

Speed Effects in Touching Behaviours: Impact on Perceived Relationships in Robot-Robot Interactions

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As a form of multiple-robot interaction, robot-robot interactions effectively provide indirect information, unlike direct interactions between people and robots. Even though numerous studies have affirmed this approach's effectiveness and the development of conversational mechanisms for robot-robot interaction, their physical interaction design has received inadequate attention. This study focuses on the impact of the speed of robots' touching behaviours because people might perceive such relationships between robots differently due to various motion speeds, even with identical motions. We explored this issue by conducting two web-survey experiments and investigated the human perceptions of a robot's touching motion and the perceived relationship between two robots when one robot touches the other at different speeds. Experiment 1 identified two peak speeds at which people perceived a robot's touch as patting (a friendly touch) or slapping (an aggressive touch). Experiment 2 demonstrated similar peak speeds, where people perceived the robots' relationships as either positive or negative in response to patting or slapping behaviours. We maintain that understanding the relationships between motion speeds and perceived friendliness between robots will significantly improve the design of physical interactions between robots.

Keywords: robot-robot interaction, physical interaction, touch

1. Introduction

Robotics researchers are exploring the usefulness of engaging multiple robots in human-robot interaction contexts [1] because the existence of multiple robots will undoubtedly exert a strong social influence on interacting people [2-4] as well as human groups [5-7]. Using multiple robots introduces a form of passive interaction, where people observe the interaction between agents, akin to television viewing, e.g., observing discussions between two commentators. This form of interaction enables robots to readily initiate and control conversation flows. In the field of conversational robot design, previous studies have demonstrated the effectiveness of this approach by employing

dialogues between agents to compensate for potential failures in speech recognition [8, 9].

The benefits of incorporating multiple robots are not confined to error recovery. Other research shows the utility of multiple robot dialogues in tasks involving information providing, i.e., conversational-style information, which among multiple robots is more attractive for people than information from a single robot for real environments [10, 11]. Moreover, people are more influenced by the behaviour of multiple robots than single agents, even though the quantity of information is identical. Past studies reported the advantages of using multiple robots in the context of attractive promotion [12, 13], praising [14, 15], education [16, 17], apologies [18], and trust [19].

However, currently designing interactions among multiple robots strongly emphasizes conversational engagement. In the human-robot interaction context, such physical interaction as touching can powerfully influence observers' perceptions—often more than conversation-only interactions [20, 21]. In the context of multiple robot interaction, a previous study explored the impact of touch interaction between robots [10] and primarily compared scenarios with/without touch interactions between robots with heuristically-designed touch behaviours.

We posit that the parameters of touch behaviours, specifically guidelines for motion speed, are critical for shaping the interpretation of touch interactions. Even at identical motions (e.g., a robot touching another with its palm or the back of its hand), varying speeds might elicit vastly different perceptions from observers. For example, a slow movement may be perceived as a friendly pat; a fast one might be interpreted as an aggressive slap. Understanding such nuances is vital for effectively designing physical interactions between robots.

Several studies that focused on the effects of motion speed mainly investigated how it changes perceived emotions via robots' gestures. For example, Deshmukh et al. reported the relationships between robot's motion speeds on perceived impressions, although their study did not focus on touch behaviours [22]. Willemse et al. investigated the touch speed effects in human-robot interaction in a video-based experiment and reported that a velocity of approximately 3 cm/s was rated as the most pleasant [23]. Although both studies provided design knowledge about motion speeds and observing touch effects, they focused less on touch behaviours in robot-robot interaction and behaviour design perspectives. In human-human interaction studies, past studies mainly focused on how the visual perception of touch elicits conscious tactile experiences in observers [24, 25]. These two studies investigated the brain activities of people who are observing touch interactions and investigated the synaesthesia process and paid less attention to the speed effects in touch interaction. Based on these considerations, a lack of knowledge exists on the speed effects of robots' motions on the perceived impressions of observers.

This study aims to identify the speed boundary that differentiates two types of robot behaviours: touching by the palm or the back of the hand with slow/fast speeds. A deeper understanding of how observers perceive varying motion speeds will enable robotics researchers to design robot touch behaviours based on valuable insights, reducing misconceptions among the observers. For this purpose, we conducted two different experiments in this study. Firstly, it is unknown where is the transition point between a pat and a slap in touching behaviours, therefore we conducted an online survey that explored the speed boundary that distinguishes robot-touching behaviours, pinpointing the transition point where a pat becomes a slap using the palm (Fig. 1) and the back of the hand (Fig. 2). Thus, the first experiment aims to retrieve hypotheses about

the relationships between the robot's motion speeds and the perceived feeling. Based on the hypotheses coming from the results of the first experiment, we build predictions then we carried out another online survey that scrutinized how perceptions about the relationships between robots shift when one robot touches another at different speeds (Fig. 3). Thus, the second experiment aims to investigate the validity of the predictions based on the retrieved hypotheses from the first experiment.

Although this paper is an extended version of a previous work by Hirayama et al. [26] (and includes their results), it contains additional related works in the introduction, additional experiments with different video stimuli, additional analysis about perceived relationships through observing robot-robot touch interaction, and more detailed discussions.



Fig. 1 Representation of a touching behaviour with a palm (speed = 0.5 m/sec. t= 0.9, 1.4, 1.7, and 3.8 seconds in video)

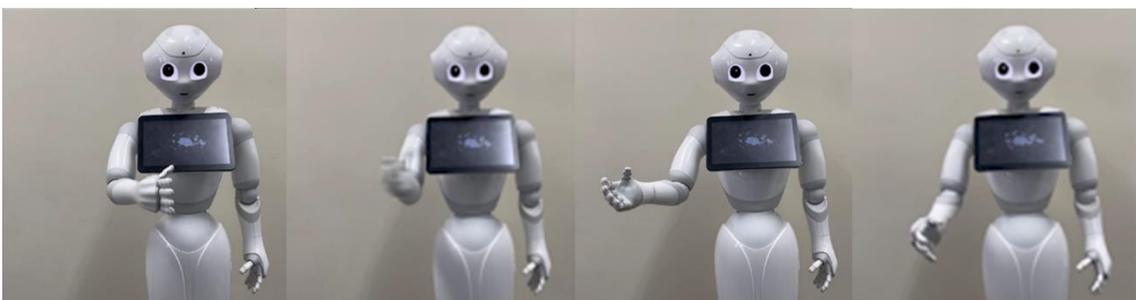


Fig. 2 Representation of a touching behaviour by the back of the hand (speed = 1.0 m/sec. t= 1.0, 1.2, 1.4, and 3.0 seconds in video)

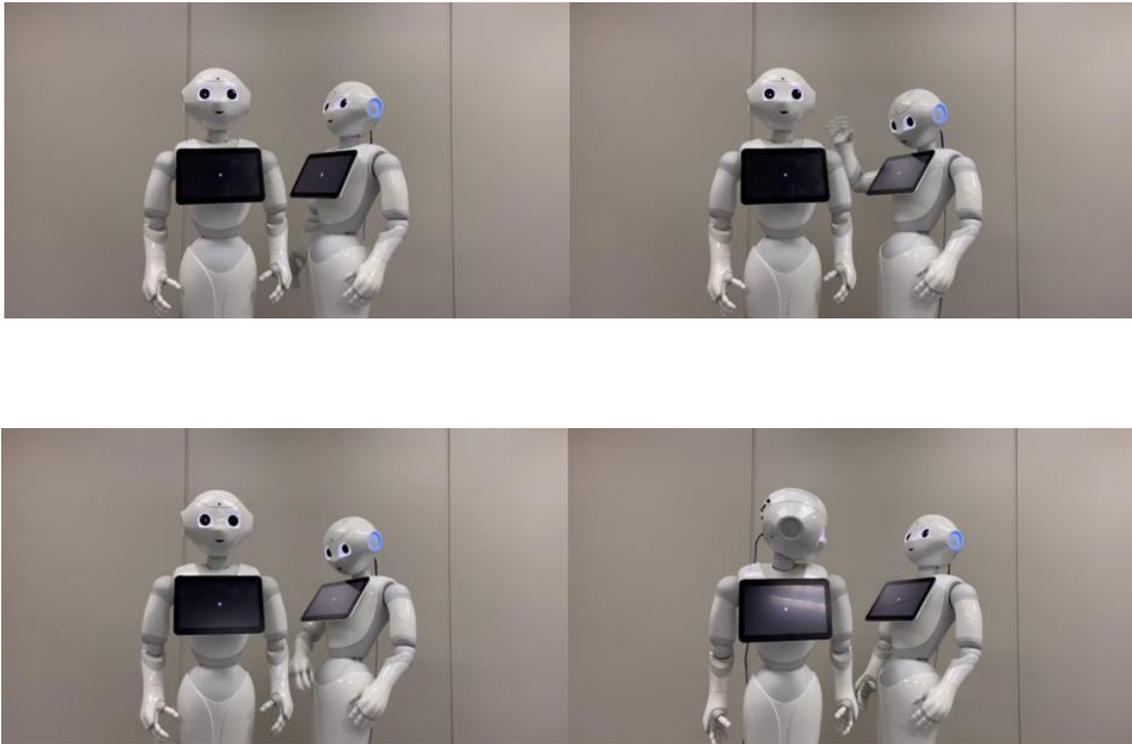


Fig. 3 Robot touching another (speed = 1.0 m/sec. $t= 0.0, 1.0, 1.5,$ and 3.8 seconds in video)

2. Experiment I

We experimentally delved into the effects of motion speed on the perception of different touches through an online survey. Because of the difficulties making predictions about the speed boundaries between our two touch behaviours in advance, we first investigated them through comprehensive comparative experiments.

2.1 Visual stimuli and conditions

We investigated the speed effects of two different touch behaviours: by the palm or the back of the hand.

We used two different touching behaviours to investigate whether the speed effects are similar. If the perceptions to touch behaviours are similar to different touch behaviours with similar speeds, that situation suggests the importance of speed characteristics in designing touch behaviours. On the other hand, if the perceptions to touch behaviours are different due to their touch type regardless of similar speed, that situation suggests the less importance of speed characteristics. For this purpose, we employed touching by the palm as was previously investigated [26], and by the back of the hand as an additional touching behaviour. Both touching behaviours use the robot's right hand; only the contact locations are different (palm or back). Being touched by the palm or the back of the hand is also common in the world, as well as in Japan, where we conduct the experiment, especially for comic manzai performances [27]. We note that a past study showed that people basically use the palm of touch in affective touch situations [28]. Therefore, we thought that using the back of the hand, not the palm, in touching situations may provide more negative impressions regardless of its speed. From another perspective, a past study reported that people's brain-related activities are different when they look at the back of the hand and the palm of the hand [29]. Although this study did not deal with a touching situation, such a phenomenon about visual stimuli between the back and palm of the hand would indicate that the two types of touch cause different impressions.

Note that we did not directly compare different touch behaviours; we individually investigated the speed effects. We prepared one factor (speed, which varied from 0.5 to 1.4 seconds in 0.1-second intervals). Given hardware constraints and the number of conditions to be examined, we only studied speeds within this narrow range.

Based on this setting, we generated ten distinct videos showcasing a robot called Pepper (Softbank Robotics), which executed a touch behaviour at varying speeds using

its palm and the back of its hand: a total of 20 videos. We captured ten separate videos for each speed setting and compiled them into a single video for each touch behaviour (Figs. 4 and 5). The order of these videos remained consistent (left-top: 0.5 seconds, right-bottom: 1.4 seconds), and the initiation timing of the robot's touch behaviour was uniform across all the videos. Each video was shown at a resolution of 960 x 540 pixels and ran at 30 fps.

Note that we investigated the effect of speed with just one swinging motion from a robot, not a situation where a robot touched another robot. We chose this style because people's perceptions might change due to the objects being touched as well as touch-receiver's reactions, which include sounds and behaviours. Even if the motion speed were too slow, a loud sound or an exaggerated looking-back behaviour might influence people's impressions. To avoid such effects, we used only one robot and show a swinging motion.

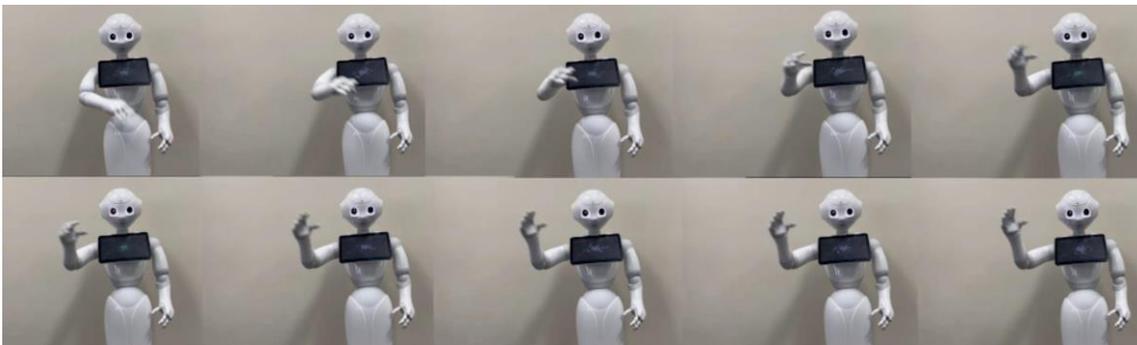


Fig. 4 Visual stimuli of Experiment I (palm): left-top video is 0.5-second motion, and right-bottom video is 1.4-second motion. Timing is 1.4 seconds in each video.

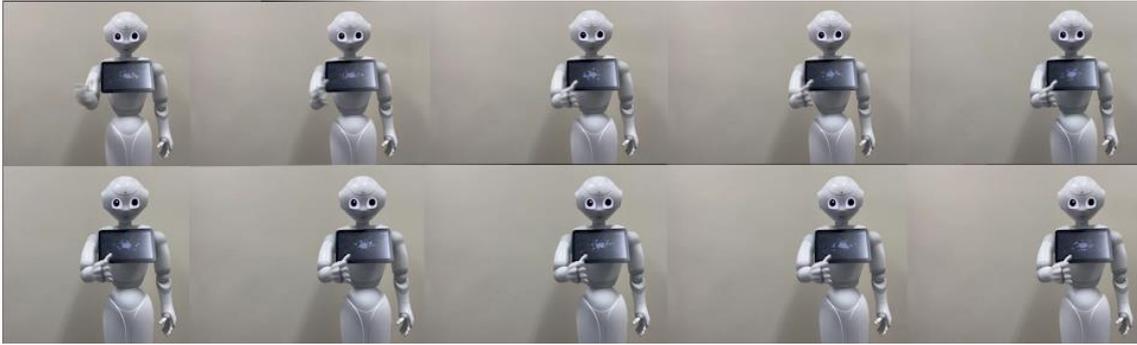


Fig. 5 Visual stimuli of Experiment I (back of hand): left-top video is 0.5-second motion, and right-bottom video is 1.4-second motion. Timing is 1.1 seconds in each video

2.2 Measurements

Our questionnaire included two subjective items: patting and slapping assessments. It used binary questions and permitted multiple selections (i.e., ten checkboxes for each question). For instance, if a participant interpreted 0.5- and 0.6-second touches as slaps, she could check both the 0.5- and 0.6-second boxes.

2.3 Procedure

All the procedures were approved by the Advanced Telecommunication Research Review Boards. We first provided participants with a comprehensive overview of the experiment and allowed them to answer practice questions to gain greater familiarity. Subsequently, they watched the videos and responded to two questionnaires that assessed whether they categorized the actions as slaps or pats. Participants were given the option to revisit the videos while answering the questionnaires. The order of the videos was counterbalanced. In line with prior studies emphasizing the necessity to screen participants in online surveys [30, 31], we also prepared dummy questions to gauge the attention paid to the videos and to assess the quality of their responses.

2.4 Participants

We conducted our experiment using the participant pools of a Japanese survey company. Our experiment was initially comprised of 205 people: 104 women, 99 men, and 2 who preferred not to specify. Post-screening winnowed that number to 166 valid participants: 84 women, 80 men, and 2 who preferred not to specify. Their average age was 40.6, with a standard deviation of 9.94.

2.5 Questionnaire results for Experiment I

The questionnaire results regarding the robot's touching behaviours, especially with the palm, are shown in Fig. 6. A Cochran's Q-test, conducted to analyse the number of perceived patting behaviours, indicated significant differences among the speeds ($Q(9) = 286.7050$, $p < 0.001$, Cliff's delta = 0.44). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) among conditions: 1.1, 1.2, 1.3 and 1.4 $>$ [0.5, 0.6, 0.7, 0.8, 0.9], 1.0 $>$ [0.5, 0.6, 0.7, 0.8], 0.9 $>$ [0.5, 0.6, 0.7], 0.8 $>$ [0.5, 0.6]. The behaviours at 1.1 to 1.4 seconds were significantly more often identified as pats by participants than at different speeds of 0.9 and below ($p < 0.05$), although no significant differences were found between 1.1 and 1.4 seconds (Fig. 6 (top)).

A Cochran's Q-test analysis for the perceived slapping behaviours also revealed significant differences across speeds ($Q(9) = 773.51050$, $p < 0.001$, Cliff's delta = 0.64). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) among conditions: 0.5 and 0.6 $>$ [0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4], 0.7 $>$ [0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4], 0.8 $>$ [1.0, 1.1, 1.2, 1.3, 1.4]. At 0.5 and 0.6 seconds, significantly more participants identified the behaviours as slaps than at other speeds ($p < 0.05$), even though no significant differences occurred between 0.5 and 0.6 seconds (Fig. 6 (bottom)).

The questionnaire results regarding the robot's touching behaviours, especially with the back of the hand, are shown in Fig. 7. A Cochran's Q-test, which was conducted to analyse the number of perceived patting behaviours, indicated significant differences among the speeds ($Q(9) = 193.177, p < 0.001, \text{Cliff's delta} = 0.66$). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) among conditions: $1.2 > [0.5, 0.6, 0.7, 0.8, 0.9], 1.1, 1.3, \text{ and } 1.4 > [0.5, 0.6, 0.7, 0.8, 0.9], 1.0 > [0.5, 0.6, 0.7], 0.9 > [0.5, 0.6, 0.7], 0.8 > [0.5]$. The behaviour at 1.2 seconds was significantly more often identified as pats by participants than at differing speeds of 0.9 and below ($p < 0.05$), although no significant differences were found among 1.0 to 1.4 seconds (Fig. 7 (top)).

Another Cochran's Q-test analysis for the perceived slapping behaviours also revealed significant differences across speeds ($Q(9) = 580.821, p < 0.001, \text{Cliff's delta} = 0.78$). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) between conditions: $0.5 > [0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4], 0.6 > [0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4], 0.7 > [0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4], 0.8 > [1.0, 1.1, 1.2, 1.3, 1.4]$. At 0.5 seconds, significantly more participants identified the behaviours as slaps than the other speeds ($p < 0.05$), even though no significant differences occurred between 0.5 and 0.6 seconds (Fig. 7, bottom).

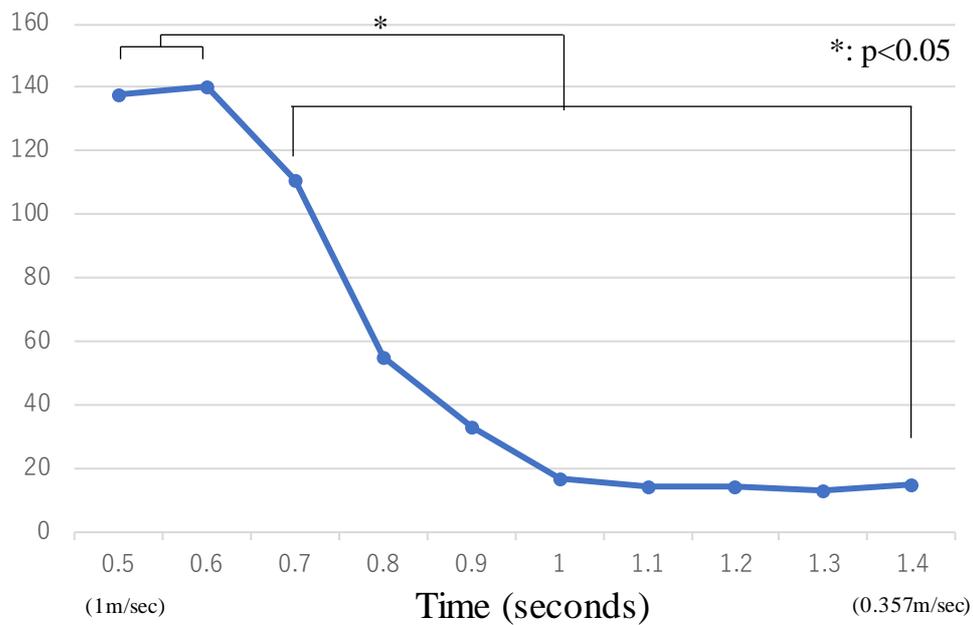
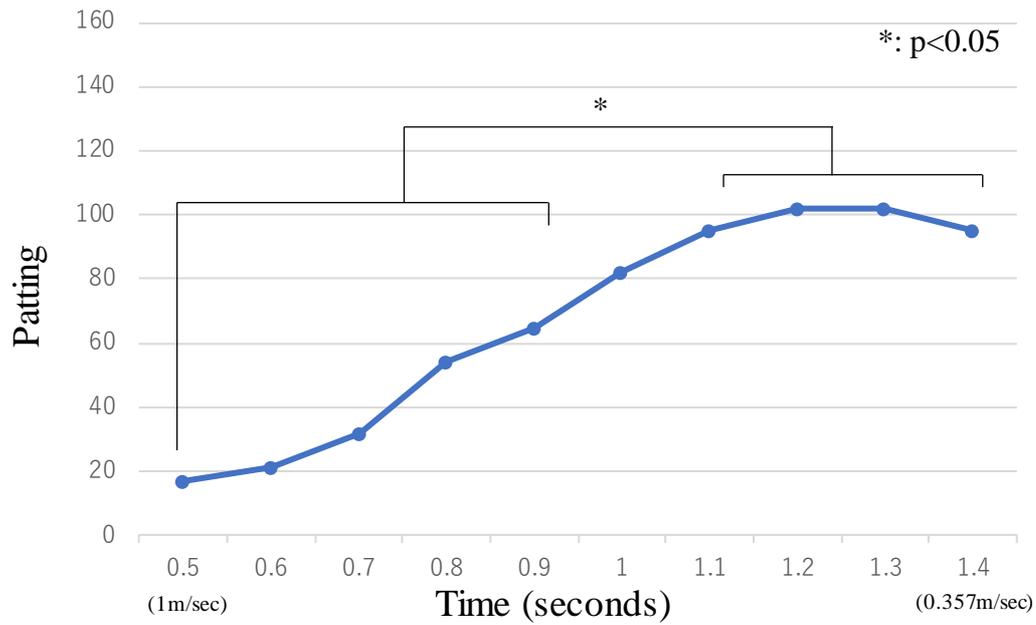


Fig. 6 Numbers who felt robot behaviours were patting (top) and slapping (bottom) when robot used palm of its hand. Only combinations that more often identified significant differences are shown.

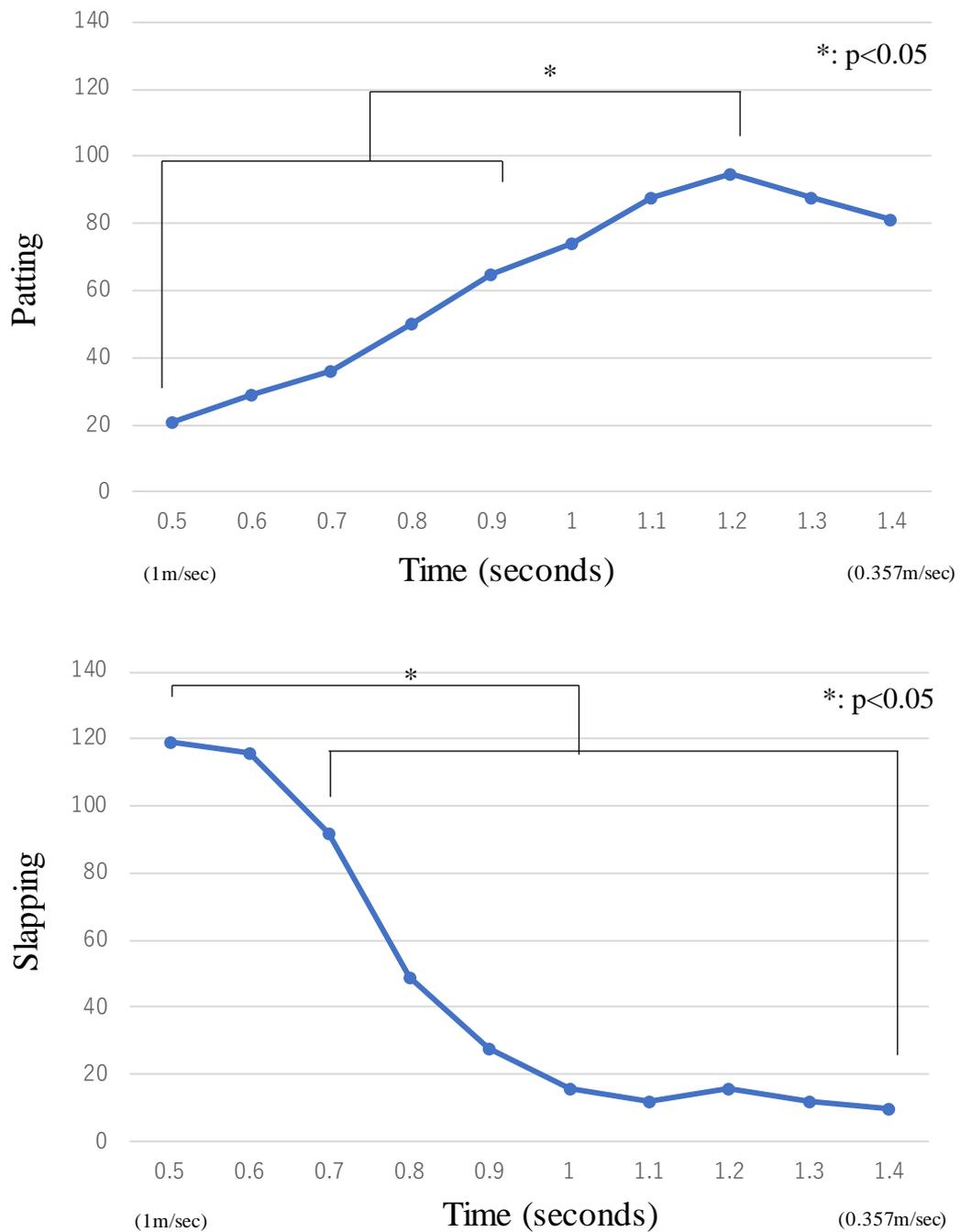


Fig. 7 Numbers who felt robot behaviours were patting (top) and slapping (bottom) when robot used back of its hand. Only combinations that more often identified significant differences are shown.

The experiment's findings indicate the crucial role of the speed of touching behaviours in altering the observers' perceptions. Although we only investigated speeds

ranging from 0.5 to 1.4 seconds, the results may indicate the relationships between the speeds and the identification of slapping/patting behaviours. We note that past studies suggested the difference of the palm or the back of the hand perceptions[28, 29], but the speed boundaries between patting and slapping are similar in these touching behaviours.

To investigate such relationships, we conducted a linear regression analysis whose results are shown in Figs. 8 (touching by the palm) and 9 (touching by the back of the hand). These results also show how people's perceptions are changed due to motion speeds; the trends between the behaviours are similar. Investigating slower/faster speeds is one possible future research direction. We think that slower speeds might increase the unnaturalness and lower the number of people who felt that the behaviours were pats; faster speeds are complicated by hardware limitations.

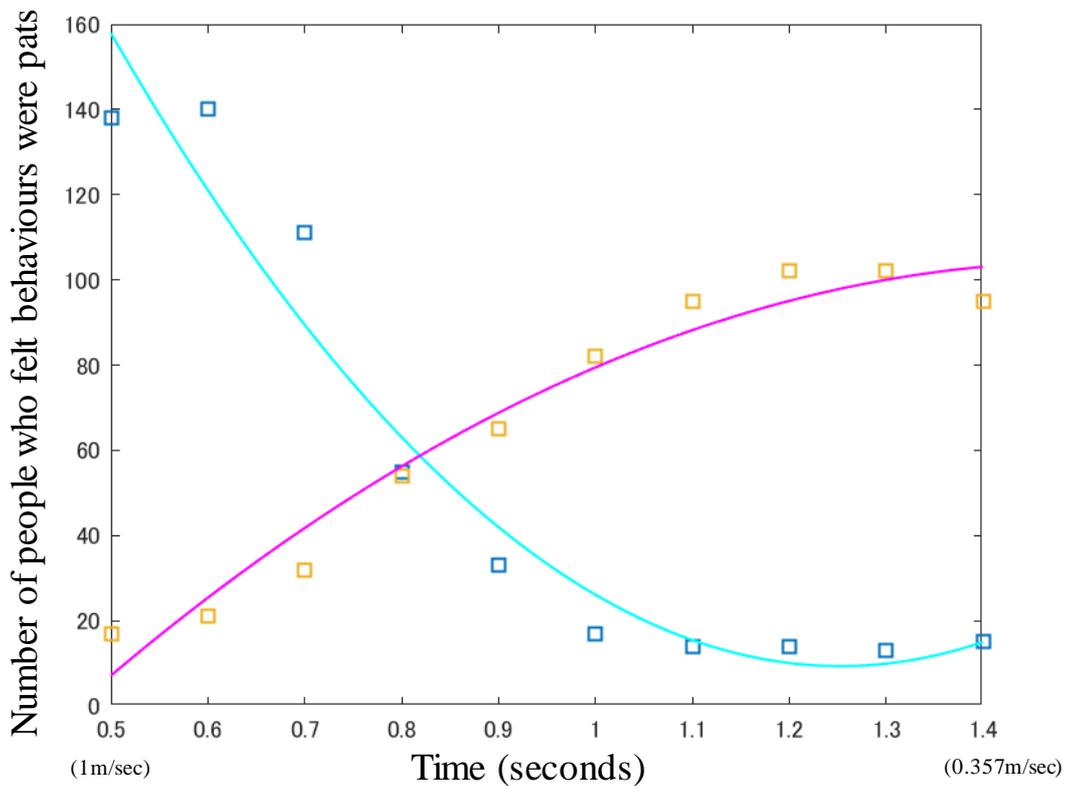


Fig. 8 Linear regression for number of people who felt behaviours were pats (yellow squares and purple line, $y = -95.08x^2 + 287.25x - 112.74$, $R^2 = 0.95$, $p < 0.05$) and slaps (blue squares and blue line, $y = 262.12x^2 - 656.82x + 420.79$, $R^2 = 0.93$, $p < 0.05$)

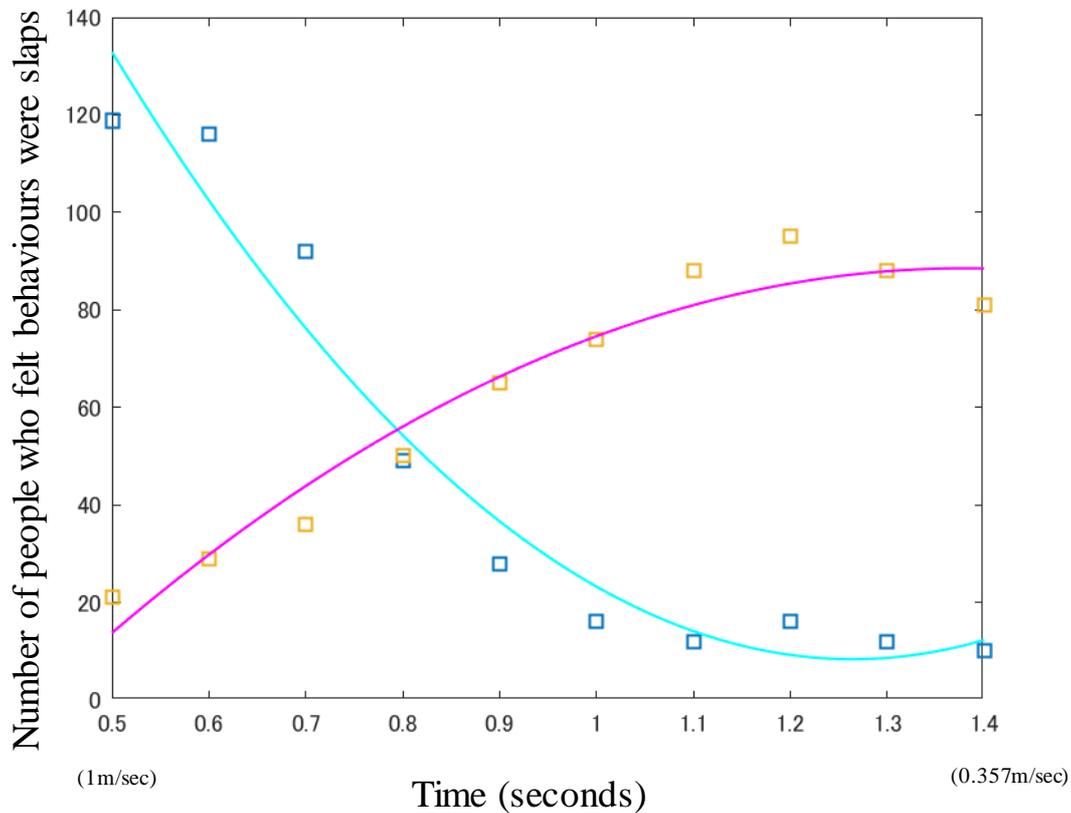


Fig. 9 Linear regression for number of people who felt behaviours were pats (yellow squares and purple line, $y = -96.60x^2 + 266.61x - 95.44$, $R^2 = 0.93$, $p < 0.05$) and slaps (blue squares and blue line, $y = 213.26x^2 - 539.25x + 349.23$, $R^2 = 0.94$, $p < 0.05$)

3. Experiment II

Our first experiment provided evidence of the changes of perceptions due to the speed of the robot's motions. Based on these results, we conducted a second experiment that investigated how the perceived relationships between robots changed due to their touch interactions. Note that in this second experiment, we only employed the touch

behaviours by the palm (i.e., excluding the touch behaviour by the back of the hand) because the first experiment showed similar trends between different touch behaviours.

3.1 Hypotheses and predictions

We hypothesized that the speed variations of the touches might lead observers to differently interpret the relationship between the two robots. For instance, observers might negatively identify a relationship between robots from a slap or a positively from a pat. Thus, we believe the speed of the touch significantly shapes the perceived relationships between robots. In fact, past studies reported that patting behaviours, which are used in touch interactions between such close relationships as families, are observed in stress-care situations [32, 33]. Therefore, we believe that people will perceive positive relationships between robots when patting behaviour is used.

Moreover, we focused on the observers' feelings both the touching robot and the robot being touched. About the former, we believe that people will think that when the touching robot uses a patting behaviour it is expressing a positive feeling toward the robot being touched. On the other hand, a slapping behaviour is much more aggressive than a patting due to its speed despite having identical trajectories. We hypothesized that people will believe that the touching robot is expressing negative feelings toward the robot being touched.

About the latter, we also evaluated the observers' feelings about the robot being touched to investigate how their perceptions changed due to the behaviours of the touched robot, even though the robot's reaction behaviors were the same. We expected that observers would anthropomorphize the robot that was being touched and apply a theory of mind [34, 35] to it, allowing them to feel that they had different impressions depending on how it was being touched. We think that investigating this effect would be useful for expressing different relationships through touch interactions between robots. For example,

even between humans, there is a tendency to use a little rough behavior when only either one has a positive impression toward others. Whether such a tendency applies to the relationship between robots can be verified by clarifying not only the relationship between the two robots, but also how each robot feels about the other.

Following these hypotheses, we made the following predictions. Note that our first experiment's results demonstrated that identical touch motions are perceived differently depending on the speed at which they are executed. Since touches at 0.5/0.6 seconds are seen as slaps and those at 1.2/1.3 seconds are seen as pats, we used these values in our predictions.

Prediction 1: When a robot touches another robot at speeds from 1.1 to 1.4, i.e., patting, the participants will perceive that the patting robot is expressing positive feelings toward the robot being touched.

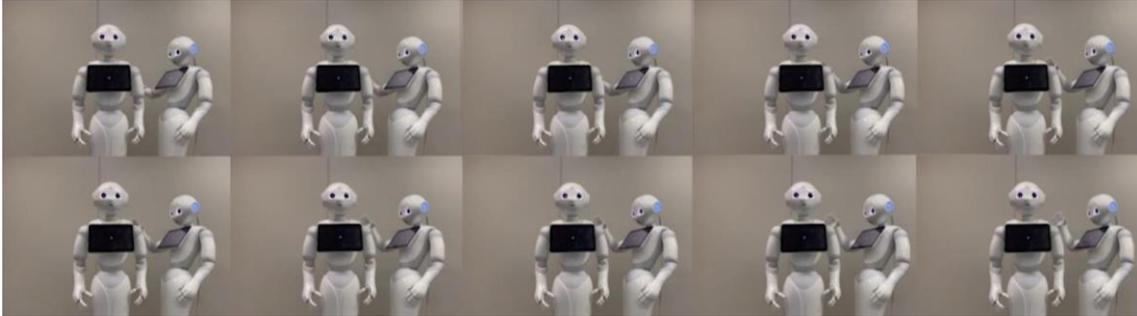
Prediction 2: When a robot touches another robot at speeds of 0.5/0.6, i.e., slapping, the participants will perceive that the slapping robot is expressing negative feelings toward the robot being touched.

Prediction 3: When a robot touches another robot at speeds from 1.1 to 1.4, i.e., patting, the participants will perceive that the robot being touched has positive feelings toward the patting robot.

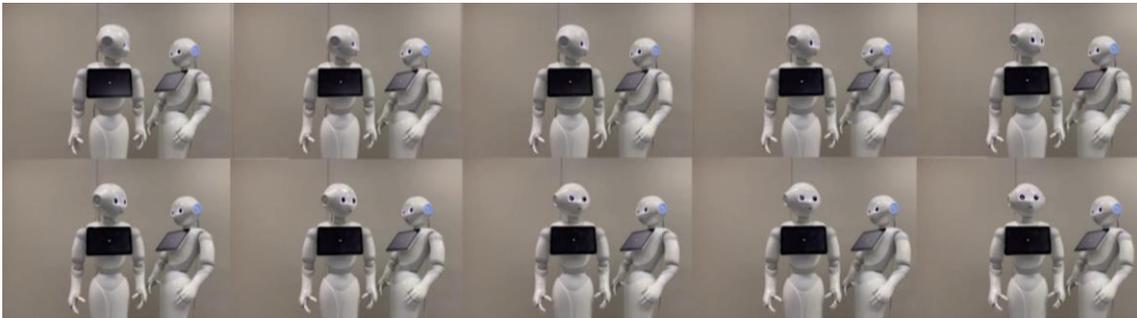
Prediction 4: When a robot touches another robot at speeds of 0.5/0.6, i.e., slapping, the participants will perceive that the robot being touched has negative feelings toward the slapping robot.

Prediction 5: When a robot touches another robot at speeds from 1.1 to 1.4, i.e., patting, the participants will perceive that they have a positive relationship.

Prediction 6: When a robot touches another robot at speeds of 0.5/0.6, i.e., slapping, the participant will perceive that they have a negative relationship.



(a) $t = 1.3$ seconds



(b) $t = 3.5$ seconds

Fig. 10 Visual stimuli of Experiment II: left-top video is 0.5-second motion, and right-bottom video is 1.4-second motion (left side: robot B, right side: robot A)

3.2 Visual stimuli and conditions

In line with Experiment I, we produced ten videos where robot A touched robot B (Fig. 10) and varied its touch's speed by its palm. We used these videos for another web-based questionnaire and incorporated two Pepper robots.

The experiment considered one factor: speed, which we varied from 0.5 to 1.4 seconds in 0.1-second increments. We recorded separate videos of different speed movements and combined them into a single video (Fig. 10). In every video, robot B (on the left) just gazes at robot A (on the right) following a touch from the latter. Robot B did

not change its facial expressions, its LED colours, or make any sounds. Similar to Experiment I, the initiation of robot A's touching behaviours remained consistent across all the videos. However, robot B's gaze behaviour varied due to different touch timings.

3.3 Measurement

Our questionnaire included six subjective items: assessments whether the touching robot has a positive/negative feeling toward the robot being touched, whether the robot being touched has a positive/negative feeling toward the touching robot, and whether the robots have positive/negative relationships.

3.4 Procedure

All the procedures were approved by the Advanced Telecommunication Research Review Boards. Experiment II's procedure was identical to Experiment I. First, we provided participants with a comprehensive overview of the experiment and allowed them to answer practice questions to gain greater familiarity. Subsequently, they watched the videos and responded to two questionnaires that assessed whether they categorized the actions as slaps or pats. Participants were given the option to revisit the videos while answering the questionnaires. We also prepared dummy questions to gauge their attention to the videos and assess the quality of their responses.

3.5 Participants

We conducted Experiment II with a different participant pool of 209 individuals again recruited by a Japanese survey company: 116 women, 91 men, and 2 who preferred not to specify. Post-screening, we had 147 valid participants: 66 women, 81 men. The average age of the participants was 39.8, with a standard deviation of 10.6.

3.6 Questionnaire results for Experiment II

The questionnaire results regarding the feelings of the touching robot toward the robot being touched are shown in Fig. 11. A Cochran's Q-test analysed the number of participants who thought the touching robot expressed a positive feeling ($Q(9) = 249.183$, $p < 0.001$, Cliff's delta = 0.91). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) between conditions: $1.4 > [0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3]$, 1.2 and $1.3 > [0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1]$. Thus, the results showed that the number of people who felt touching robot has positive feelings at 1.4 seconds is significantly higher than the number of participants at 1.3 seconds and at lower speeds ($p < 0.05$). The findings of these trends resemble those observed in Experiment I, although with slight differences concerning peak values. Therefore, prediction 1 is partially supported.

We conducted an additional Cochran's Q-test to analyse the number of participants who thought the touching robot expressed a negative feeling ($Q(9) = 370.334$, $p < 0.001$, Cliff's delta = 0.92). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) between conditions: 0.5 and $0.6 > [0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4]$, $0.7 > [0.9, 1.0, 1.1, 1.2, 1.3, 1.4]$. Thus, the results showed that the numbers of people who felt touching robot has negative feelings at 0.5 and 0.6 seconds were significantly higher than the other speeds ($p < 0.05$), even though the differences between 0.5 and 0.6 seconds did not show significant differences. Since these findings also showed the same trends observed in Experiment I, prediction 2 is supported.

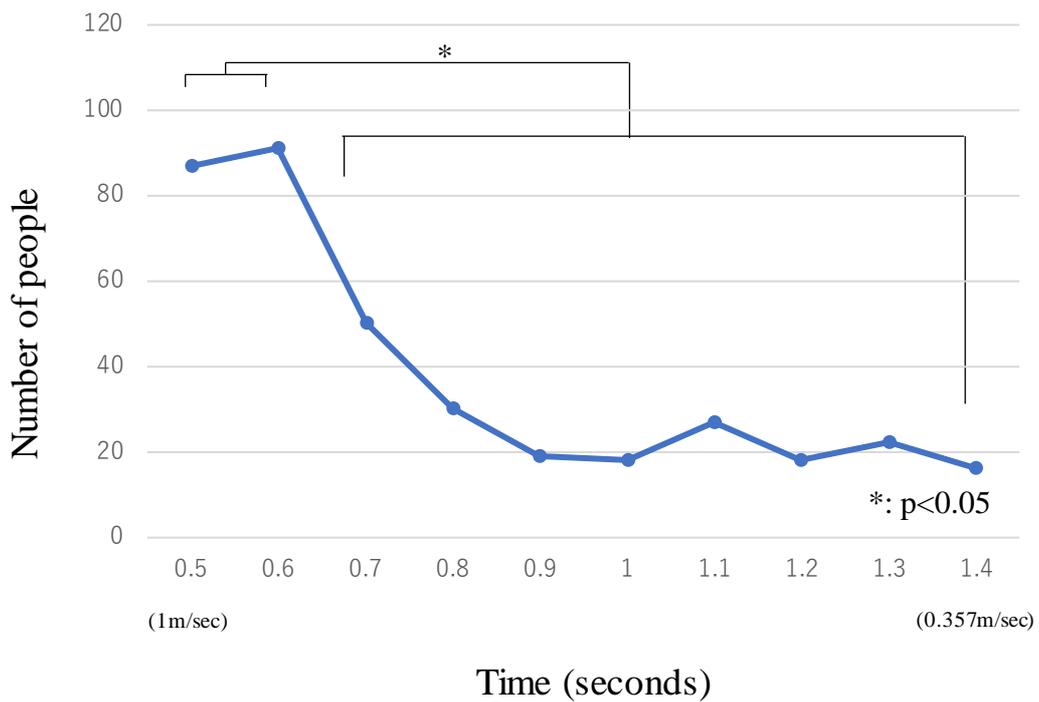
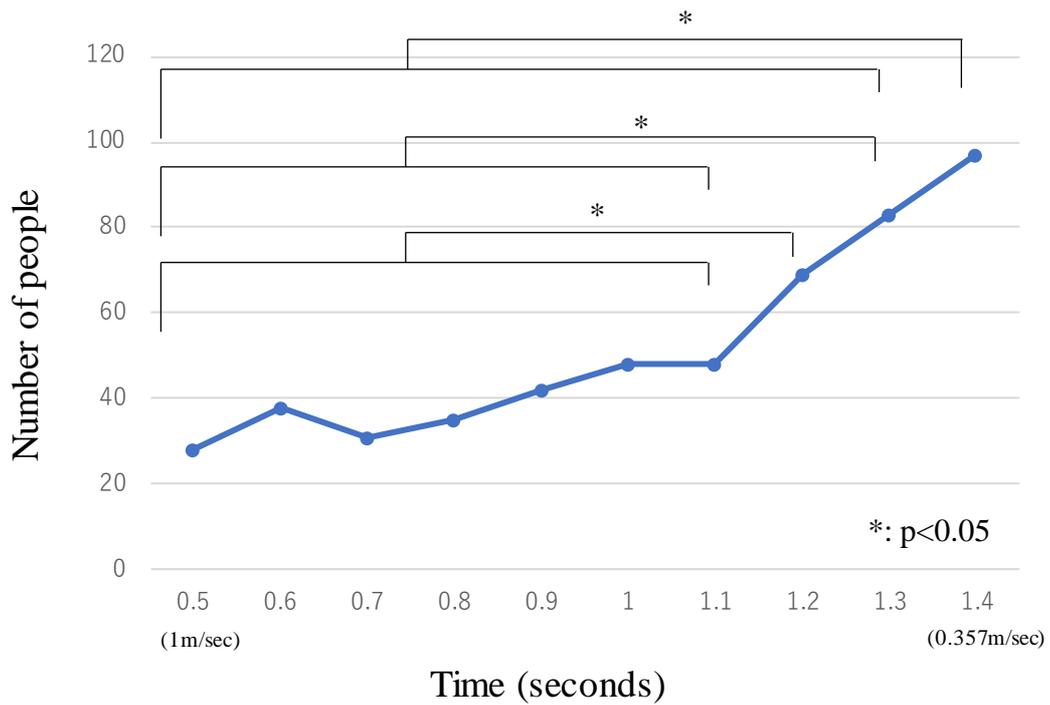


Fig. 11 Number of people who felt touching robot has positive feelings (top) and negative feelings (bottom). Only combinations related to predictions 1 and 2 are shown.

The questionnaire results regarding the perceived feelings of the robot being touched toward the touching robot are shown in Fig. 12. A Cochran's Q-test analysed the

number of participants who thought the robot being touched had a positive feeling ($Q(9) = 179.317$, $p < 0.001$, Cliff's delta = 1.00). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) between conditions: $1.4 > [0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2]$, $1.3 > [0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1]$, $1.2 > [0.5, 0.6, 0.7, 0.8, 0.9]$, $1.1 > [0.5, 0.7]$. Thus, the results showed that more participants observed positive relationships at 1.4 seconds than at 1.2 seconds and at lower speeds ($p < 0.05$). The number of participants perceiving positive relationships at 1.3 seconds is significantly higher than at 1.1 seconds and at lower speeds ($p < 0.05$). The number of participants perceiving positive relationships at 1.2 seconds is significantly higher than at 0.9 seconds and at lower speeds ($p < 0.05$). These findings showed similar trends to those observed in Experiment I, although with slight differences concerning peak values. Therefore, prediction 3 is partially supported.

An additional Cochran's Q-test analysed the number of participants who thought the robot being touched produced a negative feeling ($Q(9) = 180.695$, $p < 0.001$, Cliff's delta = 1.00). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) between conditions: 0.5 and $0.6 > [0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4]$, $0.7 > [0.9, 1.2, 1.4]$. Thus, the results concerning negative feelings at speeds of 0.5 and 0.6 seconds are significantly higher than other speeds ($p < 0.05$), even though the differences between 0.5 and 0.6 seconds did not show significant differences. These findings also showed the same trends observed in Experiment I. Therefore, prediction 4 is supported.

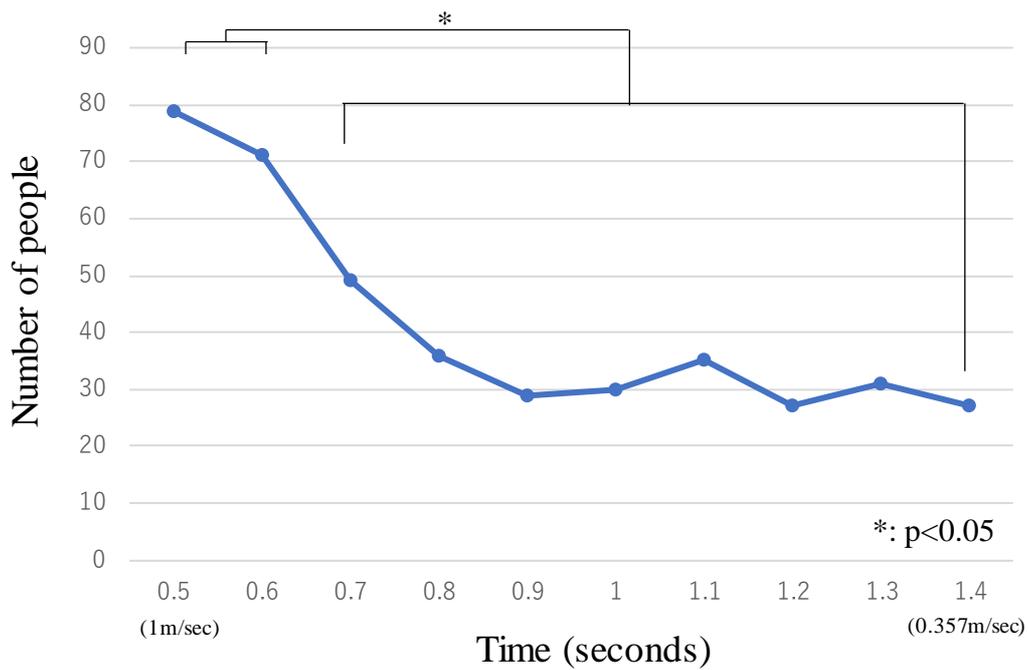
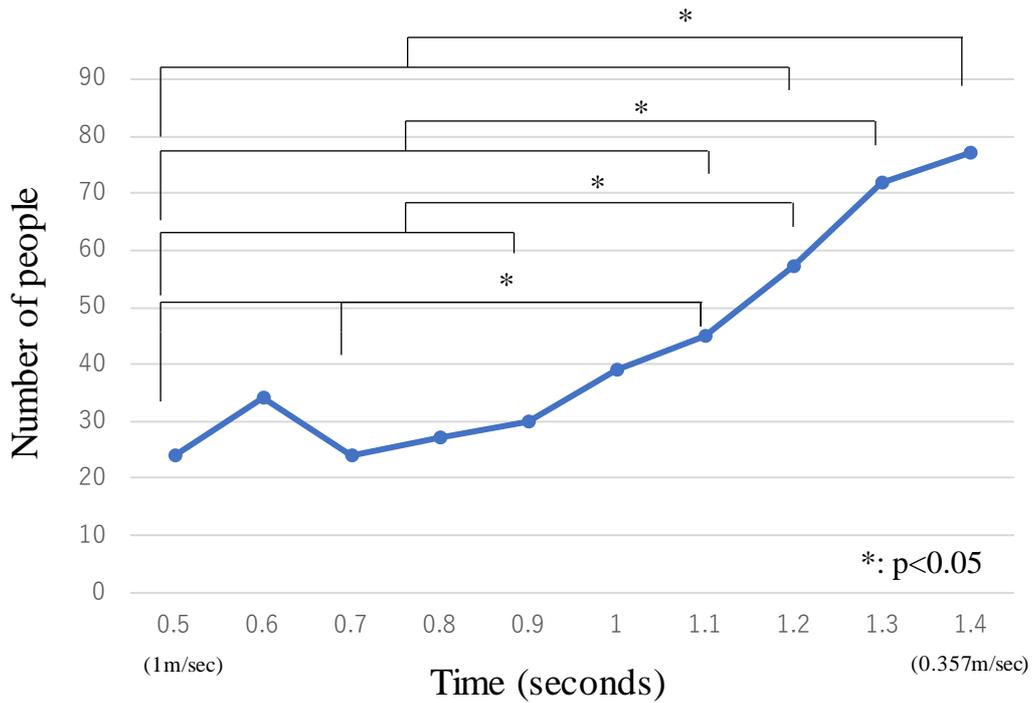


Fig. 12 Number of people who felt robot being touched has positive feelings (top) and negative feelings (bottom). Only combinations related to predictions 3 and 4 are shown.

The questionnaire results regarding the relationships between robots are shown in

Fig. 13. A Cochran's Q-test analysed the number of positive relationships and found significant differences among varying speeds ($Q(9) = 171.478$, $p < 0.001$, Cliff's delta = 0.98). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) between conditions: $1.4 > [0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3]$, $1.3 > [0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1]$, $1.2 > [0.5, 0.6, 0.7, 0.8]$. Thus, the number of participants who perceived positive relationships at 1.4 seconds is significantly higher than the number at 1.3 seconds and at lower speeds ($p < 0.05$). The number of participants who perceived positive relationships at 1.3 seconds is significantly higher than similar perceptions at 1.1 seconds and at lower speeds ($p < 0.05$), even though the differences between 1.3 and 1.2 seconds did not show any significant differences. The number of participants perceiving positive relationships at 1.2 seconds is significantly higher than at 0.8 seconds and at lower speeds ($p < 0.05$). These findings showed similar trends to those observed in Experiment I, although with slight differences concerning peak values. Therefore, prediction 5 is partially supported.

An additional Cochran's Q-test analysed the number of negative relationships and indicated significant differences among varying speeds ($Q(9) = 247.547$, $p < 0.001$, Cliff's delta = 1.00). Multiple comparisons with the Bonferroni method found significant differences (all p values are < 0.05) between conditions: 0.5 and $0.6 > [0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4]$. Thus, the number of participants perceiving negative relationships at 0.5 and 0.6 seconds is significantly higher than at other speeds ($p < 0.05$), even though the differences between 0.5 and 0.6 seconds did not show any significant differences. These findings also showed identical trends to those observed in Experiment I. Therefore, prediction 6 is supported.

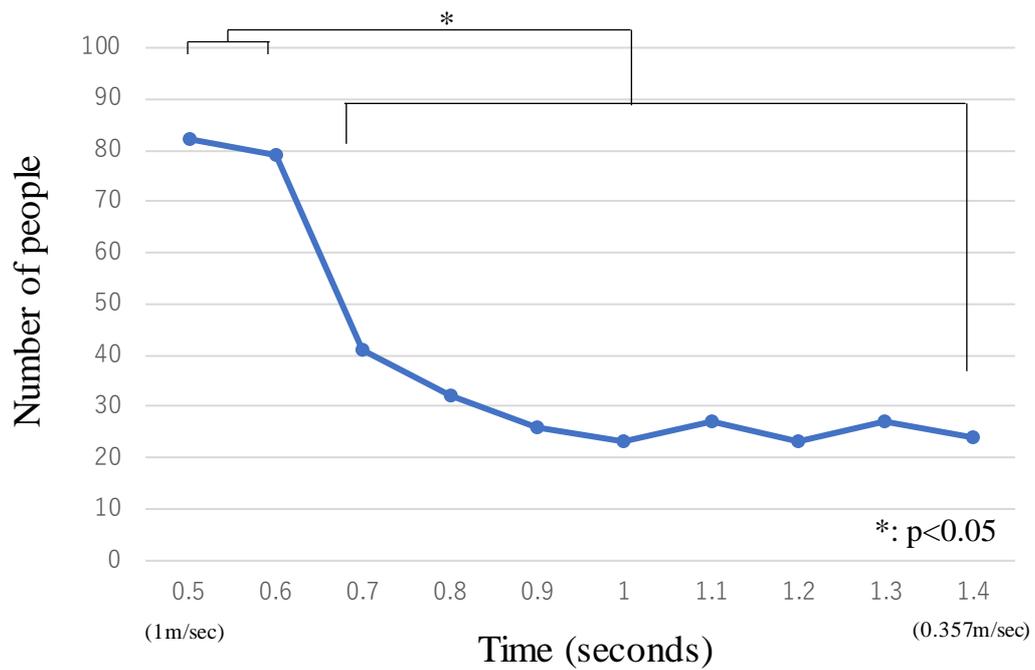
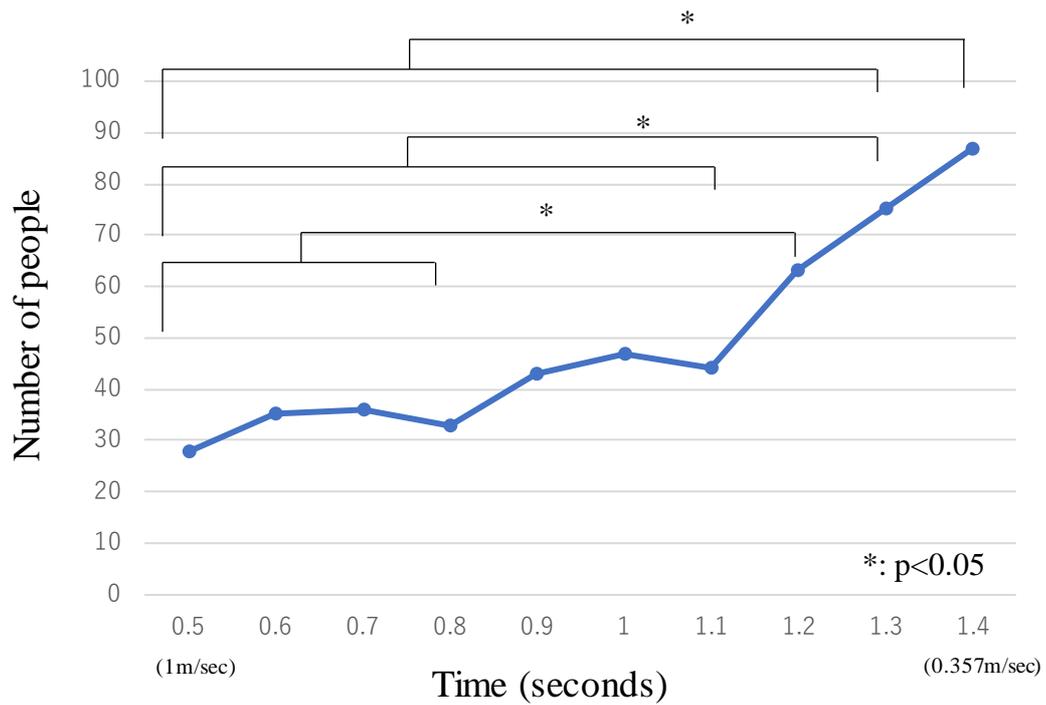


Fig. 13 Number of people who felt relationships were positive (top) and negative (bottom). Only combinations related to predictions 5 and 6 are shown.

As in Experiment I, Experiment II's findings identify the crucial role of the speed of a touching behaviour in altering observers' perceptions to the perceived relationships between robots. Despite speeds ranging from 0.5 to 1.4 seconds, the results also suggest a correlation between slower/faster speeds and positive/negative feelings and relationships between robots. Moreover, indicating that the impression of the relationship between the two robots is almost identical to that of the perceived relationship in the individual robots. In other words, the observed relationships were shown to be consistent.

We again conducted a linear regression analysis whose results are shown in Figs. 14 (perceived feelings from the touching robot to the robot being touched), 15 (perceived feelings from the robot being touched to the touching robot), and 16 (perceived relationships between them). These results also showed how people's perceptions changed due to the motion speeds, and the trends between the behaviours are similar.

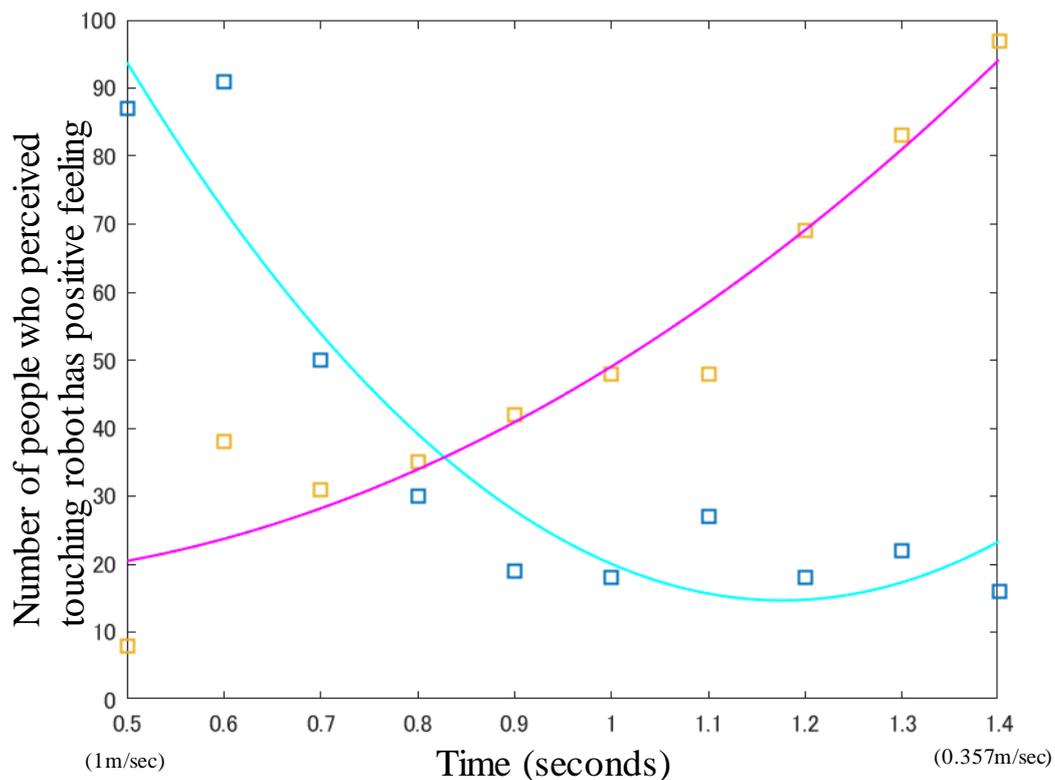


Fig. 14 Linear regression for number of people who perceived touching robot has positive feeling (yellow circles and purple line, $y = 107.20x^2 - 132.70x + 72.38$. $R^2 = 0.97$, $p < 0.05$) and negative feeling (blue squares and blue line, $y = 173.11x^2 - 407.20x + 254.13$. $R^2 = 0.89$, $p < 0.05$)

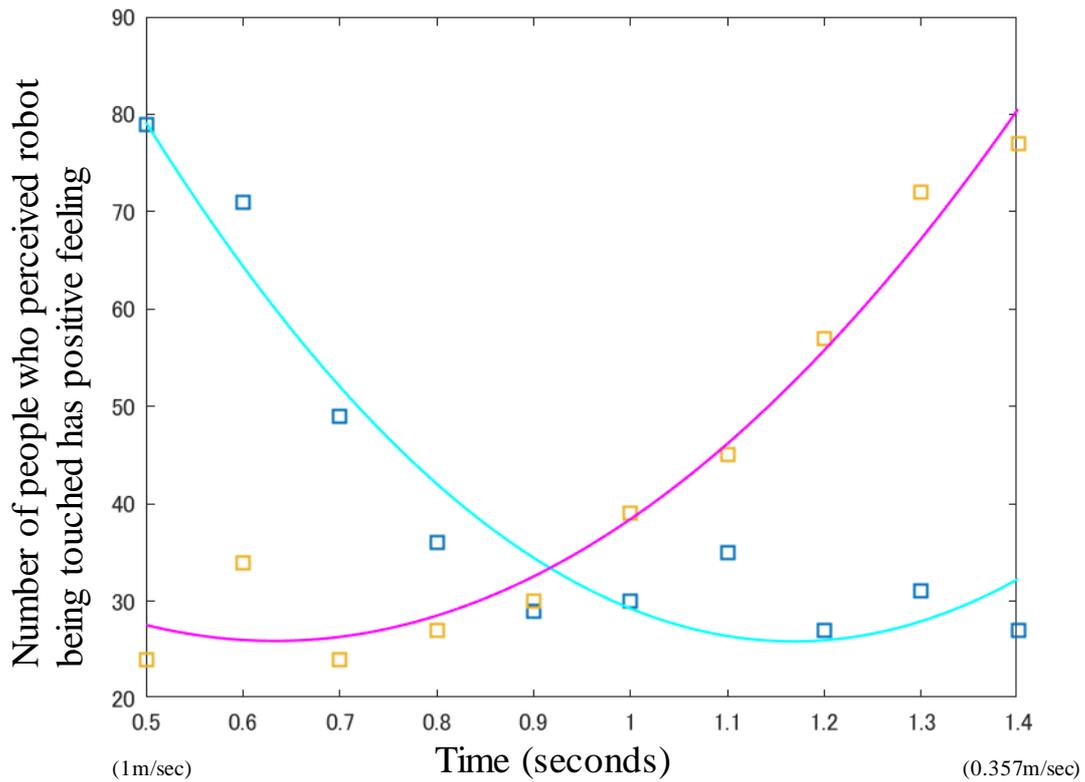


Fig. 15 Linear regression results for number of people who perceived robot being touched has positive feelings (yellow circles and purple line, $y = 92.80x^2 - 117.478x + 63.0924$. $R^2 = 0.96$, $p < 0.05$) and negative feelings (blue squares and blue line, $y = 119.32x^2 - 278.83x + 188.76$. $R^2 = 0.93$, $p < 0.05$)

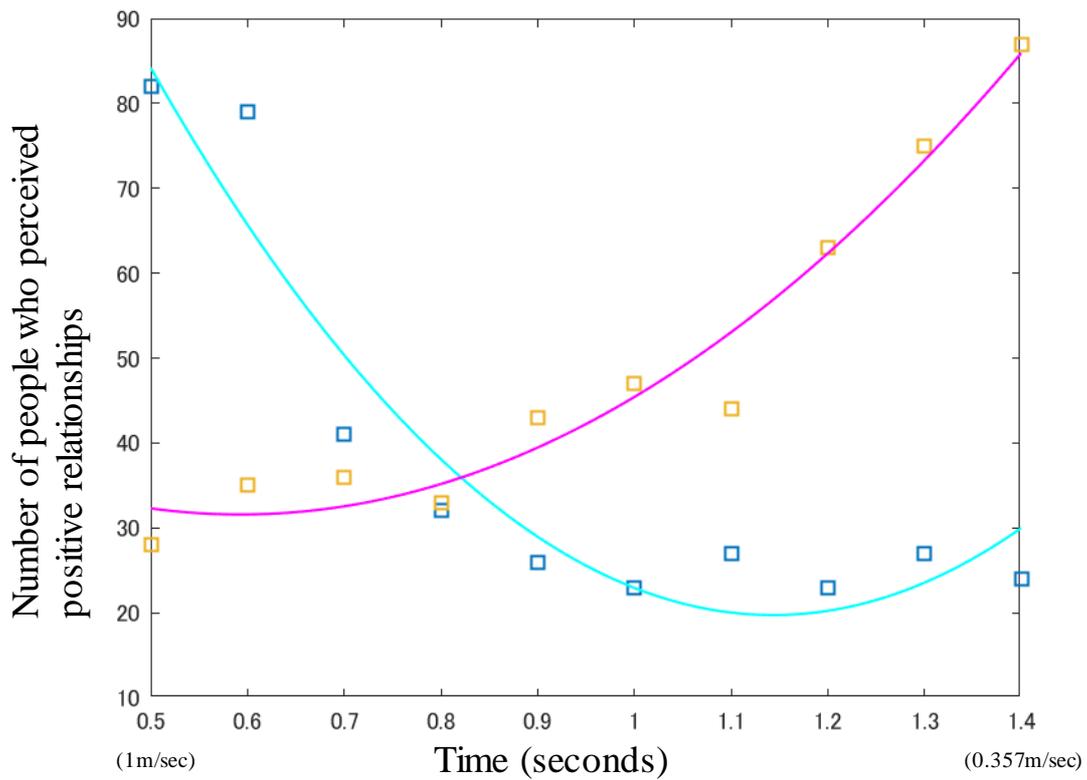


Fig. 16 Linear regression for number of people who perceived positive relationships (yellow circles and purple line, $y = 83.3x^2 - 98.76x + 60.84$. $R^2 = 0.95$, $p < 0.05$) and negative relationships (blue squares and blue line, $y = 155.68x^2 - 356.04x - 223.29$. $R^2 = 0.86$, $p < 0.05$)

4. General Discussion

4.1 Implication

Our two experiments yield several crucial implications for the design of robot-robot touch interactions. Experiment I's findings emphasize how the role of speed boundaries influences the perceptions of such touch behaviours as slapping or patting. This information carries substantial value when designing touch behaviours for social

robots that are expected to elicit distinct impressions. Further, the results of Experiment II provide evidence that varying the touch behaviours can modify the perceived relationships between robots as well as the perceived feelings in each robot. However, due to safety considerations, the effects of these touch behaviours in the context of human-robot interactions remain unexplored. Therefore, investigating the relationships between touch motion speeds and perceptions in human-robot interaction presents a compelling avenue for future research.

Moreover, the results of Experiment I suggest that people might be influenced by the motion's speed rather than the types of motions. Although past studies less focused on the perceived impressions in touching behaviours, a past study that focused on pre-touch interaction reported that people quickly react fast approaching hands [36]. They might feel that fast-approaching behaviours are more dangerous, i.e., slow-approaching behaviours are safer and have positive feelings. This phenomenon is also observed in Experiment II. Note that Experiment II focused on robot-robot touch interaction, but people's perceptions toward the motion speeds showed similar results. These consistent phenomena would be useful to design not only human-robot touch interaction but also robot-robot touch interaction.

The effects of observing diverse touches in human-robot interactions also warrant investigation. Prior research described how a robot's touch can influence an observer's trust [20]. Therefore, it stands to reason that robot-motion speeds might yield differential trust perceptions among observers. Furthermore, the location of a touch obviously creates different impressions in observers. Several studies have delved into the relationships between "touchable" body parts in human-human touch interaction [37, 38] and emotional touches and touch locations within the context of human-robot interaction [39-41]. Pertaining to this topic, the receiving robot's reactions to the touching robot will also

undoubtedly impact the observer impressions. This assumption is based on existing evidence that robots' reaction behaviours to human touch can influence perceived naturalness and likability [36, 42] as well as pre-touch reaction behaviours [42, 43].

One possible application for our knowledge is recognizing human-human relationships by observing their physical interactions. Although we only used robots to investigate the speed effects in physical interaction, this approach could also be used to probe human-human relationships. Several studies developed behaviour analysis systems related to identifying such physical actions as fighting, punching, and kicking [44, 45], although these studies focused less on understanding their relationships. The researchers assumed that such abnormal behaviours only appeared in negative relationships. Understanding the effects of motion speed might also be useful for recognizing joking behaviours between friends.

In this study, we used a touching motion with about 35 cm/s ~ 100 cm/s to investigate the perceived impressions, which are different speeds compared to past related studies like [23, 46], which reported the importance of slow speeds (~5cm/s) for comfortable touching. Because employing such slow speeds was unnatural for a swinging touch motion in our study, it might have provided different impressions toward the participants. Moreover, past touching behaviours are basically continuous motions such as stroking or rubbing, which is different from our study. Therefore, investigating the different speed sets based on touch types would be needed to investigate appropriate touching behaviour design to change perceived impressions from observers.

4.2 Application of showing negative relationships between robots

Both experiments showed that motion speeds in robot-robot touch interaction impact observers' perceived relationships: positive and negative. Showing positive relationships benefits observers and their tasks, because familiar relationships between

robots is important for gaining acceptance from observers.

On the other hand, what are the merits of manifesting negative relationships? One possible application is robot theater [47, 48], where robots are performers. As shown in the references, several robot artists have already employed robots in this context, where robots express various emotions by interaction with others on stage. In such contexts, showing negative relationships by touching others is beneficial. Therefore, knowledge from our study will contribute to establishing design guidelines for robot behaviours to show negative relationships by physical interaction. In another context, robotics researchers reported that a robot's aggressive interaction toward a perpetrator is acceptable when a robot is guarding somebody [49]. In such a situation, the robot's motion speed is designed to pose a threatening attitude for protection behaviours.

4.3 Limitations

Nevertheless, this study suffers from several limitations. We exclusively utilized both specific robots and touch behaviours. Future research must broaden this scope to encompass different types of robots and touch behaviours, including more human-like androids [50-52], pet-like robots [53, 54], and a variety of touch behaviours. Another limitation lurks in the reaction behaviour of the robot that was touched in Experiment II. Its response was limited to turning and looking at the other robot without any verbal interaction. As previously noted, varying the reaction behaviours or touching different objects might alter observer impressions. Additionally, a robot's speech content might significantly impact the perceived relationships between robots. Moreover, we omitted sound information during touching from this study to avoid such sound effects, but the loudness of motors and the sounds created from physical contacts will differently affect the perceptions of observers. Nor did we investigate the speed effects in human-human

touch interaction; we only focused on robot-robot interaction. Comparison between human-human and human-robot interactions will provide rich knowledge about behaviour design perspectives. Finally, since our experiments were conducted solely with Japanese participants, broader considerations of generality and cultural differences are paramount. Although such limitations exist, we believe the contributions of this paper will help researchers who are addressing this research topic. Such researchers can exploit our study's results as a baseline for designing new experiments to expand knowledge about touch characteristics in robot-robot interaction.

5 Conclusion

This study investigated the impact of touch motion speeds on the perceptions of relationships between robots, particularly in scenarios where one robot touches another. We conducted two web surveys to facilitate this investigation. Experiment I focused on the relationship between touch motion speeds and the perception of touch behaviours with the palm and the back of the hand, specifically distinguishing between slapping and patting. The results of Experiment I revealed that a touching motion lasting 0.5 seconds is perceived as a slap; a motion lasting 1.2 seconds is seen as a pat, regardless the side of the hand.

Building on these findings, Experiment II investigated whether these diverse touch motions altered the perceived relationships between robots and the perceived feelings in each one. Participants perceived negative relationships when a robot touched another at 0.5/0.6 seconds, a result that is aligned with the perception of slapping behaviours. Conversely, they identified positive relationships when a robot touched another at 1.4-second intervals. Although slightly different from the patting behaviours' trends in Experiment I, these findings showed consistent results that slow touch motions

effectively express positive relationships between robots.

We posit that these insights will prove beneficial in designing touch motion speeds for robots and defining their relationships when they interact physically. These findings may guide behaviour design for human-robot touch interactions.

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References:

- [1] A. Dahiya, A. M. Aroyo, K. Dautenhahn, and S. L. Smith, "A survey of multi-agent Human-Robot Interaction systems," *Robotics and Autonomous Systems*, pp. 104335, 2022.
- [2] X. Z. Tan, S. Reig, E. J. Carter, and A. Steinfeld, "From one to another: how robot-robot interaction affects users' perceptions following a transition between robots," in 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI), pp. 114-122, 2019.
- [3] M. R. Fraune, B. C. Oisted, C. E. Sembrowski, K. A. Gates, M. M. Krupp, and S. Šabanović, "Effects of robot-human versus robot-robot behavior and entitativity on anthropomorphism and willingness to interact," *Computers in Human Behavior*, vol. 105, pp. 106220, 2020.
- [4] H. Erel, Y. Cohen, K. Shafrir, S. D. Levy, I. D. Vidra, T. Shem Tov, and O. Zuckerman, "Excluded by Robots: Can Robot-Robot-Human Interaction Lead to Ostracism?," in Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction, pp. 312-321, 2021.
- [5] M. Sherif, "A study of some social factors in perception," *Archives of Psychology (Columbia University)*, 1935.
- [6] S. E. Asch, "Opinions and Social Pressure," *Scientific American*, vol. 193, pp. 17-26, 1955.
- [7] S. E. Asch, "Effects of group pressure upon the modification and distortion of judgments," *Groups, leadership, and men. S*, pp. 222-236, 1951.
- [8] T. Iio, Y. Yoshikawa, and H. Ishiguro, "Pre-scheduled Turn-Taking between Robots to Make Conversation Coherent," in Proceedings of the Fourth International Conference on Human Agent Interaction, Biopolis, Singapore, pp. 19-25, 2016.
- [9] T. Iio, Y. Yoshikawa, and H. Ishiguro, "Double-meaning agreements by two robots to conceal incoherent agreements to user's opinions," *Advanced Robotics*, vol. 35, no. 19, pp. 1145-1155, 2021.
- [10] D. Sakamoto, K. Hayashi, T. Kanda, M. Shiomi, S. Koizumi, H. Ishiguro, T. Ogasawara, and N. Hagita, "Humanoid Robots as a Broadcasting

- Communication Medium in Open Public Spaces,” *International Journal of Social Robotics*, vol. 1, no. 2, pp. 157-169, 2009.
- [11] T. Iio, Y. Yoshikawa, and H. Ishiguro, “Retaining Human-Robots Conversation: Comparing Single Robot to Multiple Robots in a Real Event,” *Journal of Advanced Computational Intelligence Intelligent Informatics*, vol. 21, no. 4, pp. 675-685, 2017.
- [12] T. Iwamoto, J. Baba, J. Nakanishi, K. Hyodo, Y. Yoshikawa, and H. Ishiguro, “Playful Recommendation: Sales Promotion That Robots Stimulate Pleasant Feelings Instead of Product Explanation,” *IEEE Robotics and Automation Letters*, vol. 7, no. 4, pp. 11815-11822, 2022.
- [13] J. Amada, Y. Okafuji, K. Matsumura, J. Baba, and J. Nakanishi, “Investigating the crowd-drawing effect, on passersby, of pseudo-crowds using multiple robots,” *Advanced Robotics*, vol. 37, no. 6, pp. 423-432, 2023.
- [14] M. Shiomi, S. Okumura, M. Kimoto, T. Iio, and K. Shimohara, “Two is better than one: Social rewards from two agents enhance offline improvements in motor skills more than single agent,” *PloS one*, vol. 15, no. 11, pp. e0240622, 2020.
- [15] M. Shiomi, Y. Tamura, M. Kimoto, T. Iio, R. Akahane-Yamada, and K. Shimohara, “Two is better than one: verification of the effect of praise from two robots on pre-school children’s learning time,” *Advanced Robotics*, vol. 35, no. 19, pp. 1132-1144, 2021.
- [16] Y. Tamura, M. Shiomi, M. Kimoto, T. Iio, K. Shimohara, and N. Hagita, “Robots as an interactive-social medium in storytelling to multiple children,” *Interaction Studies*, vol. 22, no. 1, pp. 110-140, 2021.
- [17] T. Iio, R. Maeda, K. Ogawa, Y. Yoshikawa, H. Ishiguro, K. Suzuki, T. Aoki, M. Maesaki, and M. Hama, “Improvement of Japanese adults' English speaking skills via experiences speaking to a robot,” *Journal of Computer Assisted Learning*, vol. 35, no. 2, pp. 228-245, 2019.
- [18] Y. Okada, M. Kimoto, T. Iio, K. Shimohara, and M. Shiomi, “Two is better than one: Apologies from two robots are preferred,” *Plos one*, vol. 18, no. 2, pp. e0281604, 2023.
- [19] H. Itahara, M. Kimoto, T. Iio, K. Shimohara, and M. Shiomi, “How Does Exposure to Changing Opinions or Reaffirmation Opinions Influence the Thoughts of Observers and Their Trust in Robot Discussions?,” *Applied Sciences*, vol. 13, no. 1, pp. 585, 2023.
- [20] T. Law, B. F. Malle, and M. Scheutz, “A touching connection: how observing robotic touch can affect human trust in a robot,” *International Journal of Social Robotics*, vol. 13, no. 8, pp. 2003-2019, 2021.
- [21] Y. Okada, M. Kimoto, T. Iio, K. Shimohara, H. Nittono, and M. Shiomi, “Kawaii emotions in presentations: Viewing a physical touch affects perception of affiliative feelings of others toward an object,” *Plos one*, vol. 17, no. 3, pp. e0264736, 2022.
- [22] A. Deshmukh, B. Craenen, A. Vinciarelli, and M. E. Foster, “Shaping robot gestures to shape users' perception: The effect of amplitude and speed on godspeed ratings,” in *Proceedings of the 6th International Conference on Human-Agent Interaction*, pp. 293-300, 2018.
- [23] C. J. Willemse, G. Huisman, M. M. Jung, J. B. van Erp, and D. K. Heylen, “Observing touch from video: The influence of social cues on pleasantness perceptions,” in *Haptics: Perception, Devices, Control, and Applications: 10th International Conference, EuroHaptics 2016, London, UK, July 4-7, 2016, Proceedings, Part II* 10, pp. 196-205, 2016.

- [24] S.-J. Blakemore, D. Bristow, G. Bird, C. Frith, and J. Ward, "Somatosensory activations during the observation of touch and a case of vision–touch synaesthesia," *Brain*, vol. 128, no. 7, pp. 1571-1583, 2005.
- [25] A. Serino, F. Pizzoferrato, and E. Làdavas, "Viewing a Face (Especially One's Own Face) Being Touched Enhances Tactile Perception on the Face," *Psychological Science*, vol. 19, no. 5, pp. 434-438, 2008.
- [26] T. Hirayama, Y. Okada, M. Kimoto, T. Iio, K. Shimohara, and M. Shiomi, "What is the speed boundary between patting and slapping by a robot? Investigating perceptions toward robot-robot interaction," in Proceedings of the 10th International Conference on Human-Agent Interaction, pp. 212-218, 2022.
- [27] K. Hayashi, T. Kanda, T. Miyashita, H. Ishiguro, and N. Hagita, "Robot manzai: Robot conversation as a passive–social medium," *International Journal of Humanoid Robotics*, vol. 5, no. 01, pp. 67-86, 2008.
- [28] S. Price, N. Bianchi-Berthouze, C. Jewitt, N. Yiannoutsou, K. Fotopoulou, S. Dajic, J. Virdee, Y. Zhao, D. Atkinson, and F. Brudy, "The making of meaning through dyadic haptic affective touch," *ACM Transactions on Computer-Human Interaction*, vol. 29, no. 3, pp. 1-42, 2022.
- [29] L. Zapparoli, P. Invernizzi, M. Gandola, M. Berlingeri, A. De Santis, A. Zerbi, G. Banfi, and E. Paulesu, "Like the back of the (right) hand? A new fMRI look on the hand laterality task," *Experimental brain research*, vol. 232, pp. 3873-3895, 2014.
- [30] J. S. Downs, M. B. Holbrook, S. Sheng, and L. F. Cranor, "Are your participants gaming the system? screening mechanical turk workers," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Atlanta, Georgia, USA, pp. 2399–2402, 2010.
- [31] D. M. Oppenheimer, T. Meyvis, and N. Davidenko, "Instructional manipulation checks: Detecting satisficing to increase statistical power," *Journal of experimental social psychology*, vol. 45, no. 4, pp. 867-872, 2009.
- [32] A. Cekaite, "Touch as embodied compassion in responses to pain and distress," *Touch in Social Interaction*, pp. 81-102: Routledge, 2020.
- [33] M. Burdelski, and A. Cekaite, "Control touch in caregiver–child interaction: Embodied organization in triadic mediation of peer conflict in Swedish and Japanese," *Touch in social interaction*, pp. 103-123: Routledge, 2020.
- [34] B. Benninghoff, P. Kulms, L. Hoffmann, and N. C. Krämer, "Theory of mind in human-robot-communication: Appreciated or not?," *Kognitive Systeme*, vol. 2013, no. 1, 2013.
- [35] L. Peled-Avron, and J. D. Woolley, "Understanding others through observed touch: neural correlates, developmental aspects, and psychopathology," *Current Opinion in Behavioral Sciences*, vol. 43, pp. 152-158, 2022.
- [36] M. Shiomi, K. Shatani, T. Minato, and H. Ishiguro, "How should a Robot React before People's Touch?: Modeling a Pre-Touch Reaction Distance for a Robot's Face," *IEEE Robotics and Automation Letters*, vol. 3, no. 4, pp. 3773-3780, 2018.
- [37] J. T. Suvilehto, E. Glerean, R. I. M. Dunbar, R. Hari, and L. Nummenmaa, "Topography of social touching depends on emotional bonds between humans," *Proceedings of the National Academy of Sciences* vol. 112, no. 45, pp. 13811-13816, 2015.
- [38] J. T. Suvilehto, L. Nummenmaa, T. Harada, R. I. Dunbar, R. Hari, R. Turner, N. Sadato, and R. Kitada, "Cross-cultural similarity in relationship-specific social

- touching,” *Journal of Proceedings of the Royal Society B*, vol. 286, no. 1901, pp. 20190467, 2019.
- [39] C. J. A. M. Willemse, A. Toet, and J. B. F. van Erp, “Affective and Behavioral Responses to Robot-Initiated Social Touch: Toward Understanding the Opportunities and Limitations of Physical Contact in Human–Robot Interaction,” *Frontiers in ICT*, vol. 4, no. 12, 2017.
- [40] B. Alenljung, R. Andreasson, R. Lowe, E. Billing, and J. Lindblom, “Conveying Emotions by Touch to the Nao Robot: A User Experience Perspective,” *Multimodal Technologies and Interaction*, vol. 2, no. 4, pp. 82, 2018.
- [41] X. Zheng, M. Shiomi, T. Minato, and H. Ishiguro, “What Kinds of Robot's Touch Will Match Expressed Emotions?,” *IEEE Robotics and Automation Letters*, pp. 127-134, 2019.
- [42] M. Shiomi, K. Shatani, T. Minato, and H. Ishiguro, “Does a Robot's Subtle Pause in Reaction Time to People's Touch Contribute to Positive Influences?,” in 2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), Nanjing and Tai'an, China, pp. 364-369, 2018.
- [43] D. A. C. Mejía, H. Sumioka, H. Ishiguro, and M. Shiomi, “Evaluating gaze behaviors as pre-touch reactions for virtual agents,” *Frontiers in Psychology*, vol. 14, pp. 1129677, 2023.
- [44] A. B. Mabrouk, and E. Zagrouba, “Abnormal behavior recognition for intelligent video surveillance systems: A review,” *Expert Systems with Applications*, vol. 91, pp. 480-491, 2018.
- [45] P. Pareek, and A. Thakkar, “A survey on video-based human action recognition: recent updates, datasets, challenges, and applications,” *Artificial Intelligence Review*, vol. 54, pp. 2259-2322, 2021.
- [46] M. Shiomi, K. Nakagawa, K. Shinozawa, R. Matsumura, H. Ishiguro, and N. Hagita, “Does A Robot’s Touch Encourage Human Effort?,” *International Journal of Social Robotics*, vol. 9, pp. 5-15, 2016.
- [47] S. Nishiguchi, K. Ogawa, Y. Yoshikawa, T. Chikaraishi, O. Hirata, and H. Ishiguro, “Theatrical approach: Designing human-like behaviour in humanoid robots,” *Robotics and Autonomous Systems*, vol. 89, pp. 158-166, 2017.
- [48] E. Fuoco, “Could a robot become a successful actor? The case of Geminoid F,” *Acta Universitatis Lodzianis. Folia Litteraria Polonica*, vol. 65, no. 2, pp. 203-219, 2022.
- [49] M. Cooney, M. Shiomi, E. K. Duarte, and A. Vinel, “A Broad View on Robot Self-Defense: Rapid Scoping Review and Cultural Comparison,” *Robotics*, vol. 12, no. 2, pp. 43, 2023.
- [50] D. Sakamoto, and H. Ishiguro, “Geminoid: Remote-controlled android system for studying human presence,” *Kansei Engineering International*, vol. 8, no. 1, pp. 3-9, 2009.
- [51] D. F. Glas, T. Minato, C. T. Ishi, T. Kawahara, and H. Ishiguro, “Erica: The erato intelligent conversational android,” in Robot and Human Interactive Communication (RO-MAN), 2016 25th IEEE International Symposium on, New York, NY, United States, pp. 22-29, 2016.
- [52] M. Shiomi, H. Sumioka, K. Sakai, T. Funayama, and T. Minato, “SŌTO: An Android Platform with a Masculine Appearance for Social Touch Interaction,” in Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction, Cambridge, United Kingdom, pp. 447–449, 2020.
- [53] R. Yu, E. Hui, J. Lee, D. Poon, A. Ng, K. Sit, K. Ip, F. Yeung, M. Wong, and T. Shibata, “Use of a Therapeutic, Socially Assistive Pet Robot (PARO) in

Improving Mood and Stimulating Social Interaction and Communication for People With Dementia: Study Protocol for a Randomized Controlled Trial,” *JMIR research protocols*, vol. 4, no. 2, pp. e4189, 2015.

- [54] N. Yoshida, S. Yonemura, M. Emoto, K. Kawai, N. Numaguchi, H. Nakazato, S. Otsubo, M. Takada, and K. Hayashi, “Production of character animation in a home robot: A case study of lovot,” *International Journal of Social Robotics*, vol. 14, no. 1, pp. 39-54, 2022.