How Do Communication Cues Change Impressions of Human-Robot Touch Interaction?

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Abstract Communication cues, e.g., gaze behaviors and touch styles, are essential factors in the close interaction of people with social robots. Even though the communication cues are broadly investigated in human-robot interaction, it remain unknown how they change human impressions of social robots in haptic interaction situations. For better understanding of communication cues in human-robot touch interaction, we conducted an experiment with 28 participants who interacted with a robot with gaze behaviors and touch styles. We prepared two gaze behaviors and three touch styles based on past research works. Our experimental results showed that participants preferred a gaze behavior more that only looks at their faces during a touch than a gaze behavior that looks at their faces, hands and returns to their face. They also preferred a touch style in which they touched the robot more than touch styles where a robot touches them.

Keywords Human-Robot Interaction, Haptic Interaction, Touch, Communication Cue

This paper is an extended version of a previous work of Hirano et al. [1] and contains additional experiment results and more detailed discussions.

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1 Introduction

A physical existence enables robots to communicate with people through haptic interaction like humans do (Fig. 1). Haptic interaction is one promising research topic for the human-robot interaction research field, similar to the human-human interaction research field. In human science literature, the positive effects of haptic interaction have already been broadly investigated and both mental and physical benefits have been unveiled [2-7]. Haptic interactions are well known to change the behaviors of others and facilitate various efforts in human science literatures [8-14]. Past research reported that the physical presence of robots influences interactions with people differently or more strongly than computer graphic-based agents [15-18]. Following these results, researchers investigated the following positive effects of a robot's haptic interaction: mental therapy [19], increasing motivation [20], and attitude changes by touch [21-23].

Fig. 1 Robot touches a person

For more natural touch interaction, such communication cues as gaze behaviors during touch are essential. Except for touch interactions, the following communication cues have been thoroughly investigated: gaze behavior in such contexts as approaching [24], encounters [25, 26], object-transfers [27, 28], and conversations [29-32]. These research works suggested that the design of gaze behaviors should be different, based on each context to improve the perceived naturalness or comfort. For example, Gharb et al. investigated that representing of own intention by looking at an object is essential to realize natural interaction for both humans and robots in hand-over situations [27]. But, gaze behavior effects have not been thoroughly investigated yet in haptic interaction.

Touch style should also be considered for natural touch interaction. Touch styles in past research works [20, 22, 23] can be categorized into three kinds: touching a robot, being touched by a robot, and mutual touch, i.e., a person touches a robot, which then touches the person's hand. These works investigated the influences of touch style on the impressions of a robot, but they did not compare all three touch styles together. Since they only partially compared their effects, it remains unknown which touch style is better for natural touch interaction.

Therefore, we must learn much about communication cue effects, i.e., the combination of a gaze behavior and a touch style toward perceived impressions of a robot. If we can identify the effects of these three factors, such knowledge would increase the understanding of the communication cues in human-robot touch interaction and help construct friendlier relationships between people and robots through touch interaction, like humans [5, 7]. For this purpose, we employed two gaze behaviors and three touch styles in our experiment design where a robot simply chats with a person through a touch interaction. We experimentally investigated communication cue effects in human-robot touch interaction to identify which combinations are appropriate to increase a robot's perceived friendliness. We note that the purpose of this study is to investigate basis effects of the touch style and gaze behaviors, therefore we focused on a simple situation to investigate their effects.

2 **Related Work**

2.1 Gaze cue in human-robot interaction

Gaze behaviors play an important role in conveying robot intentions to partners in human-robot interaction. In particular, robotics researchers have focused on conversation situations, e.g., Mutlu et al. designed a set of gaze behaviors for a robot to signal different participant roles in multi-party conversations [31]. Kuno et al. developed gaze behaviors for a museum guide robot to do an information-providing task more naturally [30]. Komatsubara et al. developed gaze behaviors in group conversations for an educational robot that interacts with children at an elementary school [33].

The investigation of gaze behaviors is also expanding to other situations in human-robot interaction. Satake et al. developed an approaching algorithm that included a gaze behavior design for a mobile social robot to notify a target person of its presence [24]. Hayashi et al. proposed a patrolling behavior for mobile social robots to show their availability through locomotion path and gaze behaviors [25]. Gharb et al. investigated the effects of gaze behaviors in hand-over situations and reported that gaze behaviors in which the givers first look at the object and then at the receivers are preferred patterns for such situations [27].

Similar to these situations, understanding the gaze behavior effects on a robot's perceived friendliness in human-robot touch interaction is critical for social robots. However, even though researchers are broadly investigating the effectiveness and appropriate design of gaze behaviors depending on each situation, many questions remain unanswered concerning how gaze-behaviors during touch interactions change the impressions of the interaction partners. Therefore, in this paper we consider touch styles and investigate the gaze behavior effects during human-touch interaction on the feelings of the people with whom the robot is interacting.

2.2 Touch styles in human-robot interaction

Among three touch styles in human-robot interactions, the most commonly investigated style is "touching a robot." For example, Shibata et al. developed a seal robot named Paro for mental therapy with senior citizens through haptic interaction, including touching it [19]. Yamazaki et al. investigated how huggable devices reduced anxiety through conversations [34]. Another perspective of the touching a robot style is the recognition of touch interaction from people [35-37]. For example, Cooney used inertia sensors to recognize full-body gestures by haptic interactions with a humanoid robot [37].

Compared to the touching a robot style, two other modes have received much less attention. A few research works investigated the effects of being "touched by a robot." Cramer et al. reported that being touched by a robot decreased machine-likeness but negatively affected dependability [21, 22]. Chen et al. investigated the effects of a robot's touch with verbal communication cues [23], and Shiomi et al. investigated the effects of "mutual touch" in the context of increasing the motivation of interaction partners [20]. Fukuda et al. investigated these effects by analyzing Medial Frontal Negativity by EEG to determine whether mutual touch changes people's perceived unfairness in the ultimatum game [38].

These research works illuminated the effects of touch styles in human-robot touch interaction, but they did not compare all of the combinations of touch styles or focus on the effects of other communication cues, even though gaze cues play important roles in interactions with people. Therefore, in this paper we investigate both effects between gaze behaviors and touch styles on the impressions of interactions with humans.

3 Robot for Experiment

We experimentally prepared a humanoid robot with two gaze behaviors and three touch styles and conducted our experiment with a Wizard-of-Oz technique.

3.1 Robot

We employed a personal humanoid robot, Pepper, developed by Softbank Robotics (Fig.1) that has 20 DOFs: two in its head, shoulders, elbows and waist, one for its wrists, hands, and knee, and three for its wheel. The robot is 121 cm tall and is equipped with microphones, cameras, a depth sensor, touch sensors etc. It has five fingers on its hands.

3.2 Design of gaze behaviors

To design gaze behaviors for touch interactions, we focused on related works [24, 25, 31] and found that these research works mainly reported the importance of keeping eye-contact with interaction partners. Thus, we decided to investigate a *face-only* gaze behavior that maintains eye-contact during a touch.

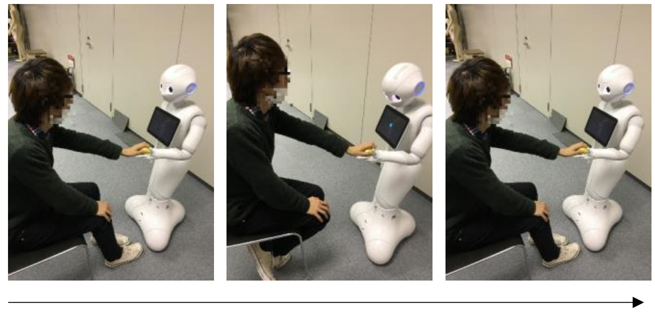
Also, we focused on related work that investigated the effects of gaze behaviors in hand-over situations where a robot hands something to a person because in such situations the hands of the givers and the receivers literally become closer like in actual touch interactions from a physical perspective. Gharb et al. investigated the influences of six kinds of gaze behaviors [27] and argued that gaze behaviors, including when the giver looks at the object and then at the receiver, are preferred by participants more than gaze behaviors where only the receiver is looked at: i.e., *face-only* gaze behavior. Therefore, we also employed this *face-hand-face* gaze behavior that looks at the face, the hand, and then the face again and maintains eye-contact during the touch.

Face-only

The robot constantly looks at the interacting person's face during the touch (Fig. 2-a). Before the experiment, we adjusted its face direction so that it directly looks at each participant's face.

Face-hand-face

The robot looks at the interacting person's face first (Fig. 2-a), then at the person's hand (Fig. 2-b), and finally at the person's face again (Fig. 2-c). The durations and timings of the gaze behaviors were based on Gharb's work [27].



(a) (b) (c)

Fig. 2 Pepper's gaze behavior: looking at participant's face (a), participant's hand (b) and participant's face again (c)

(a) (b)

Fig. 3 Round plastic yellow sphere on stand (left) and Pepper touching a hand (right)

3.3 Design of touch styles

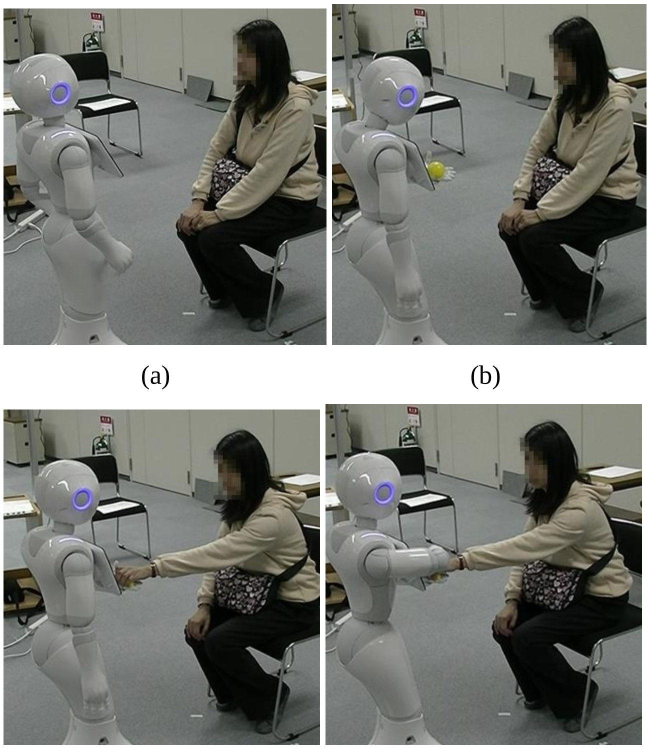
To design touch styles for interactions, we also focused on related works [20-22] (described in Section 2) and found that mainly three touch styles are used: *touching a robot*, *being touched by a robot*, and *mutual touch*.

Touch-to-robot

In this *touch style*, a person touches the robot, but the robot does not actively touch the person (Fig. 2). First, the robot asks the interaction partner to "please touch my left hand" and then extends it. We put a round plastic yellow sphere in its left hand to create uniform touch feelings among the other conditions.

Touched-by-robot

In this touch style, the robot touches a person who does not actively touch the robot. We placed a stand near the robot on which the interacting person's hand is put. The stand's height is identical to Pepper's left hand in the touch-robot condition, and the same round plastic yellow sphere is placed on the stand (Fig. 3-a). The robot asked the interaction partners to "please put your hand on the stand." After they did so, the robot touched their hands with its right hand (Fig. 3-b).



(a) (b)

(c) (d)

Fig. 4 Scene of mutual-touch style

To design the robot’s touching behavior, we employed the knowledge of human science literature that investigates the effects of touching speed on impressions [39]. Since this previous paper reported that touching at a speed of 5 cm/s was evaluated more positively than 0.5 or 50 cm/s, we set the speed of the robot’s hand during the robot’s touching to about 5 cm/s. Pepper’s touching behavior was pre-programmed, and its hand followed a fixed trajectory, based on the size of a human hand.

Mutual-touch

In this touch style, a person touches the robot, and the robot actively returns the touch. Therefore, this condition mixes both the touch-to-robot and touched-by-robot conditions. First, the robot asked the interacting person to touch its left hand (Fig. 4, a) and then extended it (Fig. 4, b), as in the touch-to-robot condition. After the interacting person touched the robot’s hand (Fig. 4, c), the robot touched the human hand with its own right hand (Fig. 4, d), as in the touched-by-robot condition. Thus, both the robot and the interacting person touch each other. For this condition, we also used the robot’s identical touching behavior of the touched-by-robot condition.

4 **Experiment**

4.1 Hypotheses and predictions

4.1.1 Hypothesis about gaze behavior

We assume that *face-only* gaze behaviors will have similar positive effects on touch interactions with people based on past related works [24, 25, 31]. However, one research work showed that *face-hand-face* gaze behavior caused more positive impressions than *face-only* gaze behavior [27]. Since phenomena related to gaze behaviors during touch are highly unexplored, we made two contradictory hypotheses about their effects based on different theories and considerations.

Hypothesis about positive effects of communicating intention of touch by gaze

A past research work, which focused on gaze behaviors in a handing situation, showed that only keeping eye-contact caused negative impressions since the robot failed to communicate its intention by a gaze. Gharb et al. reported that gaze behaviors, including when the giver looks at the object and then at the receiver, i.e., communicating intention by gaze, are preferred over gaze behaviors that only look at the receiver, i.e., only keeping eye-contact [27]. Therefore, we believe that *face-hand-face* gaze behavior will contribute to more comfortable touch behavior and be perceived as friendlier feelings of the robot. Based on these considerations, we made the following hypothesis:

Prediction 1-1-a: A touch interaction with a *face-hand-face* behavior will be perceived as more comfortable than a touch interaction with a *face-only* behavior.

Prediction 1-2-a: A touch interaction with a *face-hand-face* behavior will be perceived as friendlier than a touch interaction with a *face-only* behavior.

Hypothesis about negative effects of communicating intention of touch by gaze

Past research concluded that maintaining eye-contact is essential to realize more natural feelings of interaction with robots. Even if these research works focused on different situations from touch interactions, concentrating on eye-contact enabled robot behaviors to be perceived as more natural and contributed to friendlier impressions [24, 25, 28]. Turning the robot's eyes away from interaction partners during touch might be perceived negatively. Therefore, we believe that *face-only* gaze behavior will contribute to more comfortable touch behaviors and be perceived as friendlier feelings of the robot. Based on these considerations, we made the following hypothesis:

Prediction 1-1-b: A touch interaction with a *face-only* behavior will be perceived as more comfortable than a touch interaction with a *face-hand-face* behavior.

Prediction 1-2-b: A touch interaction with a *face-only* behavior will be perceived as friendlier than a touch interaction with a *face-hand-face* behavior.

4.1.2 *Hypothesis about touch styles*

We assume that the *mutual touch* style will have similar positive effects on touch interactions with people based on the past related works about human-robot touch interaction. However, several research works showed that touch styles cause negative impressions, including being touched by a robot. Similar to our hypothesis about gaze behaviors, since the phenomena related to touch styles are greatly unexplored, we made two contradictory hypotheses about their effects based on different theories and considerations.

Hypothesis about positive effects of robot's touch

Several past research works on human-robot touch interaction showed that the *mutual-touch* style is preferred more than the *touch-to-robot* style [20, 38]. Even though these research works did not investigate the effects of the *touched-by-robot* style, since the *mutual-touch* style includes the same touch behavior of the *touched-by-robot* style, it will probably not be negatively evaluated more than the *touched-by-robot* style. Therefore, we believe that the *mutual-touch* style will contribute to more comfortable touch behavior and be perceived as eliciting friendlier feelings than other touch styles. Based on these considerations, we made the following hypothesis:

Prediction 2-1-a: A touch interaction with a *mutual-touch* will be perceived as more comfortable than touch interactions with *touch-to-robot* and *touched-by-robot* styles.

Prediction 2-2-a: A touch interaction with a *mutual-touch* will be perceived as friendlier than touch interactions with *touch-to-robot* and *touched-by-robot* styles.

Hypothesis about negative effects of robot's touch

Past research works about human-robot touch interaction showed that *touched-by-robot* may cause negative impressions [21-23]. On the other hand, several research works about touch interaction with robots showed that touch-to-robot caused positive impressions [19, 34]. Therefore, we believe that the *touch-to-robot* style will contribute to more comfortable touch behavior and be perceived as friendlier than the other touch styles. Based on these considerations, we made the following hypothesis:

Prediction 2-1-b: A touch interaction with a *touch-to-robot* will be perceived as more comfortable than touch interactions with *touched-by-robot* and *mutual-touch* styles.

Prediction 2-2-b: A touch interaction with a *touch-to-robot* will be perceived as friendlier than touch interactions with *touched-by-robot* and *mutual-touch* styles.

4.2 Conditions

Our experiment had a within participant design. Each participant joined six sessions, combinations of two gaze behaviors (*face* and *face-hand-face)* and three touch styles (*touch-to-robot, touched-by-robot,* and *mutual touch).*

4.3 Pariticpants

Twenty-eight people (14 women and 14 men whose average ages were 36.4, S.D 9.39) participated.

4.4 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 our participants.

We placed in front of the robot a chair on which the participants sat during the experiment. In all the conditions, after requesting a touch from the robot, it had a short chat with them, such as "I'm 121 cm tall and weigh about 28 kg. I'm lighter than you thought, right?" We prepared six chat contents to avoid repeating them among the conditions. During the chat in the *touched-by-robot* and *mutual-touch* styles, the robot patted the hand of the participants three times. The order of the conditions and the chat contents were counterbalanced. The participants filled out a questionnaire after each session.

4.5 Measurements

To investigate the effects of gaze and touch on the feelings of the participants, we measured two subjective items by the questionnaires: the *feeling of comfort* of the touch interaction, and the robot's *perceived friendliness*. The items were evaluated on a 1-to-7 point scale.

5 **Results**

In our analysis, we considered gender effects in addition to the gaze behavior and touch styles because past research in the human-human interaction research field reported that touching causes different effects based on gender differences [5, 40].

5.1 Verification of predictions 1-1 and 2-1: feelings of comfort of touch interactions

Figures 5 and 6 show the questionnaire results about the feelings of comfort of the touch interactions. We conducted a three-factor mixed ANOVA for each scale on gaze, touch, and gender and identified significant main effects in the gaze factor ($F(1,26)= 5.253$, $p=.030$, *partial* $\eta 2=.168$), the touch factor ($F(2, 52)=5.706$, $p=.006$, *partial* $\eta 2=.180$), and the simple interaction effect between touch and gender ($F(2, 52)=4.114$, $p=.022$, *partial* $\eta 2=.137$). No significance was found in the gender factor ($F(1,26)= 2.476$, $p=.128$, *partial* $\eta 2=.087$), the simple interaction effect between gaze and gender ($F(1,26)= 2.574$, $p=.121$, *partial* $\eta 2=.090$), the simple interaction effect between gaze and touch ($F(2, 52)=0.928$, $p=.402$, *partial* $\eta 2=.034$), or the two-way interaction effect ($F(2, 52)=0.194$, $p=.824$, *partial* $\eta 2=.007$).

Multiple comparisons with the Bonferroni method of the simple main effects of touch in *males* were significant in *touch-to-robot* > *touched-by-robot* ($p=.001$) and *touch-to-robot* > *mutual-touch* ($p=.006$). There was no significance between *touched-by-robot* and *mutual-touch* ($p=1.000$) as well as none of the touches in *females* between *touch-to-robot* and *touched-by-robot* ($p=1.000$), *touch-to-robot* and *mutual-touch* ($p=1.000$), and *touched-by-robot* and *mutual-touch* ($p=1.000$).

Multiple comparisons with the Bonferroni method revealed significant differences in the simple main effect of touch in *touched-by-robot* (*female*>*male*, ($p=.021$)), and there was no significance between *touch-to-robot* ($p=.946$) and *mutual-touch* ($p=0.080$).

Next we summarize the effects of each factor based on the above descriptions. For gaze behavior, the participants felt significantly higher comfort in the *face-only* gaze behavior than in the *face-hand-face* gaze behavior ($p<.05$). Concerning touch style and gender effect, the *male* participants felt significantly higher comfort in the *touch-to-robot* style than in the other touch styles ($p<.05$), but *female* participants did not show any significant differences. These results support prediction 1-1-b but not prediction 1-1-a. Prediction 2-1-b is partially supported, and prediction 2-1-a is not supported.

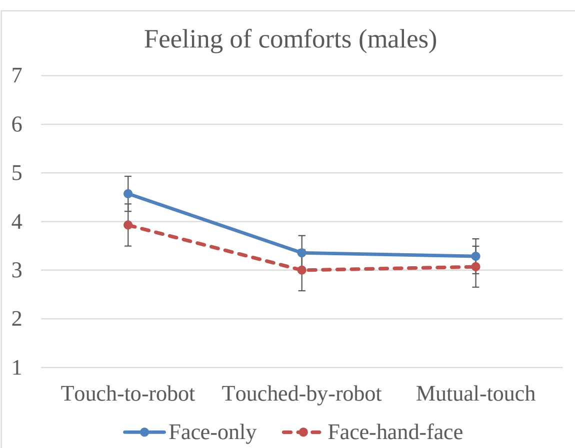


Fig. 5 Feelings of comfort of robot's touch (males). *Face-only gaze behavior* is higher than *face-hand-face gaze behavior* regardless of gender. *Touch-to-robot* is higher than *touched-by-robot* and *mutual-touch* in male participants.

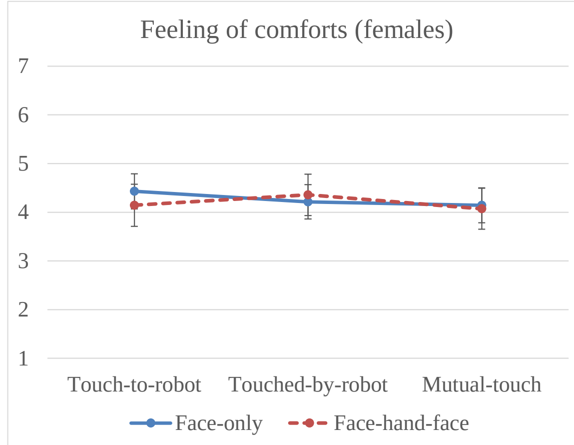


Fig. 6 Feelings of comfort of robot's touch (females). Female's *touched-by-robot* is significantly higher than male's *touched-by-robot.*

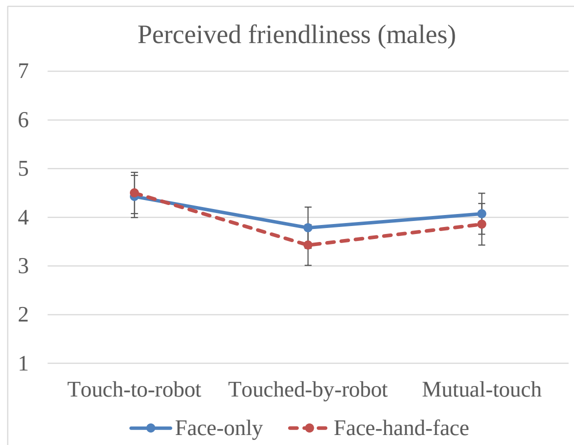


Fig. 7 Perceived friendliness (males). *Touch-to-robot* is higher than *touched-by-robot* in male participants.

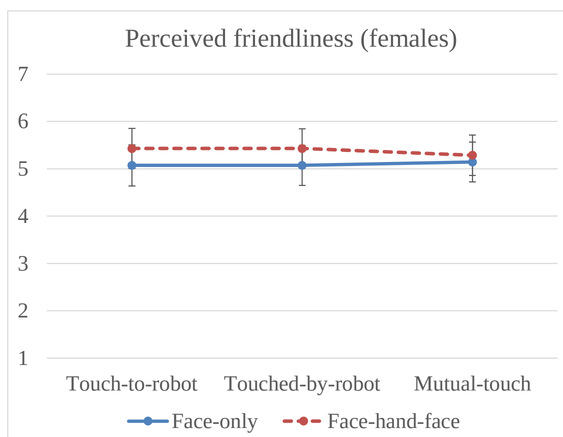


Fig. 8 Perceived friendliness (females). Female's *face-hand-face gaze behavior* is higher than male's *face-hand-face gaze behavior.* Female's *touched-by-robot* is higher than male's *touched-by-robot.* Also, female's *mutual-touch* is higher than male's *mutual-touch.*

5.2 Verification of predictions 1-2 and 2-2: perceived friendliness of robot.

Figures 7 and 8 show the questionnaire results of perceived friendliness. We conducted a three-factor mixed ANOVA for each scale on gaze, touch, and gender and identified significant main effects in the touch factor ($F(2, 52)=3.599$, $p=.034$, *partial* $\eta 2=.122$), the gender factor ($F(1,26)= 5.484$, $p=.027$, *partial* $\eta 2=.174$), the simple interaction effect between gaze and gender ($F(1,26)= 4.457$, $p=.045$, *partial* $\eta 2=.146$), and the simple interaction effect between touch and gender ($F(2, 52)=3.534$, $p=.036$, *partial* $\eta 2=.120$). We found no significance in the gaze factor ($F(1,26)= 0.309$, $p=.583$, *partial* $\eta 2=.012$), the simple interaction effect between gaze and touch ($F(2, 52)=0.311$, $p=.734$, *partial* $\eta 2=.012$), or the two-way interaction effect ($F(2, 52)=0.224$, $p=.800$, *partial* $\eta 2=.009$).

Multiple comparisons with the Bonferroni method revealed significant differences in the simple main effects of gender in *face-hand-face* (*female* > *male* ($p=.013$)) and no significance in *face-only* ($p=.067$). We found no significant differences in the simple main effects of gaze in *male* ($p=0.281$) and *female* ($p=0.071$).

Multiple comparisons with the Bonferroni method revealed significant differences in the simple main effects of touch in *males* (*touch-to-robot* > *touched-by-robot* ($p=.003$) and no significant differences in other touch in males (*touch-to-robot* and *mutual-touch* ($p=0.198$), *touched-by-robot* and *mutual-touch* ($p=0.193$)) and all touch in females (*touch-to-robot* and *touched-by-robot* ($p=1.000$), *touch-to-robot* and *mutual-touch* ($p=1.000$), and *touched-by-robot* and *mutual-touch* ($p=1.000$)).

Multiple comparisons with the Bonferroni method revealed significant differences in the simple main effects of gender in *touched-by-robot* (*female* > *male* ($p=.007$)) and *mutual-touch* (*female* > *male* ($p=0.034$)). There was no significant difference in *touch-to-robot* ($p=0.167$).

We next summarize the effects of each factor from the above descriptions. None of the gaze behaviors significantly changed the friendliness perceived by the participants; note that the *female* participants felt significantly higher friendliness in the *face-hand-face* gaze behavior than the *male* participants ($p<.05$). For the touch style and the gender effect, the *male* participants felt significantly higher friendliness in the *touch-to-robot* style than in *touched-by-robot* style ($p<.05$), but *female* participants did not show any significant differences. The *female* participants felt significantly higher friendliness in the *touched-by-robot* and *mutual-touch* styles than the *male* participants ($p<.05$).

These results showed that neither predictions 1-2-a and 1-2-b were supported. Prediction 2-2-b is partially supported, and prediction 2-1-a is not supported.

6 DISCUSSION

6.1 Design implications of gaze behavior

Our study clarifies how gaze behaviors in human-robot touch interaction changed people’s feelings toward the robot. The results show that keeping eye-contact during touch interaction improves the feelings of comfort of a robot’s touch. The results also show that preferred gaze behavior during touch interaction would be different based on gender. On the other hand, gaze behavior did not improve the friendliness perceived by the people.

Moreover, the results are contrary to past research work that focused on a handing interaction situation [27]. In handing interactions, the looked-at-object is critical to communicate the giver’s intention; but in touch interactions, such gaze behavior that communicates intention was negatively evaluated, suggesting that the required gaze behaviors are different between handing and touch interactions. This result is an important consideration for interaction designs of social robots that physically interact with people.

One possible explanation for the negative effects of *face-hand-face* gaze behavior is that the robot looked away from its interaction partners before touching them. Physical contact is a main difference between handing and touch interactions. As reported in human-human interaction literatures [2-7], physical contacts strongly influence the feelings of the interacting people; in such situations, a robot that looks away might be negatively perceived by its interaction partners. Keeping eye-contact through *face-only* gaze behavior would probably be embraced by them.

6.2 Design implications of touch style

Our experimental results showed a more complex phenomenon than past research. The *touched-by-robot* style showed more negative impressions than the *touch-to-robot* style, similar to past research works [21, 22]. On the other hand, the results showed opposite results from a past research work [20] that concluded that *touch-to-robot* is preferred over *mutual-touch* with *male* participants. These results suggest that *touched-by-robot* provides more negative feelings than *touch-to-robot*, but it remains unknown in which direction the factor will change the impressions of *mutual-touch*: positive or negative.

One possible explanation of the negative effects of *mutual-touch* is the sense of the robot’s hand. A past research work [20, 38] which reported the advantages of *mutual-touch* used sponge-based soft hands for its robot, unlike our research work. Moreover, the material of the robot’s hand would probably change the perceived warmth during the touch compared to Pepper’s plastic-based hand. Since past research reported that soft and warm feelings are important for positive impressions through touch interaction [41, 42], these factors might be one reason for the negative effects of *mutual-touch* in our experiment.

One possible future work of this research is to consider different measurements, e.g., not only questionnaires but also facial expressions and/or interviews. Deeper analysis would be useful to find the reasons why our experimental results showed different trends from past study.

6.3 Multi-modal effects between gaze behaviors and touch styles toward feelings of touch and gaze

As described in Section 6.1, the experimental results showed that gaze behaviors influence the *feeling of comfort* of the robot's touch, i.e., people felt more comfortable with the robot's touch in the *face-only* gaze behavior than the *face-hand-face* gaze behavior. To scrutinize such multi-modal effects, i.e., whether the touch style influence impressions about gaze, we additionally measured the *feeling of comfort* of the robot's gaze. The touch styles showed no significant difference, but it was a non-ignorable value (p=.056); participants preferred *touch-to-robot* to *touched-by-robot* in the context of the *feeling of comfort* of the robot's gaze.

These results suggest that since gaze behavior and touch style are mutually influential, identifying detailed relationships between other kinds of communications cues is important for more natural and acceptable touch interactions with a robot.

6.4 Limitations

Since our experiment was only conducted with an existing robot (named Pepper) robot generality is limited. The effect shown in the experiment would probably be moderated if our participants interacted with a robot with a different appearance, size, and so on. For example, Pepper's eye design is different from human eyes. Since this design simplifies making eye-contact with interaction partners, it also influences the perceived feelings in haptic interactions. In the experiment, only one participant reported that Pepper glanced up at his face while it looked at his hand.

We only investigated the touches between the hands of people and the robot. Past research work reported that people felt different feelings due to which part of the robot's body they touched [43]; our research work only investigated the effects of touching a hand. If the robot touched a different part of the interaction partner's body, it would also influence the perceived feelings of the robot. Moreover, if the robot touched a different body part, appropriate touch behaviors, touch trajectories, and the touch's force would be modified.

The perceived gender of the robot is another factor that might change impressions of its touch. We used Pepper's default text-to-speech function that produces a neutral gender voice, but people have different feelings when the robot used specific female/male voices. Since past research reported that the genders of the toucher and receiver are related to perceived feelings of touch [44], our future work must investigate the effects between the perceived robot's gender and communication cues.

Another limitations is a simple settings in touch interaction, because intention and scenario would be important to the perceived impressions. Moreover, definitions of natural interaction are also different depending on contexts. For example, Chen et al., investigated the touch effects in nursing contexts [23]; in such situations, roles of robots and meaning of touches would have important roles for touch interaction. In addition, active touch from a care robot in nursing contexts would be natural, but our results showed that such touch style was negatively evaluated at a simple touch interaction context. Gharb et al. reported that looking at an object is essential to realize natural interaction for both humans and robots in hand-over situations [27], but in our results showed that looking at a hand is negatively evaluated, too. Also, different touch interactions such as a handshake, a pat and/or a high five would provide more positive impressions to people. In this study we focused on the touch style and gaze behaviors without specific settings due to focusing on simple situations to investigate their effects without biased assumptions, but we should consider such intentions and scenarios to apply these knowledge to human-robot touch interaction.

7 **Conclusion**

We reported the effects of communication cues (combining gaze behaviors and touch styles) toward the perceived feelings to a robot in haptic interaction. Based on related works, we employed two gaze behaviors during touch (*face-only*: looking at the face of an interaction partner, and *face-hand-face*: looking at the face, the hand, and returning to the face) and the touch styles (*touch-to-robot*: a person touching a robot, *touched-by-robot*: a robot touching a person, and *mutual-touch*: a person and robot touching each other). To investigate the effects of gaze behaviors, touch styles, and gender effects, we conducted a mixed-design experiment in which a robot interacts with participants through touch.

The experimental results indicated that our participants preferred *face-only* gaze behaviors more than *face-hand-face* gaze behaviors. They also preferred *touch-to-robot* more than *touched-by-robot* and *mutual-touch*. Even though a part of our experimental results showed contradictory phenomenon compared to past research, we still believe such knowledge will help robotics researchers who are designing communication cues in haptic interaction with social robots.

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