MetaHug: Audio-Visual Stimuli Change Stress Buffer Effect of Hug*

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***Abstract*— In human science literature, a hug interaction from a close person buffers the stress of the person being hugged. In this study, we investigated whether audio-visual stimuli during a hug with a robot change such stress buffer effects. For this purpose, we developed the MetaHug system, which consists of a huggable robot and a head-mounted-display that enables a virtual agent to reciprocate hugs. In our experiment, participants did stressful serial subtraction tasks after they experienced hug interactions with either two kinds of virtual agents: female or male appearances. Experiment results with 18 participants showed that participants showed significantly low stress when they did a hug with opposite-gender appearance agent compared to same-gender appearance agent.**

I. Introduction

Every day, we face many kinds of stressors like communication failure with others, bad UIs, virus-infested computer programs, PC crashes, losing critical data, and so on. Against such stressors, social support (e.g., caring expressions and verbal and nonverbal behaviors [1, 2]) from close people such as friends, family members and lovers softens such negative effects. Several studies reported that haptic interaction like a hug from a member of a support group more effectively mitigates the negative effects of stressors and provides stress-buffering relief [3-6]. A past study reported that an imagined haptic interaction from close people also buffers stress and pain [7].

However, these past studies mainly evaluated the effects of such haptic interaction from close people only. Therefore, knowledge about the positive effects of haptic interactions remains limited for people who have close relationships with others. Instead of only dealing with haptic interaction effects with close people, in this study we investigated such stress buffer effects through a haptic interaction with an agent for two reasons: 1) since past studies reported that a reciprocated hug from a physical agent (i.e., a robot) provided such positive effects as encouraging prosocial behaviors and self-disclosures [8, 9], we thought a hug from an agent would have positive effects for buffering stress too, and 2) using an agent system enables more people to experience hug interactions, not limited to people who have close relationships with others.

To investigate the effects of hug interactions from an agent, one concern is the perceived gender of the interaction partner, because haptic interaction effects are strongly influenced by a combination of genders between interaction partners [10-14]. To solve this problem, we focused on a phonomenon that combines both pseudo and actual stimuli that could change people's perceptions, including perceived gender by audio-visual stimuli [13, 15, 16]. Thus, we chose a similar approach in this study; we developed a hug display system called MetaHug that consists of a huggable robot which can reciprocate a hug and a virtual reality application to control visual-audio stimuli and enables a virtual agent to physically hug a user (Fig. 1). Through an experiment with MetaHug, we addressed the following question:

- Does perceived gender of a virtual agent, which is controlled by audio-visual stimuli, change the stress buffer effects of hugs from the agent?

Figure 1. Participant experiencing MetaHug

II. Related Works

Already many research works exist which investigate positive effects of haptic interaction between people. For instance, Grewen et al. investigated that hug interaction during stressor events, and reported that hug interaction with close people reduce blood pressure and heart rates [3]. Cohen et al. also reported that hug interactions provide stress-buffering, and protection against the infectious virus that causes the common cold [4]. Jakubiak et al. reported that an imagined touch from close people buffers stress and pain [7]. From another perspective, researchers investigated the gender effects in haptic interaction and reported that being touched by the opposite gender may be advantageous in several situations [10] [11] [12].

In human-robot interaction research fields, several research works have started to investigate haptic interaction effects [17-26]. For instance, touching a seal robot (Paro) provided mental health benefits for elderly people [17]. Being touched by a robot increased people's motivation during monotonous tasks and improved their impressions of it [18], and prosocial behavior [19]. Moreover, a few study investigated the effects of hug interaction with robots; e.g., conversations through huggable devices decreased stress

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levels more than with a smartphone in an investigation of cortisol levels [22]. Other research reported that a reciprocal hug behavior from a robot encouraged prosocial behavior of people and their self-disclosure, as well as the willingness to interact with it [23] [24]. From another perspective, a study reported that perceived gender of a robot change hug impressions by using VR system [27].

These research works investigated the positive effects and perceived gender effects for hug interaction with a robot, but the relationships between stress buffering effects and perceived gender of a robot is still unknown. If perceived gender of a robot have influences to stress buffering effects, unveiling it would provide useful knowledge for hug interaction design with a robot. Thus, we investigated the effects of perceived gender of a robot to stress buffering effects.

III. System Configuration

Figure 2 shows the MetaHug system, which consists of a head-mounted display (HMD), a head position tracker, virtual agents, a robot, a touch sensor, and a motion controller. The details are described below.

A. HMD and head position tracker

We used Oculus Rift as a HMD to show virtual agents to the participants. 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 only investigate the effects of the audio-visual stimuli from the virtual agents, we removed all of the background images from the virtual reality application.

Oculus Rift can also be used in a head position tracker with two Oculus sensors, which increased the head-tracking accuracy by combining three different types of sensors: gyro, acceleration, and geomagnetic.

B. Virtual agents

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

The heights of both agents were identical. Based on the robot position, we also adjusted their positions in the virtual reality applications 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 them. The hug animation lasted one minute.

C. Robot and touch sensor

We used a robot, Moffuly, that resembles a large teddy bear (Fig. 3, right) as a huggable robot platform. It is 200-cm tall with two elbows (1*2 DOF) and a speaker. Its 80-cm-long arms are adequate for reciprocating hugs. We controlled it with a Raspberry Pi 2 Model B. Its hug behavior lasted one minute, during which the robot periodically patted the person on the back.

To ensure safety during hugs, we covered its frame with polypropylene cotton and used weak motors that can be easily resisted if needed. Moreover, we installed a touch sensor (ShokacCube by Touchence) in its 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. During hug interactions, if the pressure values exceed a certain threshold, the motion controller interrupts the robot's hug and opens its arms for safety.

D. Motion controller

We implemented a motion controller to autonomously manage the motions of both the virtual agents and the robot using position and pressure information from the sensors. This function controls the start/end timings of the hug animations and the behaviors of both the virtual agent and the robot.

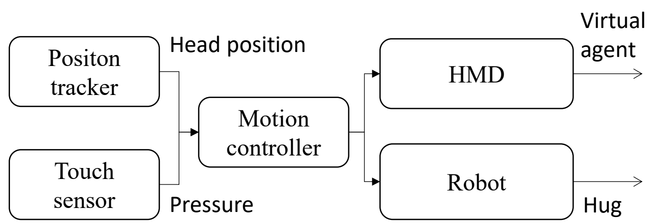

Figure 2. System overview

Figure 3. Virtual agents and Moffuly

IV. Experiment

We conducted a laboratory stress study to investigate the stress buffer effect of physical hug interaction with a virtual agent. For this purpose, we employed a serial subtraction task [7] that reliably produces stress responses, which is commonly used in cognitive science experiments.

A. Hypotheses and prediction

Hugs from close people buffer the stress of those being hugged [3] [4], even if touch interaction is imagined [7]. Past studies revealed that pseudo audio-visual information increased the feelings of the reality of physical stimuli and changed their perceptions [15] [16]. Therefore, we believe that physical hug stimuli with audio-visual stimuli will also buffer the stress of people.

However, the effects of tactile interaction (including hugs) are changed by the perceived gender of the interaction partner. Past studies reported that opposite-gender touches are more often positively evaluated than same-gender touches, and its tendency strongly occurred in males [10]. Another study reported that same-gender touches by males created complex and contradictory situations of acceptance, rejection, and suspicion in a nursing situation [12]. Therefore, if we control the perceived gender of the virtual agents using different appearances and voices, the stress buffering effect will change due to the combinations of genders between people and agents. Based on these considerations, we made the following hypotheses:

Prediction: Hug interaction with a virtual agent will buffer their stress more when the perceived gender of the virtual agent is opposite to a participant.

B. Participants

Eighteen Japanese people (9 women and 9 men, whose average ages were 37.94, age range was 21 to 56, and S.D was 9.65) were paid for their participation. They had never interacted with our robot or used an HMD.

C. Environment

We conducted an experiment in a 5 x 2 m room in a laboratory. We attached the robot to a wall and installed two cameras, microphones, and Oculus sensors near it.

D. Conditions

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

Same-gender condition: participants interacted with the robot using the HMD, which showed an agent with a same-gender appearance and voice.

Opposite-gender condition: participants interacted with the robot using the HMD, which showed an agent with an opposite-gender appearance and voice.

E. Procedure

Before the first session, the participants were given a brief description of our experiment's purpose and procedure. This research was approved by our institution's ethics committee for studies involving human participants. Written, informed consent was obtained from all of them.

We showed our robot, explained their interaction with it, and literally demonstrated how to hug it. We added that the robot's face part with which their 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 until the virtual agents stopped talking.

In both conditions, after the participants put on the HMD and approached the robot, it automatically started the hug behavior and asked them to maintain the hug for about one minute. After the hug ended, the participants were instructed to do a subtraction task, which is a part of the Trier Social Stress Test and reliably produce stress response [28, 29], from among these three patterns (the order was counterbalanced): 2091 to zero in 17-step sequences, 2337 to zero in 19-step sequences, or 3567 to zero in 29-step sequences. All three tasks require 123 subtractions to become zero.

At the beginning of the subtraction task, the experimenter instructed the participants to calculate as quickly and as correctly as possible. When they made mistakes, the experimenter played synthetic sounds that informed of their mistake and asked them to begin again from the first value. During the subtraction task and after it ended, the participants rated their stress and completed questionnaires (details are described in the next subsection)

F. Measurements

In this study, we measured the perceived stress during the task by a questionnaire, because this approach can accurately measure the perceived stress compared to before or after measurement [30]. Moreover, this past study suggested that the self-reported stress showed a temporal correlation between the physiological and the psychological stress response [30]. Other past study which investigate the stress buffering effects about imagined touch from close people employed this approach [7], therefore this approach is applicable to investigate the perceived stress during the task. Based on these considerations, we also measure the perceived stress during the task by the questionnaire. Therefore, participants rated their tress during the subtraction task on a 0 to 10 numerical stress rating scale, which ranged from no stress to great stress. They made stress ratings at 30 seconds intervals (prompted by a tone) for a total of ten stress ratings ($\alpha = .97$).

For a manipulation check about the perceived gender, we investigated whether the appearance and the voice of the virtual agents changed their perceived gender by a questionnaire on a 1-to-7 point scale, where 7 is the most same-gender and 1 is the most opposite-gender. This questionnaire is conducted after each subtraction task.

As an additional evaluation, we asked the participants to complete a short questionnaire about their perceptions of the subtraction task to assess their enthusiasm for the task, following past similar study [7]. Participants completed 7-point bipolar scales to describe their feelings about the task (i.e., not fun-fun, not enjoyable-enjoyable, boring-interesting, not frustrating-frustrating), and the item assessing frustration was reverse scored ($\alpha = .73$).

Moreover, we measured the performances of the subtraction tasks and errors. For example, a performance score of 15 indicates that the participant correctly completed 15 serial subtractions during the 5-minute task.

V. RESULTS

A. Manipulation check

Figure 4 shows the questionnaire results about perceived gender. We conducted a two-factor mixed ANOVA for the gender and agent factors, and the results showed significant differences in the agent factor ($F(1, 16)=66.038$, $p<.001$, $\eta2 =.805$), but we found no significant differences in the gender factor ($F(1, 16)=0.615$, $p=.444$, $\eta2 = .037$) or the interaction effect ($F(1, 16)=0.051$, $p=.824$, $\eta2 = .003$). The perceived gender was significantly different due to the changes of the appearances and the voices with our system.

B. Verification of prediction about perceived stress

Figure 5 shows the perceived stress of the participants. We conducted a two-factor mixed ANOVA for the gender and condition factors, and the results showed significant differences in the agent factor ($F(1, 16)=4.768$, $p=.044$, $\eta2 = .230$), but we found no significant differences in the gender factor ($F(1, 16)=0.459$, $p=.508$, $\eta2 = .028$) or the interaction effect ($F(1, 16)=2.700$, $p=.120$, $\eta2 = .120$). These results indicated that a hug interaction with an opposite-gender agent buffers the stress of both female and male participants during the tasks. Thus, prediction was supported.

C. Additional analysis: enthusiasm and task performance

Figure 6 shows the enthusiasm in all the conditions. We conducted a two-factor mixed ANOVA for the gender and condition factors, and the results showed no significant differences in the agent factor ($F(1, 16)=0.04$, $p=.951$, $\eta2 = .001$), in the gender factor ($F(1, 16)=0.123$, $p=.730$, $\eta2 = .008$) or the interaction effect ($F(1, 16)=0.004$, $p=.951$, $\eta2 = .021$). Thus, hug interactions under the opposite-gender agent condition buffers stress toward participants, but our study found no clear significant differences in the enthusiasm.

Figure 7 shows the task performances in all the conditions. We conducted a two-factor mixed ANOVA for the gender and condition factors, and the results showed no significant differences in the agent factor ($F(1, 16)=0.01$, $p=.980$, $\eta2 = .001$), in the gender factor ($F(1, 16)=1.304$, $p=.270$, $\eta2 = .075$) or the interaction effect ($F(1, 16)=0.337$, $p=.569$, $\eta2 = .021$). Thus, our study found no clear significant differences in the performances of the subtraction tasks.

VI. DISCUSSION

A. Implications

Our experimental results showed that the audio-visual stimuli changed the stress-buffering effects of hug interactions with virtual agents, and hug interaction with opposite-gender decreased their perceived stress. In human science literatures reported similar trends of same-gender and opposite-gender effects in haptic interaction, e.g., a touch from opposite-gender is more often positively evaluated than a touch from same-gender [10], and for males they reported negative attitudes to being touching by the same-gender [12]. These results suggest design policy ramifications for applications that will be used in mental therapy or counseling contexts by interacting with virtual/physical agents [31-35].

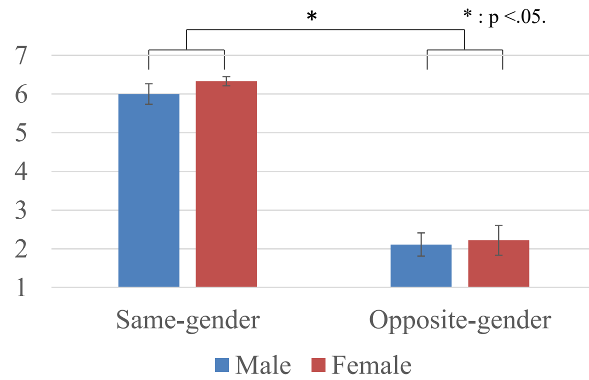

Figure 4. Perceived gender (7 is most same-gender feeling)

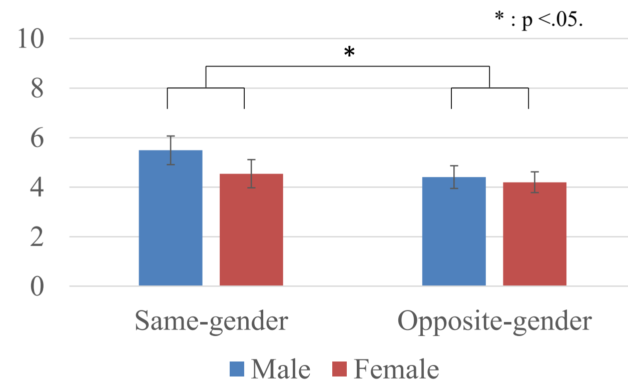

Figure 5. Perceived stress during taks

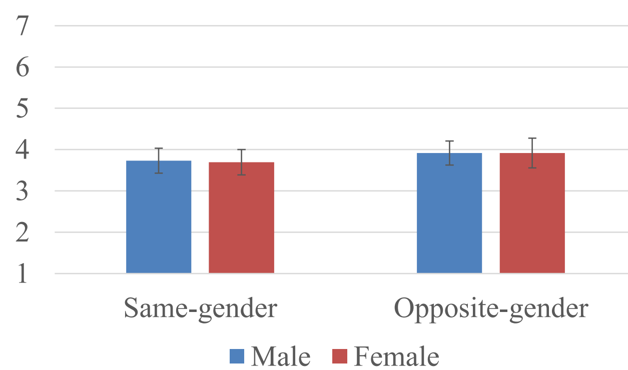

Figure 6. Enthusiasm of tasks

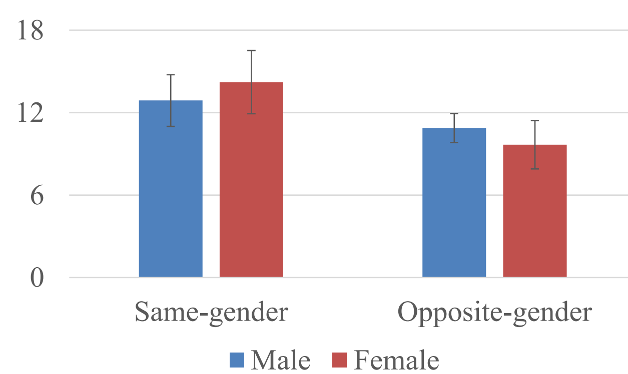

Figure 7. Performance of tasks

B. *Future work*

The experimental results revealed that perceived gender changed stress buffering effects of hug interaction with a robot, but still it is unknown why such effects occurred. We need to investigate further relationships via other measurements to discuss the effects of hug interaction with virtual agents. One possible approach is to investigate participants' impression more deeply, actually a past study reported that perceived gender of virtual agents changed hug impression more positively, such difference might be one reason to decrease their perceived stress. From another perspective, investigating physiological measurements such as cortisol, which indicates the stress levels of people, would be effective to investigate the hug interaction effects. Other physiological measures, such as brainwaves, might also help understand the effects of hug interaction with virtual agents [19].

One technical future work is to provide richer hug stimuli. In this study we used a touch sensor to detect human presence and to stop the robot's hug behavior for safety, but it also can be used to change hug stimuli for both stronger/softer. For this purpose, may be additional touch sensors to the robot's body and/or face parts would be useful to detect hug situation deeply. Moreover, adding more DOFs to the robot's arms would enable different kinds of hug interactions, such as patting a head or a stroking a back of an interacting person.

Another possible future work is to compare different setting such as non-hug condition or without HMD. For instance, past study which investigated touch effects employed non-touch conditions [18, 36]. Comparing non-touch conditions might provide richer knowledge about hug interaction with a robot. Moreover, a direct hug interaction with the robot (i.e., without HMD) might have stress buffering effect too, because past studies showed the positive effects of hug interaction with it [24]; but the main aim of this paper was to investigate the relationship between perceived gender and stress buffering effects of hug interaction. Therefore, Comparison of the level of stress buffering effect of hug interaction is out of scope in this study, but it would be one interesting future work, too.

C *Limitations*

On the other hand, we need to carefully contemplate the experiment results of this study. Since we only used a specific robot and virtual agents, we must test different types of robots and virtual agents to generalize our experimental results. Moreover, in this study we did not confirm the sexual fluidity of the participants, which might influence the haptic interaction effects. Even if such limitations exist, we still believe that our setting offers essential knowledge for researchers who are interested in hug interactions with virtual agents and/or robots.

VII. Conclusion

We developed a MetaHug system that consists of a huggable robot and a virtual reality application, and experimentally investigated how physical hug interactions with virtual agents buffer the stress of people using a serial subtraction task as a stressor stimuli. Our experimental results showed that the perceived gender of the virtual agents and their hug interactions significantly influences stress buffers, and hug interaction with the opposite-gender agent decreases perceived stress compared to the same-gender agent.

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