Robot reciprocation of hugs increases both interacting times and self-disclosures

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Abstract: Physical contact like touching and hugging plays an essential role in social bonding between people by encouraging interactions and self-disclosure. However, in a human-robot interaction context, it remains unknown whether physical activity with robots provides such similar effects, even though several positive effects of touch interactions have been unveiled. Therefore, we used a hugging robot that we previously developed and experimentally investigated its physical interactions related to encouraging interactions and self-disclosure with 48 participants. Our results showed that reciprocated hugs increased the interaction times and encouraged more self-disclosure from the hugged participants than those who did not get reciprocated hugs.

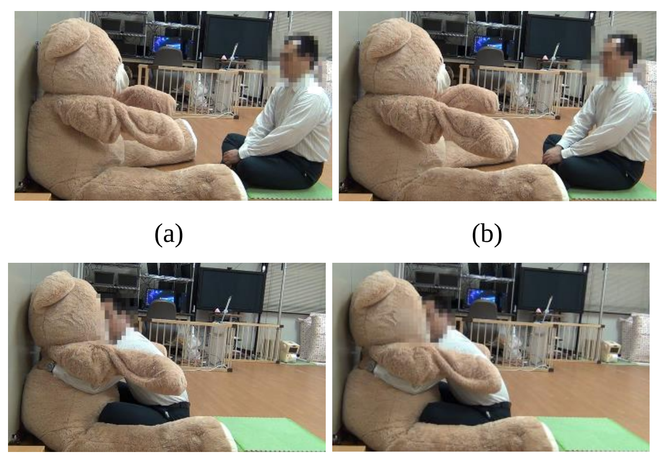
Keywords: hug interaction, human-robot touch interaction, self-disclosure

1 Introduction

Building relationships with people is essential for social robots that support them in such daily situations as education [2-6], elderly care [7-9], hospitals [10, 11], and shopping [12, 13]. Past studies focused on effective interaction strategies to build relationships between people and social agents, including behavior changes during interaction [13, 14], positioning behaviors [15, 16], and their characteristics [17-19].

In human science literature, since self-disclosure plays an essential role in building relationships between people [20, 21], researchers have focused on eliciting it from people [20, 22, 23]. For instance, researchers designed agents that asked probing questions of interaction partners to elicit self-disclosure [22]. Other studies showed that self-disclosure from agents also effectively elicited similar responses from humans [20, 23].

However, one effective way to elicit self-disclosures has received inadequate focus in human-robot interaction studies: physical interaction. In human-human interaction, past research showed the effectiveness of such physical interaction as touching to elicit self-disclosures [20, 24]. On the other hand, human-robot interaction studies mainly focused on dialog and behavior strategies to elicit them. If physical interaction with robots has similar positive effects that elicit self-disclosure from interacting people, a robot's interaction strategies should be designed to build relationships with them.



(a) (b) (c) (d)

Fig. 1 Reciprocated hug from a robot: (a) robot requests a hug, (b) opens its arm, (c) man hugs the robot, (d) robot reciprocates.

This paper is an extended version of a previous work of Shiomi et al. [1] and contains additional references, experiments with a different condition, analysis, and discussions.

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In this paper, we investigate the effects of physical interaction, i.e., hugs, with a robot for encouraging interactions and self-disclosure (Fig. 1). Our experiment used a robot named Moffuly that can give hugs. In our experiment, we measured and compared the numbers of self-disclosures during interactions with/without a robot's hug as well as the interaction times.

2 **Related Work**

2.1 Self-disclosure in human-robot interactions

Self-disclosure is a primary strategy with which both virtual agents and social robots build relationships with people [20, 22, 23]. For example, provocative questions from virtual agents can elicit it [22]. Several studies reported that people revealed more about themselves after listening to disclosure from agents [20, 23]. Past studies effectively used self-disclosure from robots to build relationships with children in education settings [14, 25] or customers in a shopping-support setting [13]. Other studies focused on whether robots can elicit self-disclosure and how interaction influences their relationships [19, 26].

These studies described the importance of self-disclosure from both robots and people for more natural and smoother interaction as well as effective strategies to encourage self-disclosure from people. One unique point of this study is its focus on the effects of touch interaction for encouraging self-disclosure to investigate whether physical interaction provides advantages for this purpose.

2.2 Touch interaction between people and robots

Several past studies focused on the positive effects of human-robot touch interaction, similar to human-human touch interaction [27-35]. Researchers focused on its effects in mental health contexts. For instance, Shibata et al. used a pet-type robot (Paro) for supporting seniors [27]. Another study reported that using a huggable device for tele-conversation decreased stress from a hormonal perspective [32]. Li et al. investigated the relationships among body accessibility, physiological arousal, and touch style while people are touching a robot [36]. Fitter et al. focused on situations where people clap hands with a robot and developed a motion classification system in the context of hand-clapping game settings. They also investigated the perceived enjoyments of social and physical interaction with a robot and the effects of related modalities like facial animation and stiffness during interaction [37, 38]

These studies focused on touch interaction from people to robots, but recent studies have also concentrated on the effects of touch interaction from robots to people, i.e., active touching. For example, several studies reported that active touching from robots provides better impressions than passive touching [28, 29]. Other studies concluded that active hug interaction provides positive impressions and encourages prosocial behaviors [33, 39]. From another perspective, researchers focused on the effect of several characteristics of hug interaction toward perceived impressions, i.e., softness, warmth, squeezing pressure, and release timing [40].

Although these studies reported several positive effects and possible applications for touching in human-robot interaction, they focused less on the outcomes that encourage self-disclosure and the willingness to engage in interactions that are strongly related to building relationships between robots and people. If a robot's hug positively affects people, this knowledge will benefit robot applications with touch interactions.

We note that this paper is an extended version of our precious work [1] and contains additional references, experiments with a different condition (the effects of a hug-only condition), analysis, and discussions.

3 **System**

3.1 Robot hardware and software

In this study, we used a large teddy-bear-type robot (Moffuly, Fig. 2) that we previously developed [1]. It only has 2 DOFs (one for each elbow) for giving a hug. It is 200-cm tall with 80-cm arms for adequately reciprocating a hug. Its arms are around 80 cm above the ground, and its elbow joints vertically bend from the upper arm. Without arms, the robot only has an internal foundation to keep its position. Its frame is covered with polypropylene. We attached a speaker near its mouth for conversational interactions and used a Japanese speech synthesis system for voice synthesis [41].

We used weak digital servo motors (MG996R, torque: 11 kgf・cm). Since the elbow joints are back-drivable, and it is easy to stop by human power. We used one Shokkaku Cube (Touchence Inc.) as a touch sensor that can measure the height changes on the top of the soft material with 16 measurement points at a maximum frequency of 100 Hz. For safety, we attached a touch sensor to the robot's left hand area (inside its fur) because this place makes contact with the participants during hugs. The pressure threshold was decided heuristically based on pre-trials done by the authors.

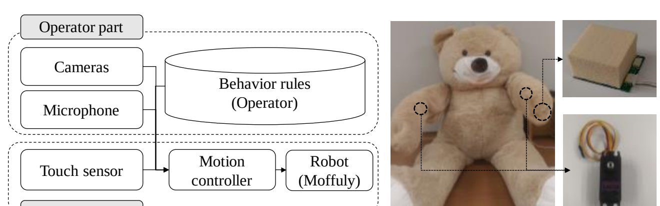


Fig. 2 System overview (left) and appearances of Moffuly and touch sensor (right)

3.2 Conversational behavior

Since this study investigates the effects of hug interaction on self-disclosure encouragement, we prepared three types of conversational behaviors: the robot's self-introduction, requesting self-disclosure, and replies as fillers. First, the robot introduces itself, offers a self-disclosure, and moves its arm. For example, it might say, "Hi, my name is Moffuly. Even though I look like a bear, my favorite food is electricity, not honey." The robot requests a self-disclosure by offering to listen to whatever is on the minds of the participants. The replies fill in the conversation lulls. We describe the details of the hug behaviors in the next subsection.

In our study, the operator systematically and partially teleoperated the robot following the Wizard-of-Oz approach [42] to choose appropriate conversational behaviors that consist of relatively simple utterances. The robot behaved as a listener to encourage self-disclosure from the participants. Thus, if they asked the robot too many questions, it might decline to answer: "Sorry, it is quite a difficult question for me. I would like to hear more about you!" This step discourages conversations that focus on the robot. The purpose of these rule designs is to avoid the effects of different interaction styles between participants and the robot. For teleoperation, we installed two cameras in our experiment room: one with a microphone on the robot's side and another on the ceiling. The operator used a microphone to listen to the participants. For analysis, we recorded the video/audio information from these cameras and the microphone.

3.3 Hug behavior

To conduct hug interactions with the robot, Moffuly first asks for a hug from the participants, depending on the experiment's conditions (Section 4.3). At the beginning of the interaction in conditions that include hugs, the robot opens its arms and says, "Before we start talking, would you please give me a hug?" After the person hugs the robot, the robot closes its arms until it detects contact between its arms and the person's body. Based on the following three rules, the robot pats her on the back by moving both of its arms at the end of its speech or her speech. If the person's speech exceeds 30 seconds, the robot pats her every 30 seconds.

4 **Experiment**

4.1 Hypotheses and predictions

Physical interaction with others provides positive impressions and encourages more self-disclosure in human-human interaction [20, 24]. In human-robot interaction, physical interaction with robots also provides positive impressions [27-30, 32]. Therefore, we believe that people who are hugged by a robot will disclose more about themselves than people who are not hugged. Previous studies reported that reciprocated touch interaction from a robot encourages more feelings and causes more behavior changes than people who are not reciprocally touched by a robot [28, 33]. Therefore, we believe that people who are hugged by a robot will disclose more about themselves than those who only hugged the robot.

We thought that people's willingness to interact with the robot would change through physical interaction. We assumed that its reciprocated hugs are useful for building good relationships. If correct, people who are hugged by a robot will interact with it more and longer interaction times elicit self-disclosures. Therefore, we made two hypotheses:

Prediction 1: A robot's reciprocated hugs will increase the interaction time of the participants more than without a reciprocated hug and without any physical interaction.

Prediction 2: Its reciprocated hugs will encourage more self-disclosure from participants than without reciprocated hugs and without any physical interaction.

4.2 Participants

Forty-eight Japanese people (24 women and 24 men, whose ages averaged 36.19, had a standard deviation (S.D.) of 9.93, and ranged from 20 to 52) were paid for their participation.

4.3 Conditions

The study had a between-participant design with the following three conditions. We assigned 16 participants (eight females and eight males) to each condition. The operator controlled the robot by following the same rules with identical conversational contents in the following three conditions:

No-hug: The participants remained in their initial position (45 cm from the robot) and only talked with it: no physical interaction.

Hug-only: The robot requested a hug from the participants and then started to chat; the robot did *not* return the hug.

Reciprocated-hug: The robot requested a hug from the participants, returned it, and then started to chat. Based on the pre-defined rules, the robot sometimes patted them on the back during the experiment.

4.4 Procedure

An experimenter briefly described our experiment's purpose and procedure before it started. The experimenter also physically demonstrated how to hug the robot, except for those in the *no-hug* condition. Next the experimenter explained the robot's limited conversational capability, i.e., it cannot understand complex conversations. It prefers listening to stories and wants to talk with them. Before starting the experiment, the experimenter left the room, and the participants remained in it.

After starting the experiment, the robot greeted the participants. Next the robot requested a hug in the *hug-only* or *reciprocated-hug* condition. It first introduced itself and requested self-disclosure and asked to hear their stories.

The minimum length of the experiment was ten minutes. It started from the end of the robot's self-introduction. After ten minutes, the participants took a short break and chose whether to end the experiment or to extend it. They could extend the session for a maximum of ten minutes; during this period, they could freely stop the interaction any time.

Before the experiment, we explained that the robot is autonomous, and after it, we prepared a debriefing session to explain our purpose. At the debriefing session, all the participants reported that they assumed that the robot was autonomous. Their acceptance might reflect the robot's simple utterances and reactions during the interactions.

Our institution's ethics committee approved this research for studies involving human participants. We obtained informed consent from all of them.

4.5 Measurements

We measured two objective items and one subjective item. For the objective measurements, we investigated the interaction times of the participants and the ratios of self-disclosure to non-self-disclosure conversations by dividing the conversations related to self-disclosures by the conversations without them. We focused on the ratios because the interaction time of the participants and the length of the conversational contents were different.

To measure the amount of both conversational contents, a coder transcribed all the conversations of the recorded video/audio data and segmented all the conversation data into 289 scripts. We defined a conversation unit as a conversational topic. The coder transcribed all the conversations and segmented the texts to each script due to the changes of the conversational topics. Therefore, when a participant talked about topics A, B, C, and returned to A again, the number of scripts was four. Each script consisted of several sentences.

Next, the coder categorized all the scripts as either self-disclosure or non-self-disclosure. For example, if the scripts included such private topics as hobbies or personal experiences, the coder placed them in the self-disclosure category. If the scripts only included mundane topics like the weather, the coder categorized them as non-self-disclosure. The coder also coded the self-disclosure contents into positive/negative categories to investigate whether the robot's physical interaction changed the types of self-disclosure. After these processes, another coder coded 10% of these data. We calculated the coding's validity based on a previous work [43]. The kappa coefficient [44] was 0.71, indicating substantial agreement between the two coders.

As the subjective item, we measured the participants' perceived positive impressions toward the robot by one questionnaire item: "I think this robot is good overall." This item was scored on a 1-to-7 point scale, where 1 is the most negative (completely disagree), and 7 is the most positive (completely agree).

5 **Results**

5.1 Verification of prediction 1

Figure 3 shows the participants' interaction times. For analysis, we conducted an ANOVA, and its results showed significant differences ($F(2, 45)=18.030$, $p<0.001$, *partial* $\eta^2=0.445$). Multiple comparisons with the Bonferroni method revealed significant differences among the conditions: *reciprocated-hug* > *hug-only* ($p<0.001$) and *reciprocated-hug* > *no-hug* ($p<0.001$). There was no significant between *hug-only* and *no-hug* ($p=1.000$). Therefore, the robot's reciprocated hugs significantly increased the interaction time more than without them and without any physical interaction. Prediction 1 was supported.

5.2 Verification of prediction 2

Figure 4 shows the ratios of the self-disclosure/non-self-disclosure conversations. For the analysis, we used an ANOVA, and its results showed significant differences among the three conditions ($F(2, 45)=8.162$, $p=0.001$, *partial* $\eta^2=0.266$). Multiple comparisons with the Bonferroni method revealed significant differences: *reciprocated-hug* > *hug-only* ($p=0.010$), *reciprocated-hug* > *no-hug* ($p=0.001$), but no significant difference between *hug-only* and *no-hug* ($p=1.000$). Therefore, the robot's reciprocated hugs significantly increased the ratio of self-disclosure more than without reciprocated hugs and any physical interaction. Prediction 2 was supported.

5.3 Analysis of total self-disclosure amount

Based on our analysis, the reciprocated hugs from the robot effectively increased the interaction time as well as the self-disclosure and non-self-disclosure ratios. We also compared the amount of both the self-disclosure and non-self-disclosure conversations between the conditions.

Figure 5 shows the numbers of both the self-disclosure and non-self-disclosure conversations. For analysis, we conducted a two-way repeated measure ANOVA with mixed factors: category (self-disclosure and non-self-disclosure) and condition (*no-hug*, *hug-only*, and *reciprocated-hug*). The results showed significant differences in the category factor ($F(1, 45)=21.378$, $p<0.001$, *partial* $\eta^2=0.322$) and in the interaction between the two factors ($F(2, 45)=4.081$, $p=0.024$, *partial* $\eta^2=0.154$). There was no significant difference in the condition factor ($F(2, 45)=2.297$, $p=0.112$).

Multiple comparisons with the Bonferroni method showed significant differences in the *self-disclosure* category (*reciprocated-hug* > *hug-only*, *p*=0.039) and in the *reciprocated-hug* condition (*self-disclosure* > *non-self-disclosure*, *p*<0.001). Our analysis also identified significant trends in the *self-disclosure* category (*reciprocated-hug* > *no-hug*, *p*=0.073) and in the *hug-only* condition (*self-disclosure* > *non-self-disclosure*, *p*=0.078). These results suggest that the robot's reciprocated hugs significantly increased the amount of self-disclosure.

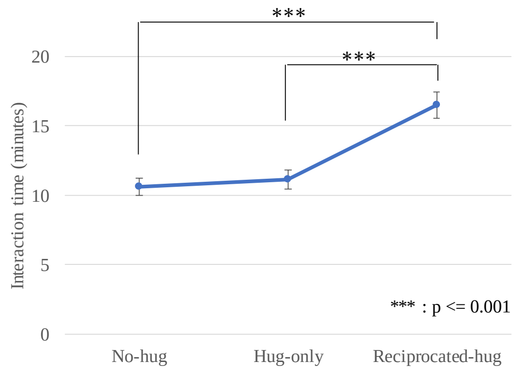


Fig. 3 Interaction time (average and standard error (S.E.))

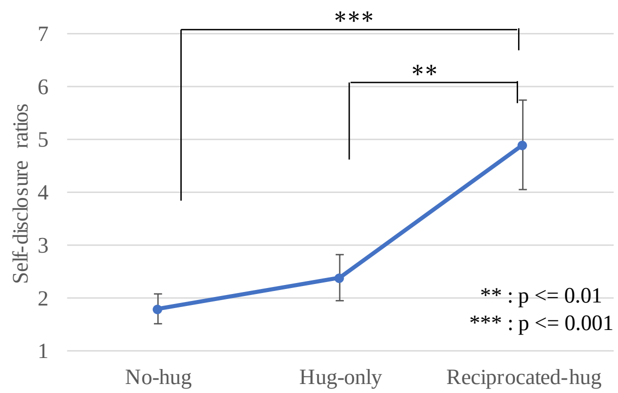


Fig. 4 Self-disclosure/non-self-disclosure ratios: 1 indicated amount of both types of contents are identical (average and S.E.)

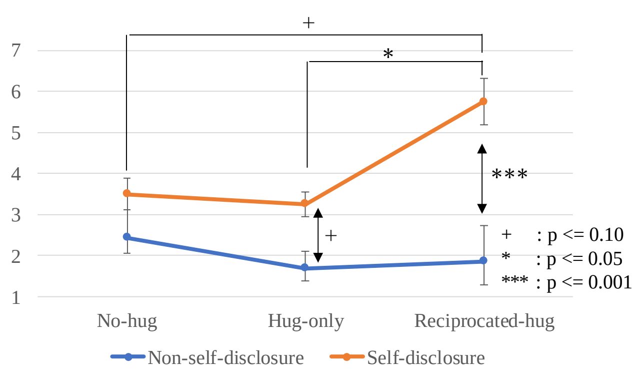


Fig. 5 Conversation contents (average and S.E.)

5.4 Analysis of participant positive impressions

Figure 6 shows the perceived positive impressions of the participants. We conducted an ANOVA and identified no significant differences (F(2,45)= 1.706, p=0.193, *partial* η^2 =0.070). Their total impressions were not significantly different among the conditions, even though the reciprocated hugs from the robot significantly influenced their behaviors.

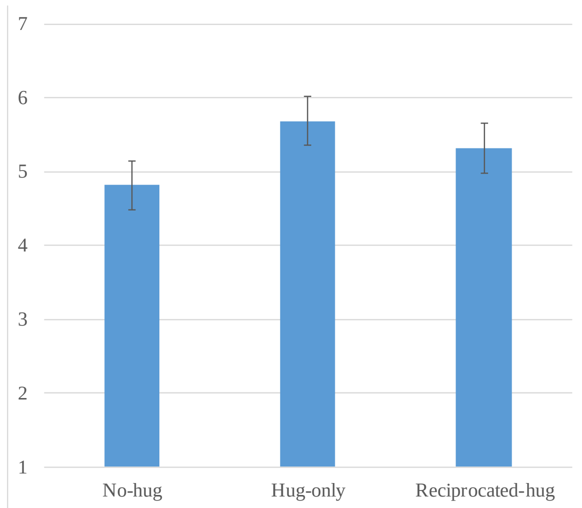
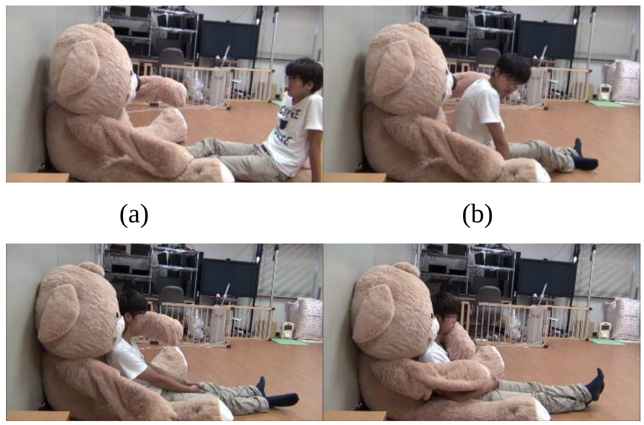


Fig. 6 Positive impressions (average and S.E.)

Fig. 7 Scene where robot hugged a participant who smiled



(a) (b)

(c) (d)

Fig. 8 Participant who requested a spooning-type hug

5.5 Observations of participants' behaviors and analysis of their self-disclosure categories

In all the conditions, participants typically talked about themselves after requests from the robot. Most seemed surprised by the robot's hug-request behavior, even though we did explain it to them. In the *reciprocated-hug* condition, sometimes participants smiled during their first hug interaction with the robot (Fig. 7). We witnessed one interesting scene in the *reciprocated-hug* condition where a participant changed his hugging style with the robot. During the second session, he asked the robot to open its arms (Fig. 8a), and he turned his back to it (Fig. 8b). He asked for another hug, closed his eyes (Fig. 8c), and waited to be hugged in such a spooning style (Fig. 8d). He silently maintained this hugging style until the end of the second session. He said that he enjoyed the hug experiences with the robot and its physical touch.

For the self-disclosure contents, the most common conversation topics were families, holidays, school, and work. For example, several participants described a traveling experience (note: the texts are translated from Japanese): "Every year, I take a cycling tour with my friends. This was our fourth straight year. Every year we've had some kind of trouble, such as heatstroke, leg cramps, and so on. This year was no different; my friend took a spill and broke his bicycle." Another participant described her job at which she struggles outside on hot summer days. The robot said, "That sounds like a very hard job." She thanked it and smiled. Some participants shared hardship stories, such as failing a graduate school entrance examination or the challenge of bringing up children.

To investigate whether the interaction styles changed the types of self-disclosure, we conducted a two-way repeated-measure ANOVA with mixed factors: category (positive and negative) and condition (*no-hug*, *hug-only*, and *reciprocated-hug*). The results did not show significant differences in the category factor ($F(1, 45)=2.042$, $p=0.160$, *partial* $\eta^2=0.043$), in the condition factor ($F(2, 45)=2.257$, $p=0.116$, *partial* $\eta^2=0.091$), or in their interaction ($F(2, 45)= 1.830$, $p=0.172$, *partial* $\eta^2=0.075$). Thus, the robot's hug interactions did not show a significant difference between the types of self-disclosures from the people with whom it interacted.

6 Discussion

6.1 Why did the reciprocated hugs increase the interaction time and the self-disclosure amount?

Our experiment results revealed that people interacted with the robot longer and provided more self-disclosure when it reciprocated hugs. This result begs the question: Which came first, the cause or the effect? It is difficult to judge whether they interacted more because they engaged in self-disclosure or whether they did self-disclosure because they stayed with the robot longer.

We believe that both are generally true, although the effects of the reciprocated hugs on self-disclosure are relatively strong for two reasons. First, we investigated the ratios of the self-disclosure/non-self-disclosure conversations at the minimum length (ten minutes). The results are not significant between conditions, suggesting that the participants did more self-disclosure during the extended time. The experiment results already showed that the participants in the reciprocated-hug condition significantly extended their interaction time. Therefore, these results also suggest that hugs resulted in more interaction time and that self-disclosure might also be encouraged. Second, simple physical reactions (i.e., patting while hugging) might be perceived as additional social signals in conversations, encouraging more conversational intent from the participants. Of course, such an interaction loop drives self-disclosure and increased their willingness to interact. Moreover, a past study reported the persuasion effects of active touch interaction [45]. Reciprocated hugs might increase the effects in the context of requesting self-disclosures.

Our experiment results also showed that the participants spent more time in the reciprocated-hug condition than the interactions in the other conditions. One possible reason is the differences in participants' behaviors because the robot in the no-hug condition did not request a hug from the participants. However, the behaviors requested by the participants are identical between the reciprocated-hug and hug-only conditions, and the robot's speech before the experiment (e.g., please give me a hug) were the same between conditions. Therefore, perhaps the interaction time was affected by the robot's reciprocated hug.

6.2 Why did the reciprocated hugs not change the perceived impressions?

Our questionnaire results did not show any significant differences of impressions toward the robot, even though their behaviors were significantly different between the *reciprocated-hug* and *hug-only*/*no-hug* conditions. One possible reason is that the perceived impression of the robot was mainly decided by its appearance, voice, and conversations rather than physical interaction. In fact, in the no-hug condition, the average value of the questionnaire results about impression exceeded four (neutral).

Another possible reason is the interaction time because all the participants interacted with the robot for at least ten minutes in all the conditions. Thus, relatively long interaction might positively affect their impressions. If we conducted the experiment with a shorter time duration or compared impressions before/after the experiments, we might clarify the effects of the hug interaction toward the impressions.

Moreover, using other physiological measurements such as hormones or brain-related activities could be useful to investigate physical interaction effects. Past studies reported the effectiveness of touch interaction with robots from these perspectives [29, 32].

6.3 Limitation and future work

Since we conducted our experiments with a specific robot, its generality is limited. We need to consider such different features as the robot's size and its touches because they are critical to apply our findings to different situations. We also implemented a relatively simple hug interaction, although several hug types exist in human cases. For example, a past study reported that touch characteristics changed the perceived impressions in human-robot touch interaction [46]. Investigating different hug interaction effects is critical to deepen our understanding of the effects of robot's hug interactions. Although several limitations continue, we believe that the knowledge from this study will be useful for human-robot touch interaction research fields.

One possible application is using reciprocated hug interaction in a clinical context. A past study reported the usefulness of computer graphics (CG) based agents for these contexts; patients preferred to disclose their personal information to such agents than to teleoperated ones [47]. Our study identified the effectiveness of physical interaction that cannot be achieved by CG-based agents. Hug interactions with robots might contribute to building relationships with patients by self-disclosure.

7 **Conclusion**

Although past studies showed that haptic interaction from people to robots provides positive effects, the effects of reciprocated haptic interaction from robots to people have received less focus. We concentrated on the effects of reciprocated hugs from a robot for eliciting self-disclosure and more interaction. For this purpose, we used a social robot that can hug people and conducted an experiment with participants.

The participants who were hugged by the robot interacted with it longer than participants who were not hugged. The participants in the *reciprocated-hug* condition made significantly more self-disclosures than participants without reciprocated hugs. These results provide evidence that shows the merits of haptic interaction from robots to people in the field of human-robot interaction.

Note that the participants' perceived positive impressions toward the robots were not significantly different between the conditions even if their behaviors were. Perhaps the minimum interaction time and the robot's appearances/voices increased the perceived positive impressions, but this remains an open question. One future work of this study will investigate the effects of hug interaction toward perceived impressions using different types of measurements, including such physiological measurements as hormones or brain-related activities.

Compliance with Ethical Standards

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

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