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Robot's Impression of Appearance and Their Trustworthy and Emotion Richness

Tetsuya Matsui[1] and Seiji Yamada[2]

Abstract— **This paper focused on the appearance of humanoid robot and their trustworthy and emotion richness perceived. Humanoid robots that used in emotional labor is needed to express emotion and be trusted. We experimented with eight robots image(four mechanical face robots and four smooth face robots) and asked the participants their impression. We conducted explanatory factor analysis to define the factors of robots' impression. As a result, the factors of robots were discovered to be different from the virtual humans' impression. Also, the trustworthy and emotion richness perceived of robots depended on another factors. The familiar robots were trusted and the human-like robots were expected to have rich emotion.**

I. INTRODUCTION

Humanoid robots was already being used in the human's daily life. for example, as a teacher[1], a cleark[2] and a counselor[3]. These roles are called "emotional Labour" that is needed to express and control their emotion and be trusted[4]. The effect of designing the robot's behavior[5][6] or conversation[7][8] to construct rapport with the users were widely researched. In this paper, we explored the first impression of the robots, the appearance. Goetz et al. showed that the familiar appearance of robots prompted the long conversation with the users[9]. Kanda et al. showed that the difference of the robot's appearance affected the user's nonverbal reactions[10]. Broadbent et al. showed that robots has more humanlike face was perceived to have their mind and personality[11]. These studied showed that the appearance of robots affected the user's impression and behavior.

In regard to the appearance of robot, the uncanny valley theory has been discussed. The uncanny valley is the hypothesis that the user become feeling weirdness to the robots as their appearance were being like humans[12]. The problem is what causes this effect. Ho et al. suggested that the lack of humanness perceived caused weirdness[13]. Seyama et al. suggested that the difference of realism of facial appearance caused the uncanny valley[14]. MacDorman and Ishiguro indicated that the uncanny valley was caused because some robots reminded people death[15]. This description can be paraphrased to that the weirdness of robot was caused when people felt only materiality, not agency. These explanation suggested that the robot's appearance give some kinds of impression, for example, humanness, realism, materiality and agency. Also the people fall in the uncanny valley when the robots lose these factor's balance.

There are another model that was suggested by Duffy[16]. He constructed triangle model to classify the robot's head design inspired by McCloud's classification of the cartoon's character[17]. He defined three apexes of triangles as abstract, human and iconic. Also he suggested that the most apposite design would achieve the balance between three apexes[16].

In this paper, we aimed to discover the factors of impression of robots' appearance that related to trustworthy and emotion richness perceived by users. For the robots used in real world, trustworthy perceived by user may be important factor, especially, in human-robot collaboration[18]. Hancok et al. conducted meta-analysis of trust between human and robot, and concluded that the robot's performance is the most important factor[19]. Salem et al. also reported that task performance was important factor of robots' trustworthy[20]. In regard to appearance, Walters et al. showed that the robot having head were perceived more intelligent than without head[21]. Siegel et al. showed that male participants tended to trust female robots[22]. However, the factors of trustworthy of humanoid robots' appearance were not sufficiently researched.

Also, emotion richness perceived seemed to be an important factor for the robots used for emotional labor. Emotional contagion, the phenomenon that the someone's emotion affects to their partner, is important process to make a rapport[23]. It was reported that this phenomenon occurred between a robot and a human, used the robot's facial expression[24] or gesture[25]. Emotional contagion bring some positive result, for example, to increase efficiency of work[26] and to increase clerk's service quality perceived by customers[27]. In research of virtual agents, expressing the agent's positive emotion increase the agent's trustworthy perceived by human[28]. This shows that emotion richness is important factor of designing trustworthy robots. However it is not clear whether robots' emotion richness perceived by humans directly correlated the robots' trustworthy.

To discover the factor contributed to trustworthy and emotional richness, we used two dimensional mind perception model. This model was suggested by Gray et al.[29]. In this paper, Gray et al. suggested two factors of mind perception, agency and experience. This model was used in field of HRI. Gray and Wegner showed that people felt weirdness to robots when the robots has only agency without experience[30]. This model was constructed by many types of agent, human, animal, god and robot. This model may valid to measure the difference of impression between animal and robot, or humanoid robot and non-humanoid robot. However, we focused on the variation of mind perception among humanoid robot. Thus we planned to use not only agency-experience model, but also familiarity-reality model. This model was suggested by Matsui and Yamada[31] to measure the difference of impression among humanoid virtual agent. We aimed to

[1]Department of Computer and Information Science, Seikei university 3-3-1, Kichijojikitamachi, Musashino-shi, Tokyo, 180-8633, Japan t-matsui@st.seikei.ac.jp
[2]National Institute of Informatics and SOKENDAI 2-1-2 Hitotsubashi, Chiyoda-ku, Tokyo, 101-8430, Japan seiji@nii.ac.jp

verify the relationship between the robot's trustworthy or emotion richness and these four factors, agency, experience, familiarity and reality.

We especially focused on the robots' face. We defined the two types of robots' face, the mechanical face and smooth face. Mechanical face means the face that exposed small metal plates and inner structures, or forms geometrical outlines with big eyes. Smooth face means the face that have human like skin or soft surface substances and smooth outlines. It was reported that robot's face affected on the users' perception. Yamashita et al. showed that the robot having mechanical face and the robot having humanoid face gave the different impressions and touch sensation[32]. Kalegina et al. showed that robots' facial appearance(eyes, mouth and skin colors) affected their perceived trustworthy[33]. Phillips et al. showed that robots' eyelashes, eyebrows and skin contributed the main factor of the robots' appearance[34]. MacDorman conducted an experience with images morphing from human to robot and showed that people felt more familiarity to human face than robot face and an intermediate face[35]. From these prior works, we hypothesized that the robots with smooth face are more trusted by participants than the robots with mechanical face.

In this paper, we aimed to verify the following hypothesis.

- H1: There are factors of the robots' impression perceived that correlating with the robot's trustworthy and emotion richness perceived
- H2: The robots with a smooth face will be more trusted by participants than the robots with mechanical face
- H3: There are high correlations between the robots' trustworthy and emotion richness perceived

We aimed to define the factor and verify these hypothesis.

II. EXPERIMENT

We recruited all participants on Yahoo Crowd Sourcing[1], the web site. All participants received a reward of 30 yen (about 28 US cents). We recruited 92 Japanese participants, and 87 remained after noise exclusion. There were 51 males and 36 females, and they were aged between 19 and 67, for an average of 40.4(SD = 9.3).

We used eight robots images(photo or illustration). All images are under Creative Commons licenses. All images are shown in Table I[2]. Four robots have mechanical face(a, b, c, d) and other four robots have smooth skinned face(e, f, g, h).

We asked the participants to answer two sets of questions to construct two-dimensional mind perception models. One set of questions was cited from Gray et al.[36] to construct an agency-experience model. This set was constructed as follows.

- Fear: How capable of feeling fear do you think this robot is?
- Pleasure: How capable of feeling pleasure do you think this robot is?
- Hunger: How capable of feeling hunger do you think this robot is?
- Self control: How capable of feeling self control do you think this robot is?
- Memory: How capable of remembering do you think this robot is?
- Moral: How capable of acting morally do you think this robot is?

The first three questions are related to the agency factor, and the latter three are related to the experience factor[36].

The other set of questions was constructed by Matsui and Yamada [31]. The questions were constructed to derive two factors, reality and familiarity. This set was constructed as follows.

- Familiarity: How capable of feeling familiarity do you think this robot is?
- Warmth: How capable of feeling warmth do you think this robot is?
- Communication: How capable of feeling communication possibilities do you think this robot is?
- Alive: How capable of feeling aliveness do you think this robot is?
- Human-likeness: How capable of feeling human-likeness do you think this robot is?
- Reality: How capable of feeling reality do you think this robot is?

The first three questions are related to the familiarity factor, and the latter three are related to the reality factor [31].

We conducted an explanatory factor analysis (EFA) to define two factors and constructed two-dimensional mind perception models. EFA is a statistical method that is widely used to define hidden factors [37]. We conducted the EFA with principal axis factoring method and varimax rotation and set the number of factors to two because our aim was to construct two-dimensional models.

Also, we asked one more question to measure the trustworthy perceived and emotion richness perceived of each robots.

- Trust: Do you feel how trustworthy is this robot?
- Emotion richness: Do you feel how rich is this robot's emotion?

We defined the average of this question as the trust level and emotion richness level. The participants answered all questions on a 7-point Likert scale.

[1]https://crowdsourcing.yahoo.co.jp/

[2]a:"S.H Horikawa Star Strider Robot Front.jpg", by D J Shin, https://www.flickr.com/photos/51940189@N04
b:"Buckley Robotics Class", by Kathrine McDowell, http://www.buckley.af.mil/News/Photos/igphoto/2000361362/
c:"Kojiro Robot.jpg", by Erico Guizzo, http://spectrum.ieee.org/automaton/robotics/humanoids/kojiro-musculoskeletal-humanoid-robot
d:"SARCOS Primus humanoid robot", by Jiuguang Wang, https://i.pinimg.com/736x/d3/21/8c/d3218c17856dc0be47905e174c7c4495–real-robots-humanoid-robot.jpg
e:The work of TheDigitalArtist, by TheDigitalArtist, https://cdn.pixabay.com/photo/2016/07/30/13/05/robot-1557085_960_720.png
f:"Sony Qrio Robot.jpg", by Dschen Reinecke, https://en.wikipedia.org/wiki/Portal:Robotics/Featured_robot
g:"Sophia (robot) 2.jpg", by International Telecommunication Union, https://en.wikipedia.org/wiki/Sophia_(robot)
h:"Sanbot King Kong.jpg", by QIHAN Technology, https://en.wikipedia.org/wiki/Sanbot_(robot)

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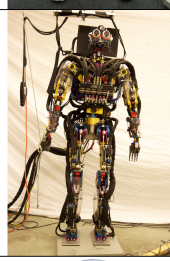
d	
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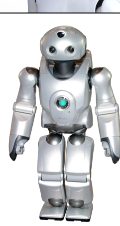
f	
g	
h	

TABLE I
ROBOTS USED IN EXPERIMENT

TABLE II
FACTOR LOADING OF "AGENCY"-"EXPERIENCE" QUESTIONS

question	factor 1	factor 2
pleasure	.893	.425
fear	.854	.501
moral	.814	.571
hunger	.776	.605
memory	.445	.893
self control	.672	.728
contribution rate	.574	.408
Cronbach's α	.986	.959

III. RESULT

A. Agency and experience model

Table II shows the factor loadings of the agency-experience questions and the contribution rate and Cronbach's α of each factors. This result didn't completely match agency-experience model. In Gray's model[36] , fear, pleasure and hunger contribute agency. However in our result, fear, pleasure, hunger and moral contributed factor 1. Also, Self control and memory contributed factor 2. We defined factor 1 as modified agency and factor 2 as modified experience, because of the difference between these factors and original agency and experience. The both of Cronbach's α are higher than 0.9, thus these factors have high degree of internal consistency. However, in this result, only two variables contributed to factor 2. In general, one factor needs at least three variables[38]. Thus, this result didn't have a high degree of confidence. We employed only modified agency factors in the following analysis.

B. Familiarity and reality model

Table III shows the factor loadings of the familiarity-reality questions and the contribution rate and Cronbach's α of each factor. This result didn't completely match familiarity-reality model suggested by Matsui and Yamada[31]. In this model, human-likeness, alive and reality contribute "reality" and familiarity, warmth and communication contributed "familiarity". However in this result, human-likeness, alive and communication contributed factor 1 and familiarity, warmth and reality contributed factor 2. We defined factor 1 as modified reality and factor 2 as modified familiarity, because of the difference between these factors with original reality and familiarity. The both of Cronbach's α are higher than 0.8, thus these factors have high degree of internal consistency.

Figure 1 shows each factor scores of robots. Each plot means each robot.

C. Trust level, emotion richness level and each factor score

Figure 2 shows the average of trust score of each robot. Error bar means standard deviation. We conducted ANOVA and there was significant difference($F(7, 688) = 5.07$, $p < .001$). We conducted multiple comparison with Tukey's method, there were significant differences between a and e, a and f, d and f, and f and g($p < .005$).

We conducted t-test between mechanical face robot and smooth face robot, and there were a significant difference($t(347) = -3.751$, $p < .001$).

TABLE III
FACTOR LOADING OF "FAMILIARITY" AND "REALITY" QUESTIONNAIRES

Questionnaires	factor 1	factor 2
human-likeness	.978	-.051
alive	.974	.214
communication	.921	.368
familiarity	.032	.979
warmth	.106	.925
reality	.345	.778
contribution rate	.481	.434
Cronbach's α	.934	.881

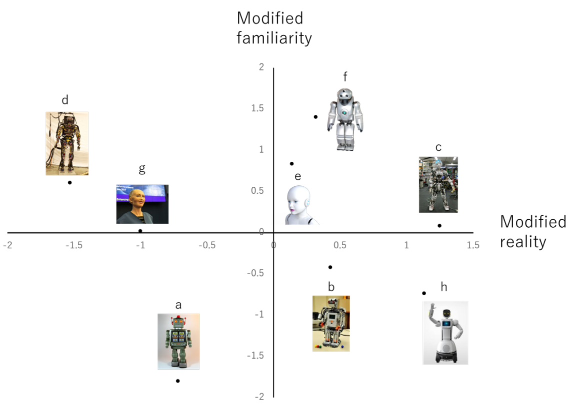


Fig. 1. Factor scores for each robot

Table IV shows the correlation coefficients between factor scores and average of each questionnaire of each robots and trust level.

Figure 3 shows the average of emotion richness score of each robot. Error bar means standard deviation. We conducted ANOVA and there was significant difference(F(7, 688) = 14.91, $p < .001$). We conducted multiple comparison with Tukey's method, there were significant differences between a and b, a and c, a and e, a and f, a and h, b and d, b and g, c and d, a and e, c and g, d and f, d and h, e and g, f and g, and g and h($p < .005$).

We conducted t-test between mechanical face robot and smooth face robot, and there were no significant difference(t(347) = -0.940, $p > .1$).

Table V shows the correlation coefficients between factor scores average of each questionnaire of each robots and trust level. Also we calculated the correlation coefficient between trust level and emotion richness level(r = .0.706).

IV. DISCUSSION

A. Explanatory factor analysis

Table II shows the EFA didn't reveal two established factors, agency and experience. This result conflicted with prior works. This result may be derived from that we used only humanoid robots. Agency and experience model was ordinary constructed by research with many kind of agents(human, animal, robots and so on)[29]. These agents had various appearances and textured. Especially, whether the robots have face or not is important factors in users' perception[21]. In this research, all robots had fundamentally similar appearance and all of them had their face. This

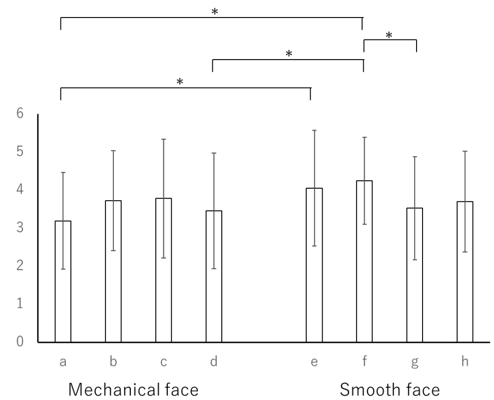


Fig. 2. The average of trust level

TABLE IV
CORRELATION COEFFICIENTS BETWEEN EACH FACTOR SCORES OF EACH ROBOTS AND TRUST LEVEL

score	correlation coefficients
modified agency	.458
modified reality	.530
modified familiarity	.783
pleasure	.670
fear	.536
moral	.695
hunger	.554
memory	.608
self control	.707
human-likeness	.426
alive	.687
communication	.815
familiarity	.800
warmth	.694
reality	.850

seemed to be reason that we couldn't reproduce agency and experience model. This is one of new insights in this paper.

Also, Table III shows the EFA didn't reveal reality and familiarity factors. These factors were derived by research about virtual humans[31]. Thus we have concluded that this conflict occurred by difference between robots and virtual agents. Regarding robots, "How capable of feeling reality do you think this agent is" is the obvious question because the robots existed in real world. Also Li showed that robots or embodied agents were more effective than virtual agents[39]. This result is suitable to the result that familiarity, warmth and reality contributed the same factor. This factor is modified familiarity, the familiarity of the robots. Alternatively, whether the robot can communicate with the user is important problem when we interact with robots. Prior work showed the smooth utterances made the participants feel the robots' mind[40] Also robots has more human-like face was perceived to have their mind[11]. These works suggest that people feel mind of robot when they can communicate smoothly or were looked like human, and having mind is almost the same as being alive. This seemed to be reason to why aliveness, human likeness and communication contributed the same factor. This factor means how capable of reacting as human the participants feel the robot is. This is modified reality, the reality of robots. This results show the new findings of robot's appearance. For people, "How

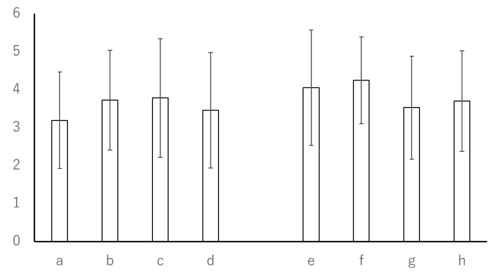


Fig. 3. The average of emotion richness level

TABLE V
CORRELATION COEFFICIENTS BETWEEN EACH FACTOR SCORES OF EACH ROBOTS AND EMOTION RICHNESS LEVEL

factor	correlation coefficient
modified agency	.912
modified reality	.925
modified familiarity	.330
pleasure	.987
fear	.935
moral	.968
hunger	.913
memory	.733
self control	.884
human-likeness	.912
alive	.976
communication	.958
familiarity	.345
warmth	.461
reality	.525

capable of feeling familiarity do you think this robot is?" and "How capable of feeling communication possibilities do you think this agent is" are another problem. Our result showed that the factor of perception of humanoid robots was different from virtual agents or other agents because of their face and embodiment.

Figure 1 shows the factor score of modified reality and modified familiarity. From this figure, we can know the trends of relationship between the robots' face and each factor. In mechanical face robots, there are no deviations. This results shows that mechanical face it self has little affect to perceptions. In smooth face robots, three of the four robots have positive values of modified familiarity. In this experiment, the smooth face brought the perception of familiarity and warmth, however didn't bring communication possibilities. Alternatively, no.g, android robot that has human-like facial skin has lower score of modified reality. This result seemed to be caused from uncanny valley effect. It is reported that immoderate human-likeness of appearance reminded people dead body[15]. Also, this experiment was conducted with only images, without movies and interactions. This may cause the more high effect of reminding death. This result is different from research of virtual agents[31]. This may be caused the appropriate aspect of robots, especially the embodiment.

B. Trust level and emotion richness level

Figure 2 shows that the robots have smooth face have higher trustworthy than the robots have mechanical face. This result supported our hypothesis 2. Also Table IV shows that modified familiarity factor and trust level are found to have a high correlation. This result supported our hypothesis 1. This result suggests that the robots' familiarity have a connection with expected performance. Prior woks pointed out that the robots' performance was important factor of the robots' trustworthy[19][20]. However, this result suggested that "How capable of feeling familiarity do you think this robot is?" is more important problem than "How capable of feeling human-likeness do you think this agent is?" when we judged only from the robots' appearance.

Figure 3 shows that we couldn't find the relationship between the robots' facial smoothness and emotion richness. There are possibility that the robots' emotion richness is affected from fineness of face, regardless of their machinelikeness or smoothness. Also Table V shows that different tendency of perceived emotion richness from perceived trustworthy. This table shows that modified agency factor and modified reality factor have high correlation with emotion richness level. This result suggests that the robots' emotional contagion effect is affected by their reality, not familiarity. When we consider the interaction with the robots, emotional expression may increase their trustworthy as virtual agents[28]. However, regarding first impression by sight, people suppose the robots' trustworthy by their human likeness and aliveness. Also there are relatively little correlation between trustworthy and emotion richness. This result conflict with our hypothesis 3. This result suggested that people use two method to suppose the robots' trustworthy. When they have enough time to interact with robots, they judged the robots' trustworthy by familiarity perceived. Although when they are forced to be judged trustworthy at a glance, they judged trustworthy by reality perceived.

V. CONCLUSIONS

In this paper, we aimed to defined factors of the robots' appearance impression and verify the correlations between these factors and the robots' trustworthy and emotion richness perceived by human. We used eight robots images that have mechanical face or smooth face. We asked the Japanese participants two sets of questionnaires to define factors. As a result, we concluded the robots have different factors from other agents and virtual agents. As robots, familiarity and reality contributed the same factor. Also aliveness and communication communication possibilities contributed the same factor. Also we measured the robots' trustworthy and emotion richness perceived. We concluded that the robots having smooth face were more trusted than robots having mechanical face and trustworthy was correlated with familiarity and emotion richness was correlated with reality. These result conclude that people perceive the robots' trustworthy and emotion richness from different factors and suggest the effective way to design the robots' appearance.

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