Two-Dimensional Mind Perception Model of Humanoid Virtual Agent

Tetsuya Matsui
National Institute of Informatics
2-1-2 Hitotsubashi, Chiyoda, Tokyo
101-8430, Japan
tmatsui@nii.ac.jp

Seiji Yamada
National Institute of Informatics/Sokendai/
Tokyo Institute of Technology
2-1-2 Hitotsubashi, Chiyoda, Tokyo
101-8430, Japan
seiji@nii.ac.jp

ABSTRACT
In this paper, we verified two kinds of two-dimensional mind perception models of humanoid virtual agents and investigate the relationship between the models and effect of emotional contagion. To verify the two kinds of dimensional models, we used questionnaires from prior works and our own questionnaire. From these questionnaires, we constructed an "agency"-"experience" model and "familiarity"-"'reality" model from EFA. These two models are valid for distinguishing humanoid agents and predicting the effect of emotional contagion. The factor scores of "experience" and "familiarity" have a high correlation coefficient with the effect of emotional contagion. This result suggests a method for designing humanoid agents that have a high emotional contagion ability.

ACM Classification Keywords
H.5.2. User Interfaces

Author Keywords
virtual agent; anthropomorphic agent: emotional contagion: appearance; mind perception; agency

INTRODUCTION
We live surrounded by many kinds of virtual agents, and these agents have many kinds of appearances. Gray et al. suggested a two-dimensional model derived from the impression of agents [4]. In an experiment, the authors used many kinds of agents including animals, male and female human, robots, and gods. The authors found an "agency" axis and "experience" axis. Gray et al. showed that this model was valid for revealing the mind perception of psychopathology patients [5]. Terada et al. used this model to investigate the effect of the appearance of virtual agents [19]. The model revealed how users perceived agents; however, 5 out of the 13 agents used were humanoid: male, girl, female, persistent vegetative state male, and "you" [4]. There were no elderly female and healthy old male, and race and ethnic groups were excluded.

HAI 2017, October 17–20, 2017, Bielefeld, Germany..

http://dx.doi.org/10.1145/3125739.3125761

In this paper, we verify Gray's two-dimensional model with humanoid agents and suggest a novel two dimensional model. With humanoid agents, there are many factors, for example, gender, race and ethnic groups, and abstraction.

Gender is a basic factor for distinguishing humanoid agents. Kramer et al. showed that when a virtual agent's gender was opposite that of a participant, the participant formed rapport with the agent [10]. However, Guadagno et al. showed that participants change their attitude positively when an agent's gender matches that of themselves [6]. Kim et al. showed that students feel that a teaching agent is more "human-like" when the agent is male rather than female [9]. These impressions seem to be derived by an agent's appearance and participant's culture.

Payne et al. showed that female participants tended to select female virtual agent assistants: however, male participants selected female and male assistants to the same degree[15]. This study showed that the effect of an agent's gender depends on the participant's gender.

These prior works showed that the gender of an agent affects users.

An agent's race and ethnic group can be expressed through appearance. Rossen et al. investigated the effect of the skin color of humanoid agents [17]. They showed that users of humanoid agent are affected by real world skin-tone biases. Peck et al. showed that using a black skin color for an avatar reduces racial bias [16]. Racial bias is a large social problem; thus, the effect of an agent's race and ethnic group is important in the HAI field.

A lot of prior works revealed that the abstraction of agents affected a user's perception. Geven et al. showed that the abstraction of an agent affected how a user perceives the agent's intelligence and trustworthiness [3]. They showed that a low abstraction brought about a positive effect for humanoid agents. Mori et al. suggested the "uncanny valley' '[14]. This theory states that excessive reality reduces a robot's familiarity.

McCloud suggested a triangular design space for distinguishing a cartoon character's face [13]. He defined three angles of this triangle as "realistic object," "iconic object," and "abstract." He also defined "abstract" as low realism. Duffy applied this triangle model to distinguishing robot faces [2]. Also, Blow et al. used this model to design robots [1]. From these prior

works, abstraction is an important parameter for designing humanoid agents.

These variations in humanoid agents seem to affect the effectiveness of the practical functions of the agents. In this paper, we focused on the emotional contagion function. Emotional contagion (EC) is a phenomenon in which one's emotion infects a partner [7]. Tsai et al. showed that EC occurred between virtual agents and users [21]. Howard and Gengler showed that EC can transit the customer's attitude for products[8]. In HAI field, we showed that EC from the virtual agent to the user increase the agent's trustworthy[12]. These researches showed that EC was important to using the virtual agents in real world. However, it is not clear which parameters of virtual agents affect EC. We aimed to reveal the factor important to EC by constructing two kinds of two-dimensional model.

Gray et al. suggested two axes of mind perception, "agency" and "experience" [4]. We used this model in this paper. In addition, we aimed to construct new axes. Takahashi et al. suggested "emotion" and "intelligence" axises of mind perception, however, 2 out of the 7 agents used were humanoid in this research[18]. We hypothesized that "familiarity" and "reality" axes can be used to construct two kinds of two-dimensional model. Familiarity was reported to be an important factor in creating rapport [11]. In the uncanny valley theory, increasing reality reduces familiarity [14]. This theory suggests that "familiarity" and "reality" are dependent of each other. We aimed to investigate this hypothesis.

EXPERIMENT

We conducted an experiment on the web. We used Yahoo crowd sourcing[1] to recruit the participants and conducted the experiment. We recruited 200 Japanese participants, 122 males and 78 females. The age distribution was 2 people under 19 years of age, 16 people aged 20-29, 68 aged 30-39, 70 aged 40-49, 37 aged 50-59, and 7 over the age of 60.

We used eight virtual agents. Caucasian agents were chosen from FaceRig[2], which is software that mimics a user's facial expression and performs lip-synching. Asian agents were chosen from FaceRig+Live2D Module[3], which is a module that adds Japanese agents to FaceRig. We accommodated three factors: gender, race and ethnic group, and abstraction. For each factor, we defined binary states, that is, male or female, Caucasian or Asian, and low abstraction or high abstraction. All agents are shown in Table 1.

The participants were asked to answer all questionnaire in experiment with seven point Likert scale; 1 was "Strongly disagree" and 7 was "Strongly agree". We used two sets of questionnaire. One set was cited from Gray et al. [5]. The questions are as follows.

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

Gray et al. [5] defined fear, pleasure, and hunger as factors of agency and self control, memory, and moral as factors of experience.

The other set was constructed of six of our own questions. These questions aimed to verify the hypothesis that humanoid agents contained a "reality" dimension and "familiarity" dimension. The questions are as follows.

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

We hypothesized that familiarity, warmth, and communication are factors of familiarity and alive, human-likeness, and reality are factors of reality.

We conducted an explanatory factor analysis (EFA) to derive the two kinds of two-dimensional model. EFA is widely used to analyze variables observed from latent variables [20]. We conducted EFA with the maximum likelihood method and varimax rotation. We set the number of factors to two because our aim was to construct two kinds of two-dimensional model.

In addition to these questions, we asked about the effect of EC.

- Do you feel happy when you see this agent?

The average of this question is the EC score. Facial recognition and physiological signals may be better; however, Tsai et al. [21] used only questions to detect EC.

RESULT

We described humanoid agents by using <gender, racial and ethnic group, and abstraction>, for example, <male, Asian, low abstraction>.

[1] https://crowdsourcing.yahoo.co.jp/special/owner
[2] http://store.steampowered.com/app/274920/FaceRig/?l=japanese
[3] http://staff.live2d.com/archives/55477552.html

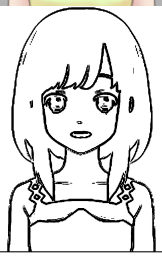
		gender	
race and ethnic group	abstraction	male	female
Caucasian	low		
	high		
Asian	low		
	high		

Table 1. Agents used in experiment

question	factor 1 (agency)	factor 2 (experience)
hunger	0.8431	0.5336
pleasure	0.8220	0.5637
fear	0.7468	0.6287
memory	0.6821	0.7151
moral	0.6517	0.7315
self control	0.5214	0.8533

Table 2. Factor loading of "agency"-"experience" questions

factor	eigenvalue	contribution rate
agency	3.1060	51.77
experience	2.7723	46.21

Table 3. Eigenvalue and contribution rate of "agency"-"experience"

question	factor 1 (familiarity)	factor 2 (reality)
familiarity	0.9359	0.3524
warmth	0.8702	0.4825
communication	0.8415	0.5350
alive	0.5564	0.8309
human-likeness	0.4502	0.8605
reality	0.3498	0.9066

Table 4. Factor loading of "familiarity"-"reality"

Figure 1 shows a two-dimensional model of "agency" and "experience." Each plot represents each agent, and the numbers mean the order of EC scores. The x-axis means the "agency" factor score, and the y-axis means the "experience" factor score.

Experience-Agency dimension

Table 2 shows the result of factor loading. We defined factor 1 as "agency" and factor 2 as "experience." This result complies with that of Gary et al. [4]. Table 3 shows the eigenvalue and contribution rate. Thus, we suggest that the "agency" and "experience" axes existed in this experiment.

Reality-Familiarity dimension

Table 2 shows the result of factor loading. We defined factor 1 as "familiarity" and factor 2 as "reality." The result complies with our hypothesis. Table 5 shows the eigenvalue and contribution rate. Thus, we suggest that the "familiarity" and "reality" axis existed in this experiment.

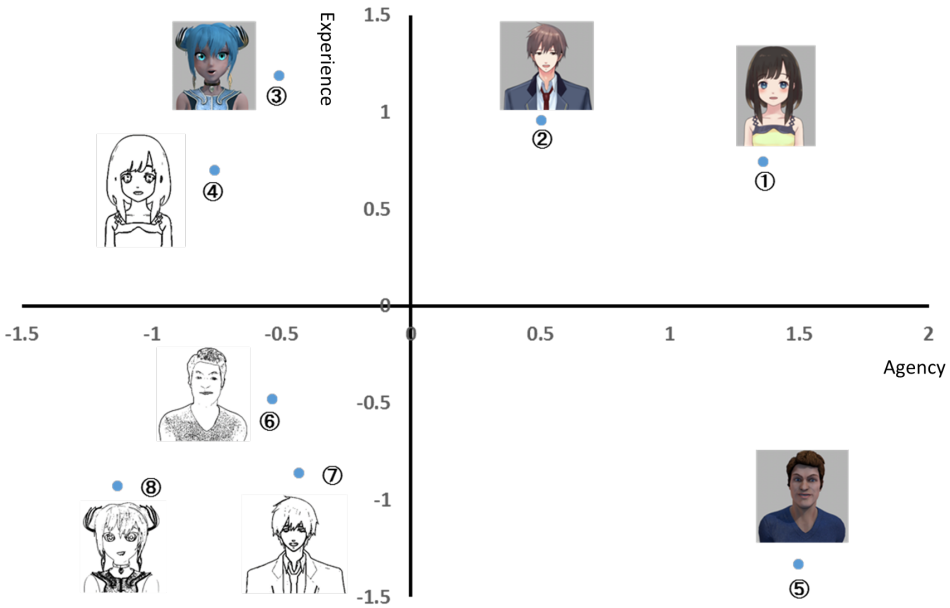


Figure 1. "Agency"-"experience" model and order of EC scores

factor	eigenvalue	contribution rate
familiarity	2.9759	49.60
reality	2.8959	48.26

Table 5. Eigenvalue and contribution rate of "familiarity"-"reality"

Figure 2 shows a two-dimensional model of "familiarity" and "reality." Each plot represents each agent, and the numbers means the order of EC scores. The x-axis means the "familiarity" factor score, and the y-axis means the "reality" factor score.

Emotional contagion

Figure 3 shows the EC score of each agent. We conducted a one-way ANOVA for this result. There were significant differences ($p < 0.01$). From sub-effect tests using Bonferroni method, there were significant differences between <male, Asian, low abstraction> and <male, Asian, high abstraction> ($p < 0.01$), <female, Caucasian, low abstraction> and <female, Caucasian, high abstraction> ($p < 0.01$), <female, Asian, low abstraction> and <female, Asian, high abstraction> ($p < 0.01$), <male, Caucasian, low abstraction> and <male, Asian, low abstraction> ($p < 0.01$), <female, Caucasian, low abstraction> and <female, Asian, low abstraction> ($p < 0.01$), <female, Caucasian, high abstraction> and <female, Asian, high abstraction> ($p < 0.01$), <male, Caucasian, low abstraction> and <female, Caucasian, low abstraction> ($p < 0.01$), <male, Asian, low abstraction> and <female, Asian, low abstraction> ($p < 0.01$), and <male, Asian, high abstraction> and <female, Asian, high abstraction> ($p < 0.01$)

Table 6 shows the correlation between EC scores and factor scores.

factor	correlation coefficient	p−value
agency	0.5588	p>0.05
experience	0.7349	p<0.05
familiarity	0.9269	p<0.01
reality	0.3383	p>0.05

Table 6. Correlation coefficient between EC score and factor score for each factor

Discussion

Two-dimensional models

From figure 1, we reinforce Gray's two-dimensional model. This model can be used to classify humanoid agents. From figure 1, we suggest that the abstraction of agents affects both "agency" and "experience."

Figure 2 reinforces our hypothesis that agents have the factors of "familiarity" and "reality." Table 4 shows that our questions fulfilled our aim. Figure 2 shows a distribution different from that of figure 1. This means our questions can reveal an agent's factors that cannot be revealed by Gray's questions.

Two-dimensional models and emotional contagions

Figure 3 shows that the effect of EC depends on an agent's appearance. Table 6 shows that a particular factor affects the EC effect. In the "agency"−"experience" model, the experience factor affects EC. Among all agents, the <female, Asian, low abstraction> agent had the highest EC score. In figure 1, the <female, Asian, low abstraction> agent had both a high "agency" factor score and "experience" factor score. In contrast, the <male, Caucasian, low abstraction> agent had a higher "agency" factor score than did the <female, Asian, low abstraction> agent; however, he had a low "experience" factor score and EC score.

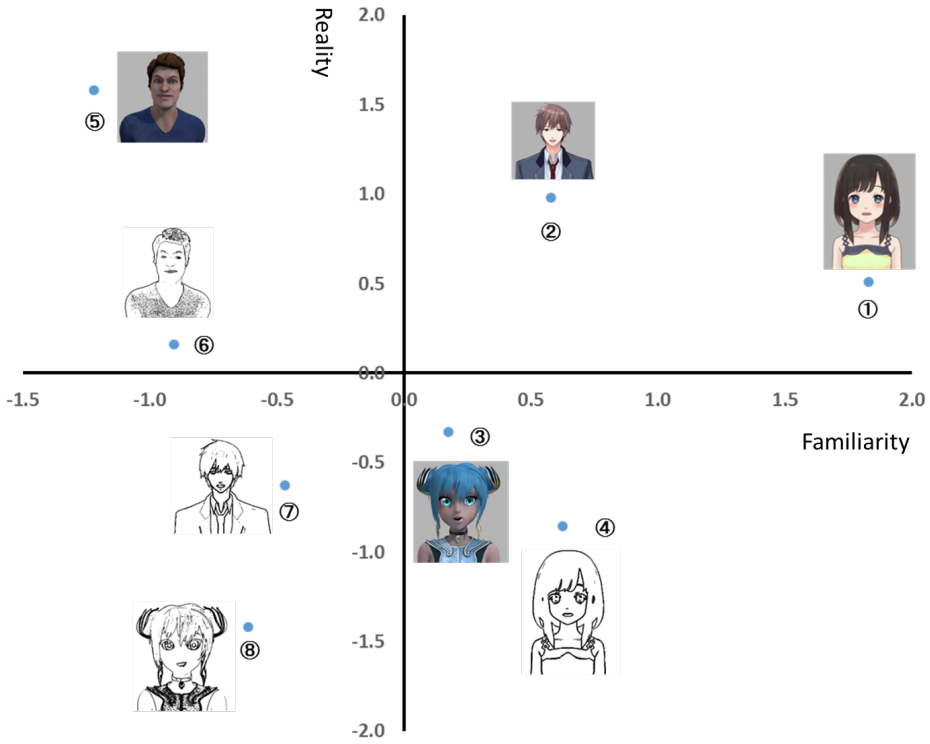


Figure 2. "Familiarity"-"reality" model and order of EC scores

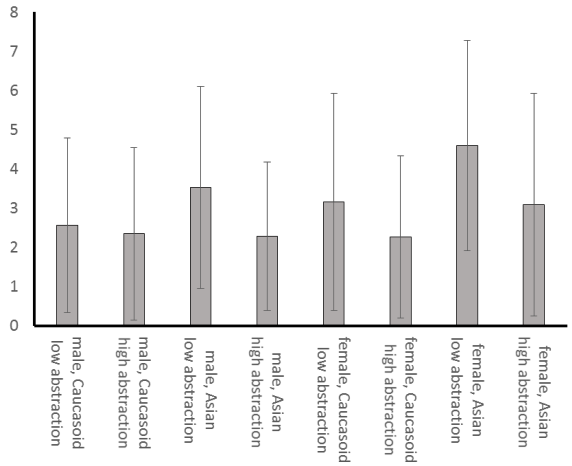


Figure 3. Average of EC(emotional contagion) score for each agent. Error bar means dispersion.

In the "familiarity"−"reality" model, the familiarity factor affected EC, as shown in table 6. In figure 2, we can see that the "familiarity" axis directly affected the EC score.

From these results, we suggest a method for designing agents. If we aim to bring EC from agents to users, we had better design agents that have "experience" and "familiarity." From this experiment, <female, Asian, low abstraction> is the best. In particular, abstraction is the most important factor for EC.

However, this experiment had structural problems. We experimented with only Japanese participants. This may have biased how they perceived the variation in agents, especially the race and ethnic groups. Conducting cross-cultural experiments is our future work.

CONCLUSION

In this paper, we verified two kinds of two-dimensional mind perception models. The first model was suggested by Gray et al. [4]. We aimed to apply this model to distinguishing humanoid agents. The second model was our original model. This model focused on "familiarity" and "reality." As a result, we showed that these two models were effective for distinguishing humanoid agents.

In addition, we verified the relationship between the effect of emotional contagion with these models. As a result, we showed that "experience" and "familiarity" factors are important to emotional contagion.

These results suggest ideas for designing agents and reveal our mechanism of mind perception toward humanoids.

ACKNOWLEDGMENTS

This study was partially supported by JSPS KAKENHI "Cognitive Interaction Design" (No. 26118005).

REFERENCES

1. Mike Blow, Kerstin Dautenhahn, Andrew Appleby, Chrystopher L Nehaniv, and David Lee. 2006. The art of designing robot faces: Dimensions for human-robot interaction. In *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction*. 331–332.
2. Brian R Duffy. 2003. Anthropomorphism and the social robot. *Robotics and autonomous systems* 42, 3 (2003), 177–190.
3. Arjan Geven, Johann Schrammel, and Manfred Tscheligi. 2006. Interacting with embodied agents that can see: How vision-enabled agents can assist in spatial tasks. In *Proceedings of the 4th Nordic Conference on Human-Computer Interaction*. 135–144.
4. Heather M Gray, Kurt Gray, and Daniel M Wegner. 2007. Dimensions of mind perception. *Science* 315, 5812 (2007), 619–619.
5. Kurt Gray, Adrianna C Jenkins, Andrea S Heberlein, and Daniel M Wegner. 2011. Distortions of mind perception in psychopathology. *Proceedings of the National Academy of Sciences* 108, 2 (2011), 477–479.
6. Rosanna E Guadagno, Jim Blascovich, Jeremy N Bailenson, and Cade Mccall. 2007. Virtual humans and persuasion: The effects of agency and behavioral realism. *Media Psychology* 10, 1 (2007), 1–22.
7. Elaine Hatfield, John T Cacioppo, and Richard L Rapson. 1994. *Emotional Contagion*. Cambridge University Press.
8. Daniel J Howard and Charles Gengler. 2001. Emotional contagion effects on product attitudes. *Journal of Consumer research* 28, 2 (2001), 189–201.
9. Yanghee Kim, Amy L Baylor, and E Shen. 2007. Pedagogical agents as learning companions: the impact of agent emotion and gender. *Journal of Computer Assisted Learning* 23, 3 (2007), 220–234.
10. Nicole C Krämer, Bilge Karacora, Gale Lucas, Morteza Dehghani, Gina Rüther, and Jonathan Gratch. 2016. Closing the gender gap in STEM with friendly male instructors? On the effects of rapport behavior and gender of a virtual agent in an instructional interaction. *Computers & Education* 99 (2016), 1–13.
11. Gerrard Macintosh. 2009. The role of rapport in professional services: antecedents and outcomes. *Journal of Services Marketing* 23, 2 (2009), 70–78.
12. Tetsuya Matsui and Seiji Yamada. 2016. Building Trust in PRVAs by User Inner State Transition through Agent State Transition. In *Proceedings of the Fourth International Conference on Human Agent Interaction*. 111–114.
13. Scott McCloud. 1993. Understanding Comics. 1993. *New York* (1993).
14. Masahiro Mori, Karl F MacDorman, and Norri Kageki. 2012. The uncanny valley [from the field]. *IEEE Robotics & Automation Magazine* 19, 2 (2012), 98–100.
15. Jeunese Payne, Andrea Szymkowiak, Paul Robertson, and Graham Johnson. 2013. Gendering the machine: Preferred virtual assistant gender and realism in self-service. In *International Workshop on Intelligent Virtual Agents*. 106–115.
16. Tabitha C Peck, Sofia Seinfeld, Salvatore M Aglioti, and Mel Slater. 2013. Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and cognition* 22, 3 (2013), 779–787.
17. Brent Rossen, Kyle Johnsen, Adeline Deladisma, Scott Lind, and Benjamin Lok. 2008. Virtual humans elicit skin-tone bias consistent with real-world skin-tone biases. In *Intelligent virtual agents*. 237–244.
18. Hideyuki Takahashi, Midori Ban, and Minoru Asada. 2016. Semantic Differential Scale Method Can Reveal Multi-Dimensional Aspects of Mind Perception. *Frontiers in Psychology* 7 (2016).
19. Kazunori Terada, Liang Jing, and Seiji Yamada. 2015. Effects of Agent Appearance on Customer Buying Motivations on Online Shopping Sites. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. 929–934.
20. Bruce Thompson. 2004. *Exploratory and confirmatory factor analysis: Understanding concepts and applications.* American Psychological Association.
21. Jason Tsai, Emma Bowring, Stacy Marsella, Wendy Wood, and Milind Tambe. 2012. A Study of Emotional Contagion with Virtual Characters. In *Proceedings of 12th International Conference on Intelligent Virtual Agents*. 81–88.