# Audio-visual stimuli change not only robot's hug impressions but also its stress-buffering effects

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**Abstract:** This paper describes how audio and visual stimuli during a robot's hug change its perceived impressions and stress-buffering effects. In human science literature, the perceived gender influences the impressions of touch interactions, including hugs. In this study we investigate whether the perceived gender of an interacting agent controlled by audio-visual stimuli affects the influence of positive hugs like a stress-buffering effect. We used a system called Metahug that integrates a robot and a virtual reality application and prepared both female- and male-appearance agents and experimentally investigated the audio-visual effects for human-robot hug interaction. Our results showed that the robot's hug impressions were significantly different based on the agents' genders. Moreover, the participants reported significantly lower tension in a stressful task when they hugged an opposite-gender-appearance agent compared to a same-gender-appearance agent. Our results suggest that the Metahug system can change both the impressions of a robot's hug and stress-buffering effects of the hug by altering the audio and visual stimuli of the virtual reality application.

**Keywords:** hug interaction, human-robot touch interaction, virtual reality

## 1 Introduction

Touch interaction is a growing research topic in the human-robot interaction research field. Due to technological advances, social robots are interacting with us by shaking hands and giving hugs at museums [2, 3], elementary schools [4, 5], and shopping malls [6, 7]. Robotics researchers consider a robot's touch a key factor not only for friendly interaction but also for providing positive effects to the people who are being touched, because past studies in human-human interaction showed various merits from touch interaction [8-13]. Past studies investigated the merits of human-robot touch interaction from the following viewpoints: mental health support [14], motivation management [15], stress-buffering effect [16], and promoting prosocial behavior [17].

However, these previous works only used machine- or pet-like-appearance robots in their touch interactions and focused less on the perceived gender of the robots and their touches. Based on human science literature, gender changes the impressions of touches between people [18][19]. However, it remains unknown how a robot's perceived gender changes the impressions of its hugs. Note that the investigation of gender effects with robots in touch interaction suffers from several difficulties, including hardware configuration for specific appearances and expense.

To investigate the merits of the perceived genders of robots by avoiding such difficulties, we integrated a virtual reality (VR) application and a huggable robot to easily change its appearances and its voice to control its perceived gender using audio-visual stimuli (Fig. 1). In this study, we used the MetaHug [1] system to address the following research questions:

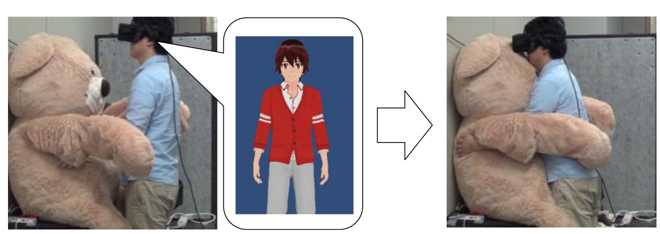

**Fig. 1** MetaHug system

This paper is an extended version of a previous work of Shiomi et al. [1] and contains additional references, experiment and discussions.

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- Can the changes of the audio-visual stimuli in a VR application alter the robot's perceived gender?

- How does the perceived gender change the human participant's feelings about the robot's hug?

In this study we also investigate the stress-buffering effects of a robot's hug. Human science literature has already identified stress-buffering effects through actual touch interaction (including hugs) both with close people [9] and imagined touch interaction from such people [10]. Another study showed a stress-buffering effect though human-robot touch interaction [16], but it failed to focus on the perceived gender effect. If the robot's perceived gender influences the stress-buffering effects, such knowledge would contribute to touch interaction between people and robots and the design of mental support robot systems. Thus, we address the following research question:

- How does the perceived gender of a robot change the stress-buffering effects of its hugs?

## 2 **Related Work**

### 2.1 Touch interaction between people

Several researchers have investigated how intimate touch interaction with friends of family, such as affective touches and hugging, provide positive effects to the people who are being touched. For instance, researchers who focused on hug effects for physical health reported that blood pressure and heart rates are reduced by hug interactions [8]. Another research described the effects on immunity and reported that touch interaction with close people decreases the risk of infections from viruses [9]. Goldstein et al. investigated the relationships between social touch analgesia and brain-to-brain coupling by observing hand-holding situations [20]. From another perspective, researchers argued that imagined touch supports might increase stress-buffering effects more than imagined voice supports [10].

To investigate the effects of touch interaction between people, the gender effect is one essential factor about responses to being touched. For example, female participants respond more positively to being touched by male participants [18]. Another researcher compared the touch effects between the same gender and the opposite gender and reported that being touched by the latter provides merits in specific situations [21]. Evans et al. reported the negative effects of same-gender touch in nursing situations, such as between male patients and male nurses [19].

These studies showed both the positive and negative effects of touch interaction as well as how gender influences them and the feelings of being touched. These results suggest that the perceived gender of robots also influences the touch interaction.

### 2.2 Touch interaction between people and robots

Robotics researchers have also shown that touch interaction with robots effectively provides positive effects to the interacting people, similar to human-human touch interaction [14-16, 22-28]. One popular touchable robot is Paro whose seal-like appearance supports elderly people from a mental health perspective [14]. Sumioka et al. reported that using a huggable device during tele-communication can decrease stress [16]. These studies focused on passive touches, i.e., from people to robots, but recently others have focused on the effects of active touches, i.e., from robots to people. For example, a robot's active touch increases human motivation and provides better impressions than a passive touch [15, 22]. Other studies focused on hug interactions between robots and people and reported that active hugs encourage prosocial behaviors (larger charitable donations) in people and self-disclosures and raised interest to interact with the robot again [25][26].

In the research field of human-robot interaction, the perceived gender effects have been broadly investigated using multiple kinds of real robots [29][30][31]. For example, Powers et al. reported that the gender of a robot's voice's influences its perceived knowledge [29]. Ghazali et al. focused on a robot's facial characteristics and gender effects in persuasive interaction and concluded that an opposite gender robot created higher psychological reactance to participants than a same gender robot. [30]. Siegel et al. also investigated the gender effects of persuasive effects in human-robot interaction and argued that people more highly evaluated a robot of the opposite gender [31].

In a touch interaction context, due to the difficulties of preparing various kinds of robots with different appearances, several researchers employed virtual agents to change/control the perceived gender of an interacting target. For instance, Suzuki et al. integrated a female-appearance agent and a mechanical hand device to investigate the effects of motivation improvement [32]. Bailenson et al. investigated gender effects using a VR application and reported that touch forces were changed by gender combinations [33]. Another study investigated the effects of a virtual agent's gender and its body size on virtual hug interactions and argued that the combinations of genders between participants and agents influenced the interaction time [34].

These studies highlighted the merits of touch interaction between robots and people and described the perceived gender effects of interacting agents. On the other hand, the stress-buffering effect of hugging a robot remains unknown, and the perceived gender effects in hug interactions have also not been investigated yet. If a robot's hug has similar stress-buffering effects that are changed by its perceived gender, such knowledge will benefit robot applications with haptic interaction.

## 3 System

Figure 2 shows the components of our MetaHug system. Its motion controller function manages both the VR application part (i.e., motions and voices of virtual agents) and the robot part (i.e., robot motions).

### 3.1 VR application part

In this study, we used Unity and Oculus Rift to control the audio-visual stimuli for the participants through a VR application. We also used two Oculus sensors to detect the Oculus Rift's position, i.e., the users' head positions.

We prepared female- and male-appearance virtual agents using commercial 3D models and speech synthesis software. We adjusted their heights to be identical to avoid size effects. These agents autonomously made eye-contact with the users using head position information and controlled their lip behavior for synchronization with the speech contents. We also prepared a hug animation for both agents.

### 3.2 Robot part

We used Moffuly [17] that can hug people. This robot has a 1 DOF for each elbow and sufficient arm length for hug interactions. For a safe hug, we installed a touch sensor (*ShokacCube*, developed by Touchence) in the tip of its arms to detect contact with people; if the sensor detects a particular amount of pressure, the hug motion stops and Moffuly will slightly open its arm.

### 3.3 Motion controller function

With the sensor information from the VR application part and the robot part, i.e., head position and pressure information, the motions and the voices of the virtual agents are controlled as well as the robot's motions for synchronized hugs. The motion controller decides the timing at which to start their hug motions based on the user's head position. During a hug interaction, the robot patted the users on the back. Since we prepared a one-minute hug for the virtual agents and the robot, their hug motions finish simultaneously. About the hug time, even though past human science literatures reported that intimate hugs provided several positive effects, they did not describe the length of the hugs; we prepared rather long hugging behavior (i.e., one-minutes) to express intimate impressions.

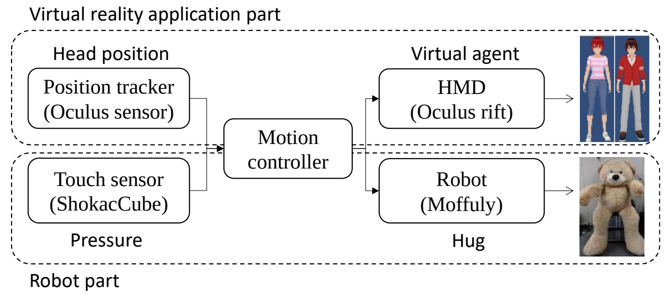


**Fig. 2** System overview

## 4 Experiment

### 4.1 Hypotheses and predictions

#### *4.1.1 Hypotheses about hug impressions and gender*

As described in Section 2, the perceived gender influences touch interactions between people [18]. For example, past studies reported that a touch from a person of the opposite gender was welcomed, and a touch from a person of the same gender caused complex situations in the context of acceptance and rejections [18] [19]. Therefore, if the MetaHug system appropriately controls the perceived gender of virtual agents, people will have more positive impressions to hug experiences when they interact with an opposite-gender agent than with a same-gender agent. Based on these considerations, we made the following hypothesis about hug impressions:

**Prediction 1:** Participants will feel more comfortable hugging and a greater willingness to hug again with an opposite-gender agent than with a same-gender agent.

#### *4.1.2 Hypotheses about stress-buffering effect*

As described in Section 2, past studies showed that hug interaction provides stress-buffering effects, regardless whether the interaction partner is an actual close person [8][9], an imagined close person [10], or a robot [16]. However, these studies did not address the perceived gender effects, which we believe influences the stress-buffering effects through hug interaction, similar to other touch interactions [18][19]. Following these considerations, we made a hypothesis about the stress-buffering effect:

**Prediction 2:** Hug interactions with an opposite-gender agent will decrease the stress of participants more than a hug with a same-gender agent.

### 4.2 Participants

Eighteen Japanese people participated in our experiment: nine women and nine men who self-reported their genders. Their average age was 36.25 and the standard deviation was S.D 8.74.

### 4.3 Environment

The experiment was conducted in our laboratory environment where the MetaHug system is installed. We recorded both video and audio information.

### 4.4 Conditions

This study has a mixed factorial design, i.e., we combined within- and between-participant designs. The number of within-participant conditions was two (same-gender and opposite-gender), and their order was counterbalanced. The between-participant factor was the participant's gender.

**Same-gender condition:** participants interacted with the same-gender agent.

**Opposite-gender condition**: participants interacted with the opposite-gender agent.

### 4.5 Procedure

First, we briefly described the experiment's purposes and its procedures. After they gave signed consent, we explained our system and how to give a hug with it by wearing an HMD. In both conditions, the agents first request a hug verbally, hug the participants so that they could experience a hug, and thank the participant's participation to this experiment. After the hug interaction ended, the participants did a subtraction task as a stressor, which is commonly used in human science literatures to reliably produce stress [35, 36]. We prepared three subtraction tasks (2091 to 0 in 17-step sequences, 2337 to 0 in 19-step sequences, or 3567 to 0 in 29-step sequences) and counterbalanced their order. Each task length was five minutes. The experimenter told them to calculate as quickly as possible and warned them that if they made mistakes, they would have to begin again.

### 4.6 Measurements

To investigate the hug interaction feelings, we prepared two questionnaire items: 1) willingness to get another hug and 2) the comfort of the hug experience on a 1-to-7 point scale, where 7 is the most positive.

To investigate the stress experienced by the participants during the task, we followed a past procedure [10], where participants self-reported their perceived stress during the tasks. We followed this approach because a past study reported that this method more accurately measures perceived stress during tasks than post-task measurements. Self-reported perceived stress also showed a temporal correlation between physiological and psychological stress measurements [37]. The participants reported their stress ratings (0-to-10 scale, where 0 is no stress and 10 is extremely stressed) at 30-second intervals (prompted by a tone) during each five-minute task. We gathered ten stress ratings for each condition. The Cronbach α value was 0.97.

## 5 **Results**

### 5.1 Verification of prediction 1

Figure 3 shows the average and the S.E. of the comfort impressions. We conducted a two-way mixed ANOVA with two factors: participant-gender (between-participant) and agent-gender (within-participant factor). The results showed significant differences in the agent-gender factor ($F(1, 14)=12.962$, $p=.002$, $\eta 2 = 0.448$) and in the interaction effect ($F(1, 14)=12.962$, $p=.002$, $\eta 2 = 0.448$). The results did not show any significant differences in the participant-gender factor ($F(1, 14)=0.899$, $p=.357$, $\eta 2 = 0.053$). We conducted a multiple comparison with the Bonferroni method, which showed a significant difference for the same-gender agent: female participants > male participants, $p=.043$). For the opposite-gender agent, we found no significant difference between the female and male participants ($p=.594$). The results also showed a significant difference for male participants: opposite-gender agents > same-gender agents ( $p<.001$). For female participants, we found no significant difference between opposite- and same-gender agents ($p=1.00$).

Figure 4 shows the average and the S.E. for the willingness to get another hug. We conducted a two-way mixed ANOVA with two factors: participant-gender (between-participant) and agent-gender (within-participant factor). The results showed significant differences in the agent-gender factor ($F(1, 14)=5.982$, $p=.026$, $\eta 2 = 0.272$) and in the interaction effect ($F(1, 14)=7.965$, $p=.012$, $\eta 2 = 0.332$) but not in the participant-gender factor ($F(1, 14)=0.429$, $p=.522$, $\eta 2 = 0.026$). We conducted a multiple comparison with the Bonferroni method, which did not show any significant difference for either the opposite-gender agent ($p=.466$) or the same-gender agent ($p=.111$). On the other hand, the results showed a significant difference for male participants: opposite-gender agents > same-gender agents, $p=.002$). But for female participants, we found no significant difference ($p=0.794$).

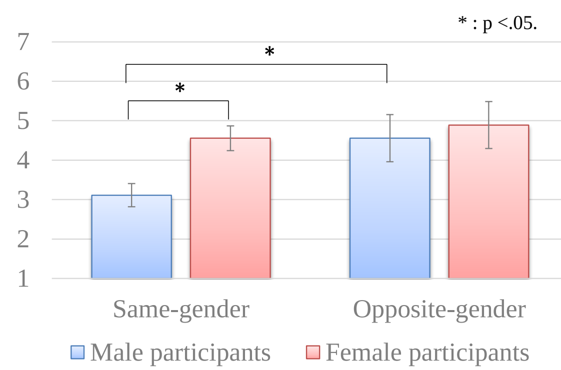


**Fig. 3** Questionnaire results about comfortableness of hug interaction

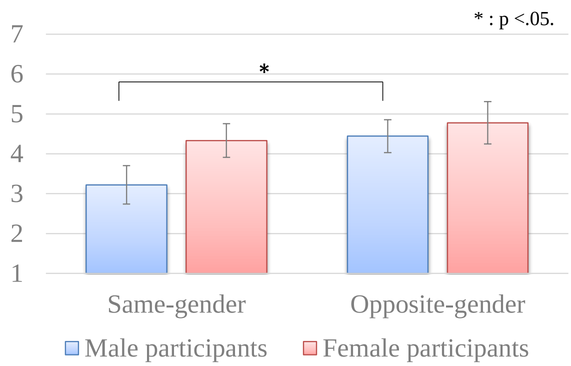


**Fig. 4** Questionnaire results about willingness for another hug

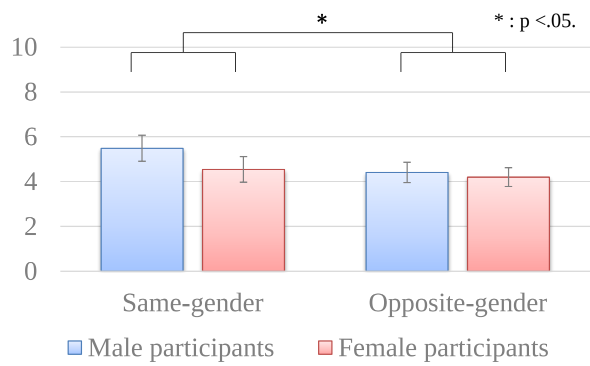


**Fig. 5** Questionnaire results about perceived stress during tasks (0 means no stress)

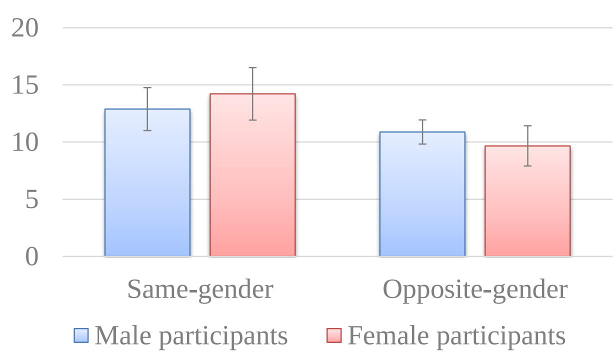


**Fig. 6** Task performance

These experimental results partially supported prediction 1. Only male participants showed significantly more positive impressions about comfort and willingness for another hug when they interacted with the opposite-gender agent than with the same-gender agent.

### 5.2 Verification of prediction 2

Figure 5 shows the average and the S.E. for perceived stress. We conducted a two-way mixed ANOVA with two factors: participant-gender (between-participant) and agent-gender (within-participant factor). The results showed significant differences in the agent-gender factor ($F(1, 16)=4.768$, $p=.044$, $\eta 2 = .230$). We did not find any significant differences in the gender factor ($F(1, 16)=0.459$, $p=.508$, $\eta 2 = .028$) or in the interaction effect ($F(1, 16)=2.700$, $p=.120$, $\eta 2 = .120$). These results indicate that for both female and male participants, a hug interaction with an opposite-gender agent relieved their stress more than with a same-gender agent. Thus, prediction 2 was supported.

## 6 Discussion

### 6.1 Implications

Our results show that hug interactions with opposite-gender agents offer stress-buffering effects for both female and male participants. On the other hand, the agent-gender factor significantly changed the hug impressions only for male participants. These results seem complex because a part of our hypotheses was not supported. But basically, hug interactions with an opposite-gender agent provide greater benefits than with a same-gender agent.

Another critical implication is that the experimental results showed similar trends between human-human and human-robot touch interactions. Past studies showed that females react more positively to touch interaction than males [18], and male-male touch has a negative effect [19]. These results showed promising effects for hug interaction with a robot using a VR application to manipulate the perceived gender of the interacting agents, because this approach provides opportunities to more easily change the appearances and the voices of agents than actual robots.

### 6.2 Hug effects toward task performances

In this study, we only investigated the stress-buffering effects and the impressions of hug interactions by controlling the perceived gender of the interacting agents. To deepen our understanding about the effects of hugs, we investigated how perceived gender during hug interactions changed the participants' task performances.

We measured their performance scores, i.e., the number of correctly completed serial subtractions (Fig. 6). We conducted a two-way mixed ANOVA with two factors: participant-gender (between-participant) and agent-gender (within-participant factor). The results did not show any significant differences for any of the factors: the agent-gender factor ($F(1, 16)=0.01$, $p=.980$, $\eta 2 = .001$), the participant-gender factor ($F(1, 16)=1.304$, $p=.270$, $\eta 2 = .075$), or the interaction effect ($F(1, 16)=0.337$, $p=.569$, $\eta 2 = .021$). Thus, the perceived gender did not significantly affect the task performances.

### 6.3 Hug interaction effect compared to no-hug

We investigated whether the perceived gender changed the stress-buffering effect. But we did not compare a hug's power in the stress-buffering effect with a no-hug interaction, because a previous study showed that a hug interaction provided more stress-buffering effects than a no-hug interaction [16]. However, an additional investigation about a hug's stress-buffering effect with an opposite-gender agent might provide evidence that strengthens the positive effects of a robot's hug and contribute to knowledge for the human-robot interaction research field.

We conducted another experiment with 18 participants (nine women and nine men who self-reported their genders) whose procedure was basically the same as the first experiment except for the hug interaction. Instead of a one-minute-hug interaction with virtual agents, the participants imagined a digital video camera and its functions for one minute. We defined the additional participant condition as *no-hug*. We also measured the perceived stress during the task by questionnaire. We only compared these results to the *opposite-gender* condition and integrated the participants' genders because our results showed that this condition outperforms the *same-gender* condition regardless of the participants' genders from the stress-buffering viewpoint.

We conducted a t-test for the perceived stress during tasks between the opposite-gender and no-hug conditions (Fig. 7), and the results showed a significant difference ($t(34)=2.228$, $p=.033$, $r=0.36$). Thus, hug interactions with an opposite-gender agent have a more significant stress-buffering effect than the no-hug interaction. We also conducted a t-test for the task performance between the opposite-gender and no-hug conditions (Fig. 8), and the results did not show a significant effect ($t(34)=1.422$, $p=.164$, $r=0.24$). Note that the comparison between a hug interaction with a same-gender agent and no-hug conditions did not show significant differences for either the perceived stresses or the task performances. Even if these results are investigated with an additional experiment, the results might suggest the benefit of hug interactions with an opposite-gender agent from a stress-buffering viewpoint.

### 6.4 Sexual orientation and preferrence

Our experiment results identified the positive effects of hug interaction with an opposite-gender agent, but these results must be examined from subjective sexual orientation viewpoints. All of the participants in our study self-identified as heterosexual, which undoubtedly influenced their impressions.

Moreover, we used virtual agents with an animation-appearance and a doll-like robot. Possible future works include investigating the effects of a more realistic (more human-like) appearance virtual agent, the existing character's appearance virtual agents (more character-like), and/or robots that provide different touch feelings during hug interactions. Using such different agents or robots will provide additional knowledge about human-robot touch interaction.

### 6.5 Limitation and future work

This study has several limitations. We used a one-minute hug as a stimulus, but that length was decided heuristically to represent an intimate hug behavior. It would be interesting to investigate the effects of hug length as well as the minimum times to decrease stress by a hug. Moreover, we experimented in a laboratory; an interesting future work would be to install our system in real environments. For this purpose, a natural context for hug interactions and an appropriate conversational design must be prepared, which was not covered in this study.

To investigate the stress of participants, some related works used such objective measurements as electrodermal activity to investigate stress [38, 39]. In this study we only measured perceived stress by questionnaires to evaluate the stress-buffering effects of hug interaction. However, using such objective measurements would provide additional evidence about the stress-buffering effects of hug interactions.

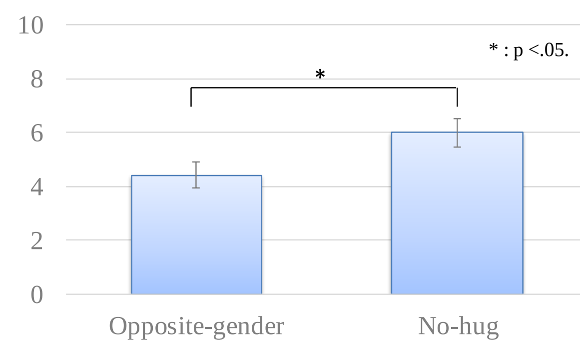


**Fig. 7** Questionnaire results about perceived stress during tasks with/without hug interaction (0 means no stress)

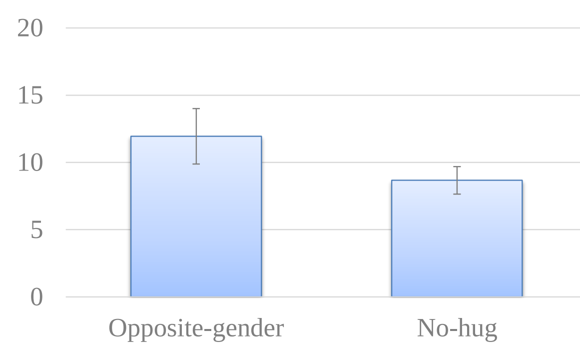


**Fig. 8** Task performance between with/without hug interaction

## 7 Conclusion

We investigated how the perceived gender of virtual agents changes the impressions and the stress-buffering effects of hug interaction. We experimented with the *MetaHug* system, which provides physical hug interactions to people with virtual agents using an actual huggable robot and a VR application. Participants experienced two hug interactions with different virtual agents, experienced stressful tasks, and reported their perceived stress and hug impressions. Our experimental results showed that a hug interaction with an opposite-gender agent provided stress-buffering effects regardless of the participants' gender. However, hug impressions only improved in male participants.

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**Conflict of Interest:** The authors declare that they have no conflict of interest.

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