of appearance.

The mean of the covered robot's score for "Friendliness" is 4.67, whereas that for the naked robot is 2.90. A significant difference was observed ($F(1,40) = 13.51, p < 0.01$). The mean of the covered score for "Appearance is good" is 4.33, and that for the naked is 2.76. A significant difference was observed ($F(1,40) = 14.72, p < 0.01$). The mean of the covered score for "Handiness" is 4.14, the naked score is 3.71. A significant difference was not observed ($F(1,40) = 0.89, p = 0.35$). The mean of the covered robot's score for "Sophistication" is 4.33, the naked robot's score is 3.05. A significant difference was observed ($F(1,40) = 8.11, p < 0.01$). The mean of the covered robot's score for "Robustness" is 5.10 and that of the naked robot's score is 2.76. A significant difference was observed ($F(1,40) = 30.24, p < 0.01$). The mean of the covered score for "Brittleness" is 5.24 and that of the naked robot is 5.52. A significant difference was observed ($F(1,40) = 0.53, p = 0.47$).

B. Result of Factor Analysis

We found four extracted factors by factor analysis of the questionnaire results. We defined these as the Intimacy factor, the Beauty factor, the Simplicity factor and the Robustness factor. Table IV shows the result of factor analysis. In addition, we analyzed the factor scores of the Intimacy factor,

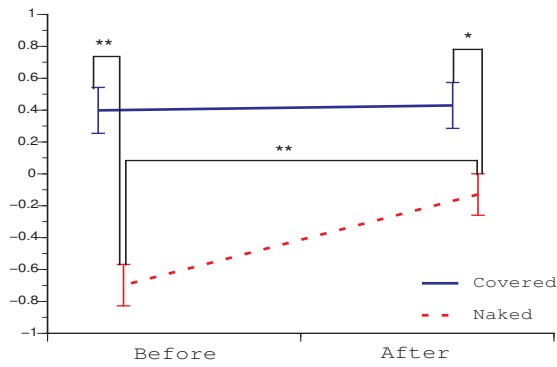


Fig. 3. Intimacy Factor

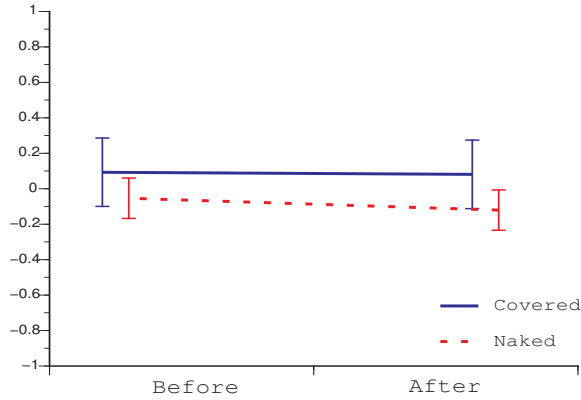


Fig. 4. Beauty Factor

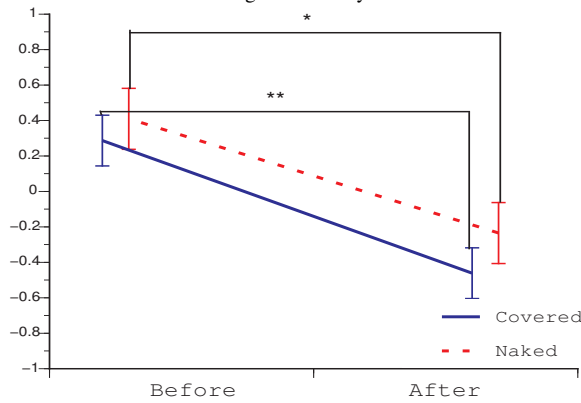


Fig. 5. Simplicity

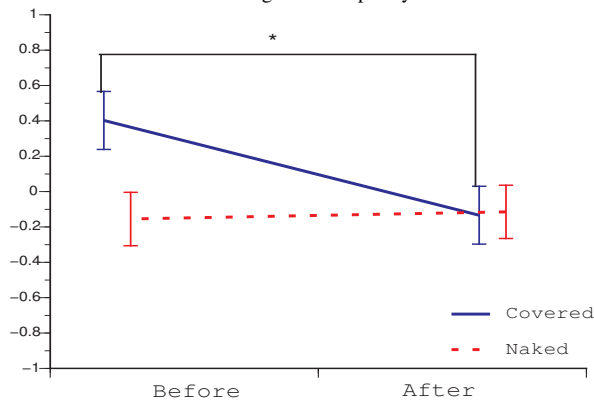


Fig. 6. Robustness Factor

TABLE IV
RESULT OF FACTOR ANALYSIS

Factor	Content	Extracted basic factor			
		Intimacy	Beauty	Simplicity	Robustness
Intimacy	Friendliness	.85	.07	-.02	.18
	Familiarity	.84	.19	-.24	.14
	Appearance is good	.73	.10	-.04	-.08
	Familiar	.69	-.02	.05	.00
	Loveliness	.62	.15	.06	.10
	Look like creature	.62	.12	-.17	.14
Beauty	Fascination	.61	.33	-.07	.20
	Emotionality	.41	.23	-.18	.10
	Originality	.31	.30	.03	.16
	Beauty	.15	.99	-.03	-.04
	Grace	.18	.59	.00	.06
Simplicity	Smartness	.03	.59	.10	.02
	Solemn	.07	.40	-.11	.18
	Handiness	.27	.02	.94	.20
	Glitz	-.11	.21	.05	.17
	Poorness	-.23	.02	.25	.07
Robustness	Brittleness	-.10	-.13	.04	-.00
	Hugeness	-.08	-.00	.13	-.00
	Sophistication	.25	.39	.10	.88
	Robustness	.26	-.04	.15	.30

the Beauty factor, the Simplicity factor and the Robustness factor using a two-way ANOVA. Figs. 3, 4, 5 and 6 show these results.

C. Intimacy Factor

We analyzed the factor score of Intimacy using a two-way ANOVA. Fig. 3 shows the result of the ANOVA. The interaction of the Appearance with the Interaction factor revealed significant difference ($F(1,40) = 6.62, p < 0.05$). Then, we used a simple main effect test for recording the simple main effect.

A result of the simple main effect test of the Appearance factor in each level of the Interaction factor, significant differences were observed in the before ($F(1,54) = 17.29, p < 0.01$) and after phase ($F(1,54) = 4.49, p < 0.05$). A simple main effect of Interaction factor was observed for the naked level $F(1,54) = 14.82, p < 0.01$.

D. Beauty Factor

We analyzed the Beauty factor using a two-way ANOVA. Fig. 4 shows the result of ANOVA. Interaction of the Appearance factor with the Interaction factor did not reveal a significant difference ($F(1,40) = 0.05, p = 0.82$).

The main effects of the Appearance factor ($F(1,40) = 0.37, p = 0.55$) and the Interaction factor ($F(1,40) = 0.37, p = 0.55$) did not reveal a significant difference.

E. Simplicity Factor

We analyzed the factor score of Simplicity using a two-way ANOVA. Fig. 5 shows the result of the ANOVA. Interaction of the Appearance factor with the Interaction factor did not reveal a significant difference ($F(1,40) = 0.09, p = 0.77$).

The main effect of the Interaction factor was revealed as a significant difference ($F(1,40) = 15.84, p = 0.01$). Using Tukey's HSD post-hoc test, we found significant differences between the covered and naked versions, which revealed a significant difference between the beforecovered and before-naked in the Simplicity factor.

F. Robustness Factor

We analyzed the factor score of Robustness using a two-way ANOVA. Fig. 6 shows the result of the ANOVA. The interaction of the Appearance factor with the Interaction factor did not reveal a significant difference ($F(1,40) = 2.61, p = 0.11$).

The main effects of the Appearance factor ($F(1,40) = 1.18, p = 0.28$) and the Interaction factor ($F(1,40) = 1.93, p = 0.17$) did not reveal a significant difference.

G. The Effects of Interaction with the Appearance Impression

We examined the effects of the emotional interaction between human and robot that influenced the impression of the robot's appearance. Interaction was observed only for the Intimacy factor ($F(1,40) = 6.62, p < 0.05$). This result confirmed that emotional interaction improves the Intimacy factor of an unattractive robot.

H. The Effects of only Appearance or Interaction

Significant interactions were observed only for the Intimacy factor. The Simplicity factor did not have significant interaction, but the main effect of interaction was observed ($F(1,40) = 15.84, p < 0.01$).

I. Simple Main Effect

We used a simple main effect test for each level of the Interaction factor for observing the simple main effect of the Appearance factor. Simple main effects were observed for the period before ($F(1,54) = 17.29, p < 0.01$) and after ($F(1,54) = 4.49, p < 0.05$) interaction for the Intimacy factor.

We used a simple main effect test for each level of the Appearance factor for observing the simple main effect of the Interaction factor. Simple main effects were observed for the covered robot in the Simplicity factor ($F(1,40) = 9.15, p < 0.01$) and the Robustness factor ($F(1,40) = 4.51, p < 0.05$), naked level of the Intimacy factor ($F(1,40) = 14.82, p < 0.01$) and the Simplicity factor ($F(1,40) = 6.78, p < 0.05$).

J. The Effect of The Willingness to Interaction with a Robot by Difference Between the Quality of Appearance

We analyzed score of the item "Do you want to play with robot?" described only in Before-Questionnaires by a one-way ANOVA. Mean of Covered-level is 5.00 ($SD = 1.27$), mean of naked level is 4.52 ($SD = 1.66$). significant difference was not observed in both level.

Using a one-way ANOVA, we analyzed the score of the item "Do you want to play with the robot?" included only in the before questionnaires. The mean of the covered level is 5.00 ($SD = 1.27$), the mean of the naked level is 4.52

($SD = 1.66$). A significant difference was not observed in both levels.

K. The Effect of Impression of the Robot's Motion by the Difference Between the Quality of Appearance

Table III shows mean and standard deviation of items that are only in the after questionnaires. We analyzed the scores of these items using a one-way ANOVA. However, a significant difference was not observed in any items.

IV. DISCUSSION

A. Manipulation Check

We verified the presence of the exterior relative merits of the appearance. The robot with an exterior was rated excellently in question number three "Friendliness," four "Appearance is good," 17 "Sophistication," and 18 "Robustness," compared to the robot that has no exterior. However, the robot having an exterior and the robot having no exterior regardless of the presence or absence of exterior for 11 "Handiness" and 19 "Brittleness" had the same evaluation. The ratings for "Appearance is good" and "Sophistication" were direct results on the appearance. These evaluations of the attractive robot were higher than those of the unattractive robot. With respect to "Handiness" and "Brittleness," these concerned operability and functionality, rather than appearance directly. For this reason, we concluded that initially the expected effect was obtained by two levels that were previously prepared. In addition, the mean of the covered robot was higher than the mean of the naked robot for some items. Significant levels were observed not only for the above items but also for one, "Familiarity," five, "Emotionality," six, "Look like creature," seven, "Loveliness," 10, "Originality." We referred to Iwamura's study [8] for considering this result. This study showed that when shopping with a robot, the evaluation of a humanoid robot that is able to talk is higher than that of a cart robot that is able to talk. The results of Iwamura's study and this study were similar in that the evaluation of a robot is higher when the contents of the interaction and appearance are matched. From this, the presence of a robot that has an exterior whose head mimics that of an animal matches the contents of interaction of this study. As a result, there is a possibility that the impression of the robot that has an exterior was better.

B. Intimacy Factor

Emotional interaction improved the evaluation of the unattractive robot's Intimacy factor. As to why it has such a negative result, we propose that a positive adaptation gap occurred because unattractive robots that perform a gradual attachment received a higher evaluation than that which participants predicted from appearance. This positive adaptation gap improved the evaluation of the Intimacy factor of the unattractive robot.

C. Beauty Factor

The main effects of the Interaction factor and the Appearance factor were not observed for the Beauty factor. As to why it has produced such a result, the Appearance of the covered robot is nearly rectangular. The Appearance gave the impression of simplicity rather than beauty to the participants. For this reason, a significant difference was not observed in the before questionnaires. Then, the emotional interaction did not change the appearance of the robot. So the emotional interaction did not generate an adaptation gap. Therefore, we think that factor score did not change.

D. Simplicity Factor

The factor score of the after questionnaires for the naked and covered robots decreased. The main effect of Interaction was observed in the Simplicity factor. As to why such a result is produced, participants deemed that an attractive robot is simple. However, the actual behavior of the attractive robot was different from what the participants had expected. Thus, a negative adaptation gap occurred. The negative adaptation gap lowered the factor score of the attractive robot. Participants also predicted that the behavior of the unattractive robot would be bad. However, the actual behavior was different from what participants expected. Thus, a negative adaptation gap occurred. The negative adaptation gap lowered the factor score for the unattractive robot.

E. Robustness Factor

A simple main effect is observed in the covered robot for the Robustness factor. In our estimation, participants deemed that an expensive-looking robot would be simple. An attractive robot is evaluated higher than an unattractive one in the before questionnaires on the Robustness factor. However, the function of the robot was determined through interaction with the robot. That function is inferior than the function predicted. As a result, a negative adaptation gap occurred. The negative adaptation gap made the covered and naked robots equal.

F. The Influence of the Will to Interaction with Robot by Difference Between the Quality of Appearance

We determined the willingness to interact with the robot using question number 21, "Do you want to play with a robot?" appearing in the before questionnaire. A significant difference was not observed in the results of analysis between the covered and naked robots. As a result, concerning question number 21, the relative merits of appearance do not affect the willingness to interact with a robot.

G. The Influence of Impression of Robot's Motion by Difference Between the Quality of Appearance

We checked the impression of robot's behavior using questions number 21-32 on the after questionnaires. A significant difference was not observed in the analysis' results between the covered and naked robots. As a result, the relative merits of appearance do not affect the impression of the robot's behavior.

V. CONCLUSION

This study investigated whether emotional interaction with a robot would improve a negative impression of its appearance. As a result, the Intimacy factor of an unattractive robot is likely to improve, to reach that of a good looking robot, through emotional interaction with the robot. We estimate that what we have learned from this research about how interaction with a robot can change the impression of a robot's appearance is useful for designing robots that interact with humans. In future, we will conduct experiment that uses non-emotional interaction such as participants observed stopping robot for researching whether participants were attached to unattractive robot or used to unattractive robot.

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