Do Audio-Visual Stimuli Change Hug Impressions?

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Abstract: This paper presents the effects of audio-visual stimuli on the impressions of hug interactions with a robot. In human-human interaction, perceived gender is an essential factor to change the impressions of haptic interactions. But in human-robot interaction, such perceived gender effects in haptic interactions have received less focus due to the difficulties of hardware limitations. Therefore, to investigate perceived gender effects in human-robot haptic interaction, we developed a system called *MetaHug* that consists of a huggable robot and a virtual reality application that uses a head-mounted-display to easily change the audio-visual stimuli during hug interactions. We prepared both female and male virtual agents, which use identical hug animations in the virtual application and synchronized them with the robot's hug motions. We investigated whether our system can change the perceived genders of the robots during hug interactions by different audio-visual stimuli, and whether their perceived genders can change the impressions of the hugs. Experiment results with 16 participants showed that their perception of the robot genders was significantly changed by the virtual agents. Their hug impressions were also significantly changed by the gender of the virtual agents. These results suggest that we can change the impressions of a robot's hugs through audio-visual stimuli.

Keywords: Hug, Human-Robot Interaction, Virtual Reality

1 Introduction

Physical existence enables social robots to haptically interact with people through such physical contact as touching and hugging. In human science literature, the positive effects of haptic interaction have already been broadly investigated, and both mental and physical benefits have been identified [1-6]. Based on these results, researchers also investigated the following positive effects of haptic interaction between robots and people: mental health benefits [7], improving motivation [8], decreasing stress levels [9], and encouraging prosocial behaviors [10]. These research works showed the follow-up results of human-robot haptic interaction on haptic interaction between people.

However, one essential factor, i.e., perceived gender, which changes the impressions of haptic interactions [11], has not been adequately investigated yet in the research field of human-robot haptic interaction. A few studies investigated gender effects in touch interactions with an agent or a robot, but they are limited to cross-gender effects in tele-conference situations [12] or failed to address the robot's gender because they used non-human-like robots [10]. Therefore, it remains unknown whether a robot's perceived gender influences touching interactions with it. To design more acceptable haptic interactions between robots and people, we must investigate the effects of the perceived robot gender by the impressions of haptic interactions with people.

However, several difficulties impede the investigation of the effects of perceived gender in human-robot touch interactions. To investigate such effects, changing both a robot's appearance and its voice is needed. By simply altering their appearances and voices, the perceived gender of computer-graphic-based agents can be easily changed; on the other hand, for robots, hardware limitations complicate changing appearances. Moreover, considering the balance of both appearance and functional designs is another difficult problem for building a robot. It would be too expensive to make multiple robots with adequate capability for natural motions with different appearances. A few android robots might fulfill both requirements [13], but since the number of such robots in the world remains small, preparing so many robots with different appearances is unrealistic.

In this study, we addressed the difficulty related to changing a robot's appearance using a virtual reality application and investigated whether a robot's perceived gender changes the impressions of haptic interactions. We developed a system called *MetaHug* (Fig. 1) that consists of a huggable robot and a virtual reality application that uses a head-mounted-display (HMD). We investigated whether our system can change a robot's perceived gender and the impressions of haptic interactions with it due to such perceived gender changes. In this study, we addressed the following research questions:

- Does a change in an agent's appearance and voice in a virtual reality application change the robot's perceived gender?
- Does the perceived gender change the hug impressions?

Fig. 1 *MetaHug* system: a robot hugs a participant wearing a HMD that shows a computer-graphics-based agent

2 Related works

In human science literatures, haptic interactions including touching and hugging have been broadly investigated. Haptic interaction provides physical and mental benefits. For example, Grewen et al. reported that hug interactions reduce blood pressure and heart rates during stressor events [1]. Cohen et al. reported that hug interactions provide protection against the infectious virus that causes the common cold [2] and stress-buffering social support. Jakubiak et al. reported that imagined (virtual) touches provide a better buffer against stress and pain than imagined verbal support [3].

Gender effects in haptic interaction have also been broadly investigated in the human-human interaction research field. Stier et al. investigated gender differences in touch interactions and concluded that females tend to respond more positively to touch than males [11]. Hubbard et al. investigated the effects of touch from both same- and opposite-gender effects and argued that being touched by the opposite gender may be advantageous in certain situations [14]. Another study identified complex and negative effects in a nursing context where males were touched by other males [15].

A few research works have started to investigate gender effects in haptic interactions with a robot or an agent. Suzuki et al. investigated the gender effects of mediated touch in a tele-conference situation and found that being touched by an opposite-gender agent provides positive impressions. But they only investigated with male participants [12]. Shiomi et al. investigated only participants' gender differences in hug interactions with a non-humanlike appearance robot [10]. Therefore, the gender effects on haptic interactions with robots remain relatively uninvestigated. Also, no research works have untangled the difficulties related to the change of a robot's appearance for haptic interactions using a virtual reality application. In this research work, we develop a novel system to solve such difficulties and investigate both same-gender and opposite-gender effects in human-robot haptic interactions.

3 System overview

Figure 2 shows an overview of our system that consists of the following six components: position tracker, touch sensor, motion controller, HMD, virtual agents for audio-visual stimulus, and robot for hug stimulus.

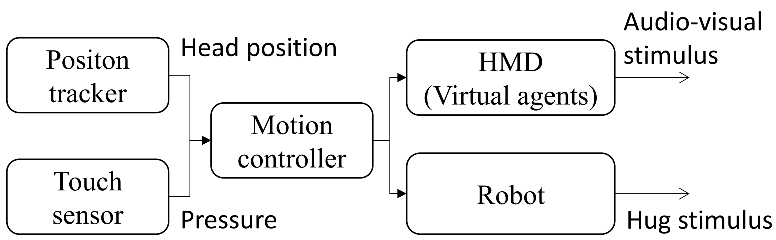

Fig. 2 System overview

3.1 Sensors: position tracker and touch sensor

We used Oculus Rift and two Oculus sensors as a position tracker because the participants also used Oculus Rift as a HMD (details are in the section 3.3). The Oculus sensors increase the head-tracking accuracy of Oculus Rift by combining a gyro sensor, acceleration sensors, and a geomagnetic sensor.

We also placed a touch sensor, *ShokacCube* by *Touchence*, in the robot's left arm that makes the first contact with the participants during the hug. This sensor, which can measure the height change on the top surface of a soft material with 16 measurement points, is 36 x 20 x 30 mm and sends pressure information to the motion controller function with a maximum of 100 Hz.

3.2 Motion controller

This function autonomously controls the motions of both the virtual agents and the robot using position and pressure information from the sensors. After the participants approach the robot, this function sends signals to both the virtual agent and the robot to start the hug animations/behaviors. During hug interactions, if the pressure values exceed a certain threshold, the motion controller interrupts the robot's hug behaviors and opens its arms for safety.

3.3 HMD

We used Oculus Rift as a HMD to show the virtual agents to the participants and to track their head positions. Oculus Rift provides high-resolution (1080 x 1200 pixels per eye) stereoscopic images with a 110 field of view with 90-HZ refresh rates. To just investigate the effects of audio-visual stimuli from the virtual agents, we removed all of the background images from the virtual reality application.

3.4 Virtual agent

Using Unity we prepared two virtual agents: a female and a male (Fig. 3). For the female agent's appearance and voice, we combined a 3D model from the *Futaba Honoka Character Pack* by *Game Asset Studio* and speech synthesis software from *VOICEROID+ Kyomachi Seika EX* by *AHS*. For the male agent's appearance and voice, we combined a 3D model from the *Taichi Character Pack* by *Game Asset Studio* and speech synthesis software from *VOICEROID+ Minase Kou EX* by *AHS*.

The heights of both agents were identical. Also, their positions in the virtual reality applications were adjusted based on the robot position to maintain the same distance relationship between the application and the real world. We implemented eye-contact and lip-sync behaviors for both virtual agents during idling states or speaking as well as hug animation for both agents. The hug animation lasted one minute.

3.5 Robot

We used *Moffuly*, a robot that resembles a large teddy bear (Fig. 4) [10] as a huggable robot platform. It is 200-cm tall with two elbows (1*2 DOF) and a speaker. Its 80-cmlong arms are adequate for reciprocating hugs. To ensure safety during hugs, we covered its frame with polypropylene cotton and used weak motors that can be easily resisted if needed. We controlled the robot with a Raspberry Pi 2 Model B. The hug behavior lasted one minute, during which the robot periodically patted the person on the back.

Fig. 3 Virtual agents (left: female, right: male)

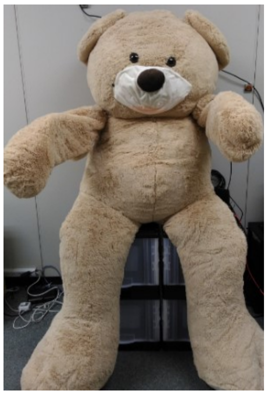

Fig. 4 Moffuly

4 Experiment

4.1 Hypothesis and predictions

In human science literature, perceived gender is essential for changing the impressions of haptic interactions [11]. Past studies reported that changes of perceived gender alter the impressions of touch stimuli from a mechanical device in a teleconference situation [12]. Therefore, in hug interactions with a robot, the changes of audio-visual stimuli will also influence the impressions of a robot's hugs.

Past studies reported that opposite-gender touches are more often positively evaluated than same-gender touches [11]. Another study reported that same-gender touches by males on males created complex and contradictory situations of acceptance, rejection, and suspicion in a nursing situation [15]. Based on these considerations, we made the following predictions:

Prediction 1: People will report feminine hug impressions when a female agent is shown in the HMD than when a male agent is shown, even if the control method of the robot's hug motion is the same.

Prediction 2: People will report more comfortable hugs and a greater willingness for another one when an opposite-gender agent is shown in the HMD than when the same-gender agent is shown.

4.2 Participants

Sixteen Japanese people (8 women and 8 men, whose average ages were 36.25, S.D 8.74) were paid for their participation. They had never experienced interaction with our robot or used an HMD.

4.3 Environment

We conducted our experiment in a 5 x 2 m room in our laboratory. We attached the robot to a wall and installed two cameras and microphones on the ceiling and one camera/microphone near it. We used the information from these sensors to analyze the experiment.

4.4 Condition

The study had a within-participant design with the following two conditions whose order was counterbalanced:

Male-agent condition: Participants interacted with the robot using the HMD, which showed an agent with a male appearance and voice.
Female-agent condition: Participants interacted with the robot using the HMD, which showed an agent with a female appearance and voice.

4.5 Procedure

Before the first session, the participants were given a brief description of our experiment's purpose and procedure. In this explanation, we showed our robot and explained their interaction with it and literally demonstrated how to hug it. We added that the robot's face part with which the participant faces make contact during hugging was replaceable to alleviate any sanitation concerns. We also explained how to use the HMD and asked them to maintain the hug interaction with the robot until the virtual agents stopped talking.

After the participants wearing the HMD approached the robot, it automatically started the hug behavior and asked them to continue hugging for about one minute. After the hug behavior ended, the participants filled out questionnaires about their impressions of the hug interaction. Then they wore the HMD again, hugged the robot, and filled out questionnaires. In total, the participants did two hug interactions. The order of showing the virtual agents was counter-balanced.

This research was approved by our institution's ethics committee for studies involving human participants. Written, informed consent was obtained from them.

4.6 Measurement

We investigated whether the appearance and the voice of the virtual agents changed their perceived gender and their effects on hug impressions by measuring the impressions of participants through two questionnaires. Questionnaire 1's items are 1) perceived agent gender and 2) degree of feminine hug impressions on a 1-to-7 point scale, where 7 is the most feminine and 1 is the most masculine. Questionnaire 2's items are 3) willingness for another hug and 4) the pleasantness of the hug interaction on a 1-to-7 point scale, where 7 is the most positive.

5 Results

5.1 Manipulation check

Figure 5 shows the questionnaire results of perceived gender. We conducted a two-factor mixed ANOVA for gender and agent factors, and the results showed significant differences in the agent factor ($F(1, 14)=51.946$, $p=.001$, $\eta 2 = 0.788$) . We found no significant differences in the gender factor ($F(1, 14)=0.615$, $p=.446$, $\eta 2 = 0.042$) or the interaction effect ($F(1, 14)=0.216$, $p=.649$, $\eta 2 = 0.015$). The perceived gender of the virtual agents was significantly different due to the changes of the appearances and voices, by using our system.

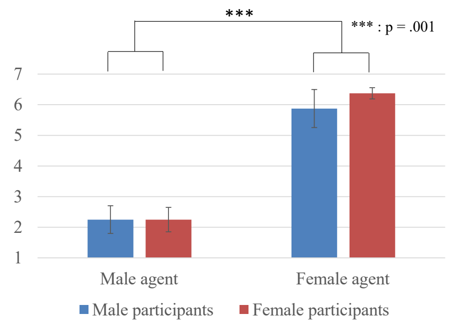

Fig. 5 Perceived gender

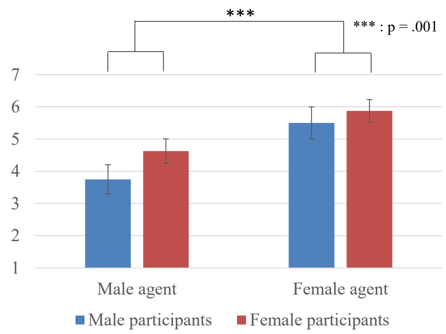

Fig. 6 Feminine hug impressions

5.2 Verification of predictions

Figure 6 show the questionnaire results of the degree of feminine hug impressions. We conducted a two-factor mixed ANOVA for the gender and agent factors, and the results showed significant differences in the agent factor ($F(1, 14)=20.160$, $p=.001$, $\eta 2 = 0.590$). But we found no significant differences in the gender factor ($F(1, 14)=1.577$, $p=.230$, $\eta 2 = 0.101$) or the interaction effect ($F(1, 14)=0.560$, $p=.467$, $\eta 2 = 0.038$). Prediction 1 was supported.

Figure 7 show the questionnaire results of the willingness for another hug. We conducted a two-factor mixed ANOVA for the gender and agent factors, and the results showed significant differences in the agent factor ($F(1, 14)=6.125$, $p=.020$, $\eta 2 = 0.331$) and the interaction effect ($F(1, 14)=5.091$, $p=.041$, $\eta 2 = 0.267$). However, we found no significant differences in the gender factor ($F(1, 14)=1.220$, $p=.288$, $\eta 2 =$

0.080). Multiple comparisons with the Bonferroni method revealed a significant difference for male agents: female participants > male participants, p=.047); but for female agents, no significant differences were revealed between female and male participants (p=.857). Multiple comparisons with a Bonferroni method revealed a significant difference for male participants: female agents > male agents, p=.047); but for female participants, no significant differences were revealed between female and male agents (p=.794)

Figure 8 show the questionnaire results of the pleasantness of the hug interactions. We conducted a two-factor mixed ANOVA for the gender and agent factors, and the results showed significant differences in the agent factor ($F(1, 14)=10.889$, $p=.005$, $\eta 2 = 0.437$) and the interaction effect ($F(1, 14)=14.222$, $p=.002$, $\eta 2 = 0.504$). However, we found no significant differences in the gender factor ($F(1, 14)=1.032$, $p=.327$, $\eta 2 = 0.069$). Multiple comparisons with the Bonferroni method revealed a significant difference for male agents: female participants > male participants, p=.029); but for female agents, no significant differences were revealed between female and male participants (p=.586). Multiple comparisons with the Bonferroni method revealed a significant difference for male participants: female agents > male agents, p=.001); but for female participants, no significant differences were revealed between female and male agents (p=.744).

Therefore, prediction 2 was partially supported; male participants reported significantly higher impressions of comfortable hugs and a willingness for another hug when the opposite-gender agent was shown than when the same-gender agent was shown. But questionnaire results from female participants did not significantly different among agents.

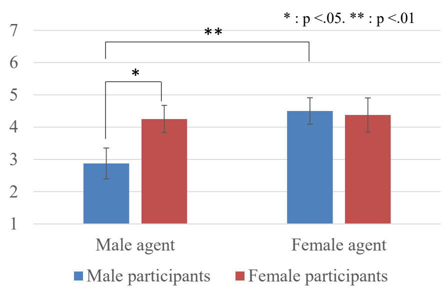

Fig. 7 Willingness for another hug

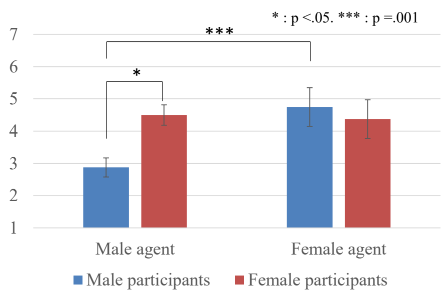

Fig. 8 Pleasant hug feelings

6 Discussion

6.1 Design implications

Our experimental results revealed that audio-visual stimuli changed the genders perceived by the participants in hug interaction with a robot as well such impressions of the hug interactions as pleasantness. Moreover, the trends of same-gender and opposite-gender effects resemble human science literatures: a tendency for females to respond more positively to being touched than males [11] and negative attitudes to being touching by the same-gender in males [15]. We believe that these results provide evidence for changing the hug impressions of a robot through audio-visual stimuli and will contribute to scrutiny of the relationships between a robot's hug impressions and its perceived gender because changing a virtual agent's appearance/voice is easier than performing the same manipulation in a robot.

One possible future work might investigate the effects of different virtual agents by focusing on a preferred character of each participant. This current study used specific combinations of appearances and voices in virtual agents, but if each participant could tailor his/her own choice and type of character as an audio-visual stimulus, impressions of hug impressions would undoubtedly rise.

6.2 Limitations

Robot and agent generalities are limited since our experiment was conducted with our developed robot and specific virtual agents that have a huggable appearance and doll-like touch feelings or animation-appearances. We cannot ensure that our findings can be applied to all huggable devices and virtual agent because appearances and feelings about being touched are essential for hug interactions. To generalize hug impressions, we must investigate them with different kinds of virtual agents and robots with different touch feelings. However, we believe that our setting offers essential knowledge for researchers who are interested in hug interactions with VR applications.

7 Conclusion

We focused on the effects of audio-visual stimuli in hug interactions with a robot to investigate whether the perceived gender changes a hug's impressions. We developed a system called *MetaHug* that consists of a huggable robot and a virtual reality application using an HMD and conducted an experiment where participants hugged a robot by looking at both male and female virtual agents. The participants experienced different impressions to the hugs when looking at different virtual agents, even if the hug behaviors were identical.

Acknowledgements

This research work was supported by JSPS KAKENHI Grant Numbers JP15H05322 and JP16K12505.

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