

Touch Me Right: Lateral Preferences During Touch in Human-Robot-Interactions

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Abstract—This study investigated the influence of behavior variations in a robot-initiated greeting. Previous studies on the physical interaction between humans and robots typically focused on constructing behaviors to increase the perceived naturalness of the interaction. The specific parameters of the physical contact were of secondary interest. The experiments in our study were designed to mainly focus on the physical aspect of the robot’s interaction with the participants. We varied two parameters of our interaction, which consisted of a shoulder tap to initiate a greeting by the robot. This scenario was selected to withdraw the robot from the participant’s awareness as much as possible. The parameters were the timing of the vocal salutation as well as an optional social cue in the form of a waving motion the robot executed when the participant looked at it after the shoulder tap. The results of the experiments showed, contrary to our predictions about the influence of timing and the performance of greeting motion, that those parameters affect the perceived naturalness of the participants in no significant captivity. Our results showed that in the conducted experiments, the most influential factor on the participants was the shoulder (left or right) on which the robot tapped them.

I. INTRODUCTION

In the recent decade, research into HRI (Human-Robot Interaction) became increasingly popular [1], [2], [3], [4]. Previous research has already established that emulating human interactive traits like speech, gaze, and gestures can improve the emotional response of humans when interacting with robots [5]. Besides purely contact-less interaction, which is needed for collaborative robots and assistants, robots can, due to their embodiment, make use of physical contact to convey intentions non-verbally. But in comparison to the contact-less modalities of interaction, the field of physical interaction between robots and humans is an approach which exploration started more recently [6], [7]. In the meantime, more researchers investigated the potential of physical touch interaction to augment interaction between robots and humans and make them appear more natural to humans [8], [9], [10], [11], [12].

However, most of this research considers situations where the interaction between humans and robots was already initiated. A key aspect is still what kind of behavior from a robot can be perceived as acceptable to humans when the robot initiates the interaction. Direct physical contact is one of the most intimate forms of contact a human can allow a peer to enact on oneself. It, therefore, needs to be established carefully, especially when the robot is initiating the physical

interaction and the human is not previously aware of the robot’s attempt.

It is, therefore, fundamental to understand the underlying rules for natural robot-initiated physical interaction besides the sole use of physicality for reassurance purposes during an ongoing interaction.

Based on this rationale, we designed an experiment to evaluate the influence of the variation of two behaviors on the perception of the human passive interaction partner. The scenario is a shoulder tap as a part of a greeting behavior. In this research, we investigated the influence of the timing of the salutation relative to the moment of the shoulder tap, as well as the possible positive impact of a social cue, which; for our case, we decided to be a waving motion with the non-touching arm of the robot.

Our initial prediction included the observation of a positive response to the execution of a social cue as well as a preference for a specific timing of the salutation. Still, our collected data could not support these expectations. The data, however, confirmed our third assumption, which predicted that participants would express a dominant or preferred side for the robot to interact with them. This couldn’t only be observed on a per-participant basis but showed a strong correlation over the complete pool of participants.

Based on these results, we discuss possible causes for this outcome, as well as possible limitations and linking points to more in-depth future experiments.

II. BACKGROUND

Research in the field of HRI is currently of great interest internationally, fueled by the near-term need for robotic service workers in fields like nursing to help with physically demanding tasks such as the movement of patients but also to help, especially in elderly care to interact with patients in a cognitively exercising way to ease the effects of degenerative conditions like dementia. Currently, the main focus in this field lies on verbal interaction partly with an embodied component. Those research aims to design verbal communication with humans as naturally as possible as one major part of the functional repertoire for robots intended for HRI. This research aims to provide insights into the next step of HRI, where other researchers designed conversational interactions that are natural to humans, the next step should be to elucidate how robots can physically interact with humans when the interaction leads to physical contact. A particular case here is when the interaction will consist of an operation that needs human trust, such as being lifted or carried by a robot. We think that this research is one of

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the first steps for contact-based research in HRI as it can be found in the survey of Avelino et al. [13]. Kyrrarini et al. [14] in 2021 surveyed the current state of robotic research in the healthcare field, assessing future needs in this sector. From their results, it can be noticed that currently, not much focus is brought to the actual point of physical interaction between a patient and a robot to the degree that exceeds the exchange of objects. As in earlier research for verbal communication between a robot and a human, we know that an introduction is essential to build up an initial degree of trust or intimacy so that the human feels comfortable interacting with the machine in a physical way. Analog to this, our research assumes that this is also the case when it comes to physical interaction between humans and robots and even to a greater degree when the interaction, later on, relies on the trust of the human in the robot's capabilities.

III. SYSTEM DESIGN

A. Hardware

Robot: For our experiments, we used Sciurus17 Figure 1, a dual 7-DoF upper body humanoid robot from RT Corporation [15]. In addition to the two arms, the robot also has a rotatable wrist and a head that allows that is articulated with two additional servos for yaw and pitch. This robot was chosen due to its reasonable price, humanoid morphology with neutral facial features, and the before mentioned dual arm arrangement. For our experiment, this system showed the highest compatibility for physical interaction, range of motion, and visual neutrality that was needed to receive meaningful feedback from our participants.

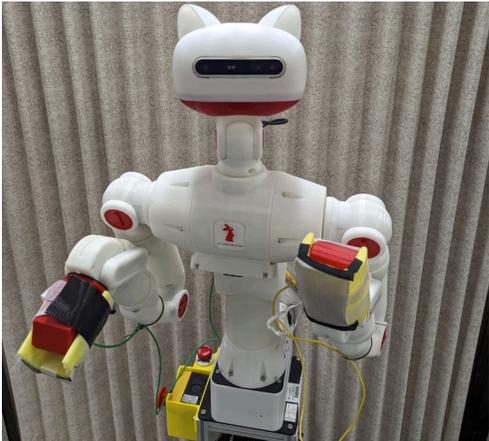


Fig. 1. This image shows the Sciurus17 robot from RT Corporation.

Motion Tracking: For the 3-dimensional tracking of the participants, we used the Azure Kinect DK from Microsoft and its body tracking library. The camera was externally positioned during the experiments to oversee the scene and track the participants. In the second step, the participants' position was projected into the robot frame using an AprilTag marker attached to the robot and in the camera's field of view. We considered several alternative 3D camera solutions, but the Azure Kinect showed the most significant intersection

with our requirements for space regarding its field of view and stability of its body detection library [16], [17], [18].

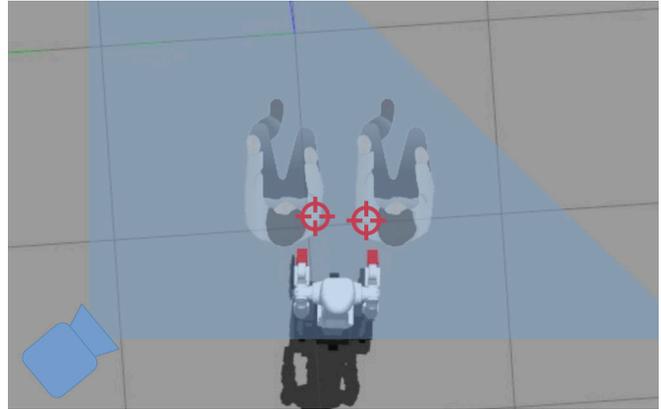


Fig. 2. This image illustrates the arrangement of the 3D camera for our experiment.

Sensors: To detect when touching the participant's shoulder, we used a capacitance-based touch sensor developed by Hidenobu Sumioka [19], which we attached to both of our robot's end-effectors. We decided to use additional sensors over the robot's torque feedback as, in this specific scenario, we could achieve faster detection with the sensors, which leads to a lower load on the participants' shoulders and, therefore, a more comfortable experience.

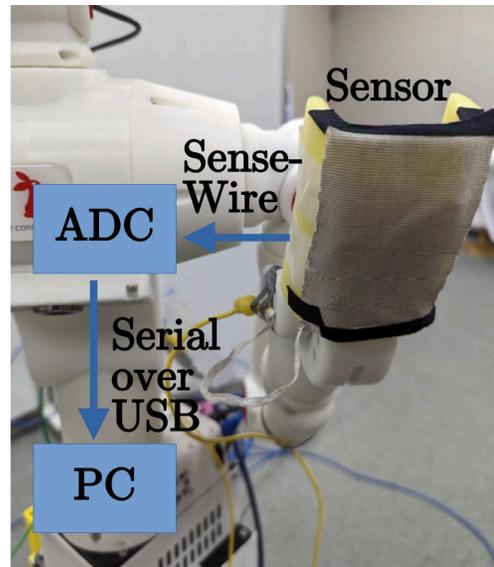


Fig. 3. This image shows the sensor used to detect the touch with the participant's shoulder.

B. Software

Communication Middleware: The three subsystems of our experiment setup are all based on ROS to speed up the development cycle and simplify the addition of new components. This choice drastically reduced the work needed to distribute the system onto three computers. The robot's

embedded PC was the primary system, which ran the manipulation planning software. The vision system runs on a different Desktop PC due to the need for a dedicated graphics card for the body tracking library. The experiment control nodes ran on a notebook. The notebook, however, didn't need high computational power as the control node only called services and wrote the results to the hard disk.

Vision: Our vision system was based on the Azure Kinect DK from Microsoft, and we used its Azure Kinect Body Tracking SDK to detect the participants in 3D space. This detection was relative to the camera; we used fiducial markers to transform it into the robot space in a separate step. The general tracking quality of this system was commonly high, but it also detected the robot's features as a possible person. To distinguish between the participant and the robot, we first transformed all detections into the robot space. We then rejected those matches which occupied the same area as the robot.

Behavior: Our *Social Cue* behavior which we optionally executed after the participant turned to the robot after the should tap, was a waving motion. In our preparations, we tried a multitude of different movements. The goal was to select a commonly understood hand gesture that signals a greeting, which was also compatible with our robot's morphology. From our set of feasible motions, we selected an upright oscillating rotation with the end-effector, which is not used for the current touch interaction. The two states are shown in Figure 4. The robot moves between these two states within one second. The midpoint of the rotation was selected as the same that was used to orient the head toward the participant to emulate eye contact and, thereby, attention. This behavior could then be triggered if needed based on the current permutation in the process of running the experiment.

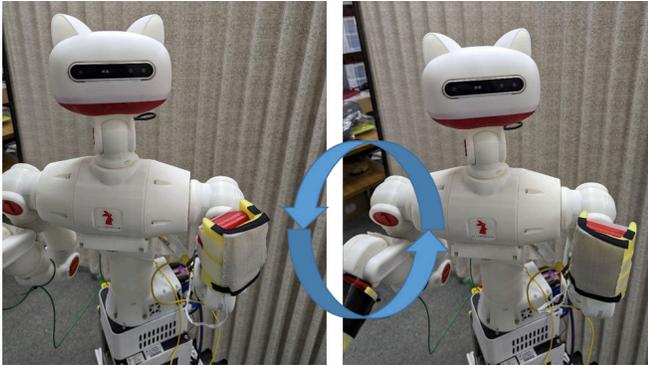


Fig. 4. This image illustrates the two states between which the robot is oscillating to emulate a waving motion.

The *Touch Timing*, which is illustrated in Figure 5, was pre-calculated. To determine a viable timing for the salutation before the touch, we considered testing, with up to what velocity the robot can touch a participant's shoulder so that the interaction was not regarded as irritating. When then estimated how long the interaction would take using this velocity to travel through the safety clearance between the robot and the participant. This time turned out to be about

1.5s for moving from the safe position over the participant's shoulder down until the robot's end-effector made contact. The timing for the salutation *During* the touch gets executed at the moment the robot registers, making contact with the participant's shoulder. For the *After* timing, we started a timer the moment when the robot stopped registering contact with the participant and executed the salutation 1.5s after this happened. The greater variation in the timing when the salutation is executed before the touch interaction is due to the considerable low velocity used to initiate making contact with the participant and the different joint configurations, which require slightly deviating amounts of time to approach the participant's shoulder.

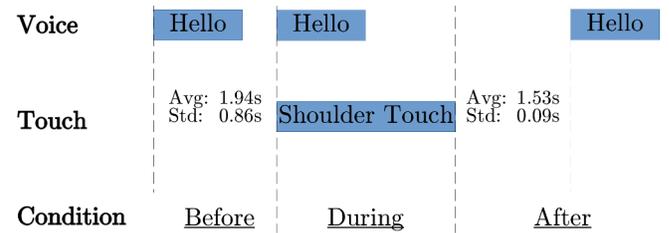


Fig. 5. This figure illustrates the timing of the robot's announcements and the moments of its touch-interaction with the participant.

IV. METHODOLOGY

A. Conditions

For the investigation of the effect of behavioral changes on the perceived the naturalness of the participants, we decided to alter the moment the robot announces his introduction approach via voice. This condition was realized in three different ways. First, the robot announces itself before the touch interaction. Second, the robot introduces itself when the touch of the participant's shoulder is registered, and third, after the robot's end-effector loses contact with the participant's shoulder. A timing diagram and the resulting average timings and their standard deviations can be seen in Figure 5.

The second condition was the execution of a greeting gesture which the robot can execute in 50% of the interactions once the participant turned their upper bodies toward the robot. Specifically, this gesture was designed to recreate a rotational waving motion by raising the non-active arm and rotating its wrist by $\pm \frac{\pi}{6} rad$ on top of the offset used for the head to establish eye contact.

B. Hypotheses and predictions

In the following, we would like to present the hypothesis we constructed from common sense deliberations, as well as self-experiments we conducted with our robot.

Prediction 1: *The participants will respond to the greeting gesture with a measurable amplification of their assessment, at least in the categories of Likeability, Warmth and Naturalness of Timing. Further, is a decrease in the category of Discomfort expected.*

Prediction 2: From our own experiences, it was expected that the participants would react positively when the robot's announcement was played after the participant's shoulder was touched.

Prediction 3: It is expected that candidates would express through their questionnaire answers a preferred shoulder to be interacted with.

C. Procedure

While having a considerable amount of conditions to test and the need for the participant to fill out a questionnaire for each, we tried to conduct the experiments as streamlined as possible to avoid fatigue in our participants. The complete set of experiments finally took about 20 minutes per participant. Because one of our measures was the preference for one shoulder, the starting side was randomly decided for each participant. At this moment, the behavior combinations' permutation was randomly generated. After an introduction to the experiment and the robot, each participant, we conducted the experiment as follows:

- 1) The participant was sitting and oriented in the same direction as the robot.
- 2) The robot touched the participant's shoulder.
- 3) Once the robot released the participant's shoulder, they turned around using the chair to face the robot.
- 4) The participant observed the current combination of behaviors of the robot. After finishing, the robot instructed the participant to return to the initial position. When the robot was done with its instruction, the participant turned back into the initial position, facing the same direction as the robot.
- 5) The participant had time to fill out the questionnaire for this iteration.
- 6) (If all permutations of one side were done, the participant was placed in front of the other robot's other arm.)
- 7) Start again from (1) until all conditions are tested.

D. Questionnaire Measures

Our questionnaire measures consisted of a combination of demographic information and selected scales from the RoSAS and Godspeed [20] questionnaires. The demographic measures inquired from the participants about their age, gender, and handedness. The question for the dominant hand was added as a possible influence on a possible preferred shoulder could be the handedness of the participant. Unfortunately, for our evaluation, it turned out that all except one of our participants were right-handed. From the RoSAS [21] questionnaire, we used the scales for Warmth, Competence, and Discomfort. From the Godspeed questionnaire, we used the scales for likeability and perceived safety. Due to our hypothesis about the timing of a greeting in relation to the moment of the engagement into touch behavior, we added one custom scale consisting of three individual questions. These questions were about how natural the way and timing of speech, the way and timing of touch, and the robot's behavior after the participant turned toward the robot were

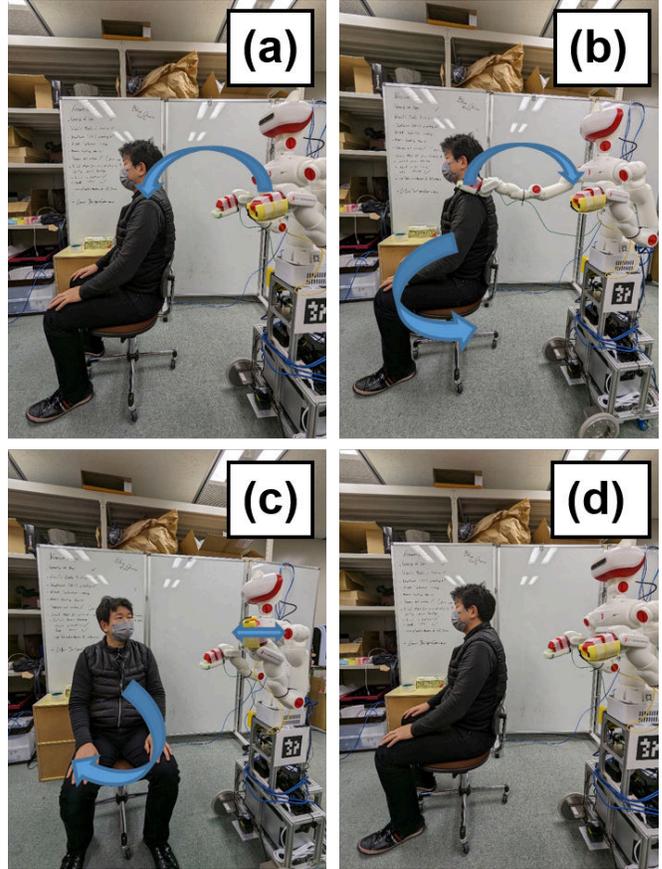


Fig. 6. This image shows the procedure of one touch-interaction. From initial position (a), over the touch and turning phase (b), to the eventual greeting gesture in (c), back to the initial position (d) in which the participant had time to fill out the questionnaire.

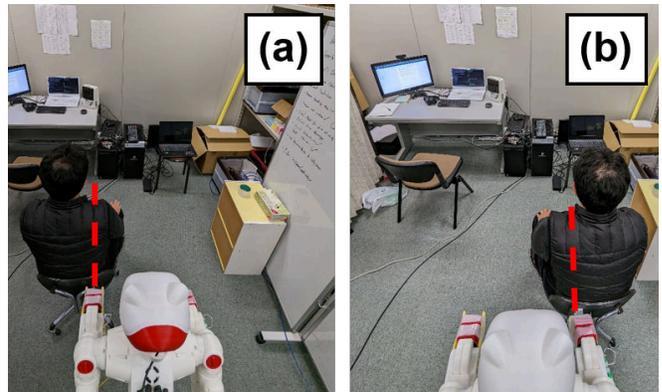


Fig. 7. The interaction was tested with both of the participant's shoulders. The robot was positioned symmetrically (a) & (b) to allow for comparability.

perceived. Each questionnaire was filled out by the participant after each interaction.

E. Participants

From the demographic segment of our questionnaire, we could deduce the following information about the pool of our participants. In total, we had 30 participants. All 30 had Japanese names and were recruited from a Japanese human resource company. By this, we can assume that our participants were socialized in Japan. Regarding gender, we had a 50% split of 15 females and 15 males. The age ranged from 20 to 50 years. The average age was 34.3, with a standard deviation of 10.3 years. The age ranges were 11 participants $\geq 20 < 30$, 7 participants $\geq 30 < 40$ and 12 participants $\geq 40 \leq 50$. In the age group $\geq 20 < 30$, our participant group consisted of five females and six males. In the age group $\geq 30 < 40$, our participant group consisted of four females and three males. In the age group $\geq 40 \leq 50$, our participant group consisted of six females and six males. The shoulder with which the experiment started was randomly selected for every participant. Over all 30 participants, the distribution was 13 starting on the left and 17 starting on the right shoulder. Regarding the handedness, which could have been essential data for a possible explanation for one of our predictions, we could assess that 29 of our 30 participants were right-handed, which is a very lopsided distribution. With an exception for handedness, our pool of participants had a sufficient distribution of demographic properties for a representative experiment.

V. RESULTS

A. Verification of predictions

Tables I-VI contain the average and the standard error (S.E.) of the questionnaire results. We conducted a three-way ANOVA with three factors: direction, cue, and timing for all measurements.

TABLE I
WARMTH

Warmth	Left Shoulder		
	Before	During	After
Cue	Avg: 3.97 S.E.: 0.75	Avg: 3.97 S.E.: 0.72	Avg: 3.83 S.E.: 0.72
No Cue	Avg: 3.93 S.E.: 0.88	Avg: 3.88 S.E.: 0.77	Avg: 4.01 S.E.: 0.73

Warmth	Right Shoulder		
	Before	During	After
Cue	Avg: 4.16 S.E.: 0.77	Avg: 4.33 S.E.: 0.82	Avg: 4.19 S.E.: 0.76
No Cue	Avg: 4.24 S.E.: 0.77	Avg: 4.11 S.E.: 0.81	Avg: 4.13 S.E.: 0.85

In the analysis of the competence, the analysis results did not show significant differences in all factors: the direction factor ($F(1, 29)= 0.928, p=0.343, \eta^2 = 0.031$), the cue factor ($F(1, 29)= 0.031, p=0.862, \eta^2 = 0.001$), the timing factor ($F(2, 58)= 1.030, p=0.363, \eta^2 = 0.034$), the simple interaction effect between direction and cue ($F(1, 29)=$

TABLE II
COMPETENCE

Competence	Left Shoulder		
	Before	During	After
Cue	Avg: 3.94 S.E.: 0.61	Avg: 4.08 S.E.: 0.57	Avg: 3.88 S.E.: 0.58
No Cue	Avg: 3.97 S.E.: 0.70	Avg: 3.91 S.E.: 0.58	Avg: 4.04 S.E.: 0.68

Competence	Right Shoulder		
	Before	During	After
Cue	Avg: 3.83 S.E.: 0.71	Avg: 4.36 S.E.: 0.60	Avg: 4.11 S.E.: 0.66
No Cue	Avg: 4.10 S.E.: 0.61	Avg: 4.05 S.E.: 0.66	Avg: 4.04 S.E.: 0.59

TABLE III
DISCOMFORT

Discomfort	Left Shoulder		
	Before	During	After
Cue	Avg: 2.61 S.E.: 0.64	Avg: 2.13 S.E.: 0.52	Avg: 2.24 S.E.: 0.74
No Cue	Avg: 2.31 S.E.: 0.64	Avg: 2.33 S.E.: 0.71	Avg: 2.14 S.E.: 0.63

Discomfort	Right Shoulder		
	Before	During	After
Cue	Avg: 2.45 S.E.: 0.76	Avg: 2.13 S.E.: 0.55	Avg: 2.39 S.E.: 0.65
No Cue	Avg: 2.29 S.E.: 0.68	Avg: 2.24 S.E.: 0.59	Avg: 2.43 S.E.: 0.83

0.220, $p=0.643, \eta^2 = 0.009$), the simple interaction effect between direction and timing ($F(2, 58)= 0.800, p=0.454, \eta^2 = 0.027$), the simple interaction effect between cue and timing ($F(2, 58)= 1.919, p=0.156, \eta^2 = 0.062$), and the two-way interaction effect ($F(2, 58)= 0.651, p=0.525, \eta^2 = 0.022$).

In the analysis of the warmth, the analysis results showed a significant difference in the direction factor ($F(1, 29)= 8.052, p=0.008, \eta^2 = 0.217$). The other factors did not show significant differences: the cue factor ($F(1, 29)= 0.110, p=0.742, \eta^2 = 0.004$), the timing factor ($F(2, 58)= 0.096, p=0.909, \eta^2 = 0.003$), the simple interaction effect between direction and cue ($F(1, 29)= 0.584, p=0.451, \eta^2 = 0.020$), the simple interaction effect between direction and timing ($F(2, 58)= 0.057, p=0.945, \eta^2 = 0.002$), the simple interaction effect between cue and timing ($F(2, 58)= 0.737, p=0.483, \eta^2 = 0.025$), and the two-way interaction effect ($F(2, 58)= 0.567, p=0.571, \eta^2 = 0.019$).

In the analysis of the discomfort, the analysis results did not show significant differences in all factors: the direction factor ($F(1, 29)= 0.065, p=0.800, \eta^2 = 0.002$), the cue factor ($F(1, 29)= 0.161, p=0.692, \eta^2 = 0.006$), the timing factor ($F(2, 58)= 1.632, p=0.204, \eta^2 = 0.053$), the simple interaction effect between direction and cue ($F(1, 29)= 0.152, p=0.700, \eta^2 = 0.005$), the simple interaction effect between direction and timing ($F(2, 58)= 1.436, p=0.246, \eta^2 = 0.047$), the simple interaction effect between cue and timing ($F(2, 58)= 1.469, p=0.239, \eta^2 = 0.048$), and the two-way interaction effect ($F(2, 58)= 0.160, p=0.852, \eta^2 = 0.006$).

TABLE IV
LIKABILITY

Likability	Left Shoulder		
	Before	During	After
Cue	Avg: 4.51 S.E.: 0.38	Avg: 4.56 S.E.: 0.34	Avg: 4.59 S.E.: 0.38
No Cue	Avg: 4.49 S.E.: 0.51	Avg: 4.45 S.E.: 0.31	Avg: 4.70 S.E.: 0.37

Likability	Right Shoulder		
	Before	During	After
Cue	Avg: 4.47 S.E.: 0.43	Avg: 4.79 S.E.: 0.45	Avg: 4.53 S.E.: 0.48
No Cue	Avg: 4.57 S.E.: 0.43	Avg: 4.56 S.E.: 0.48	Avg: 4.51 S.E.: 0.42

TABLE V
SAFETY

Safety	Left Shoulder		
	Before	During	After
Cue	Avg: 4.03 S.E.: 0.59	Avg: 4.07 S.E.: 0.41	Avg: 4.18 S.E.: 0.42
No Cue	Avg: 3.98 S.E.: 0.48	Avg: 4.22 S.E.: 0.39	Avg: 4.36 S.E.: 0.45

Safety	Right Shoulder		
	Before	During	After
Cue	Avg: 4.09 S.E.: 0.53	Avg: 4.39 S.E.: 0.42	Avg: 4.11 S.E.: 0.43
No Cue	Avg: 4.18 S.E.: 0.42	Avg: 4.18 S.E.: 0.40	Avg: 4.08 S.E.: 0.45

In the analysis of the likeability, the analysis results did not show significant differences in all factors: the direction factor ($F(1, 29) = 0.029, p=0.866, \eta^2 = 0.001$), the cue factor ($F(1, 29) = 0.112, p=0.740, \eta^2 = 0.004$), the timing factor ($F(2, 58) = 0.307, p=0.737, \eta^2 = 0.010$), the simple interaction effect between direction and cue ($F(1, 29) = 0.112, p=0.740, \eta^2 = 0.004$), the simple interaction effect between direction and timing ($F(2, 58) = 0.921, p=0.404, \eta^2 = 0.031$), the simple interaction effect between cue and timing ($F(2, 58) = 0.458, p=0.635, \eta^2 = 0.016$), and the two-way interaction effect ($F(2, 58) = 0.190, p=0.827, \eta^2 = 0.007$).

In the analysis of the safety, the analysis results did not show significant differences in all factors: the direction factor ($F(1, 29) = 0.064, p=0.802, \eta^2 = 0.002$), the cue factor ($F(1, 29) = 0.077, p=0.784, \eta^2 = 0.003$), the timing factor ($F(2, 58) = 0.943, p=0.395, \eta^2 = 0.032$), the simple interaction effect between direction and cue ($F(1, 29) = 0.968, p=0.333, \eta^2 = 0.032$), the simple interaction effect between direction and timing ($F(2, 58) = 1.686, p=0.194, \eta^2 = 0.055$), the simple interaction effect between cue and timing ($F(2, 58) = 0.083, p=0.921, \eta^2 = 0.003$), and the two-way interaction effect ($F(2, 58) = 0.738, p=0.483, \eta^2 = 0.025$).

In the analysis of the naturalness, the analysis results did not show significant differences in all factors: the direction factor ($F(1, 29) = 0.191, p=0.665, \eta^2 = 0.007$), the cue factor ($F(1, 29) = 0.847, p=0.365, \eta^2 = 0.028$), the timing factor ($F(2, 58) = 1.763, p=0.181, \eta^2 = 0.057$), the simple interaction effect between direction and cue ($F(1, 29) = 1.142, p=0.294, \eta^2 = 0.038$), the simple interaction effect

TABLE VI
TIMING

Timing	Left Shoulder		
	Before	During	After
Cue	Avg: 4.44 S.E.: 0.74	Avg: 4.60 S.E.: 0.49	Avg: 4.41 S.E.: 0.60
No Cue	Avg: 4.59 S.E.: 0.62	Avg: 4.70 S.E.: 0.68	Avg: 4.71 S.E.: 0.59

Timing	Right Shoulder		
	Before	During	After
Cue	Avg: 4.29 S.E.: 0.52	Avg: 4.97 S.E.: 0.49	Avg: 4.64 S.E.: 0.57
No Cue	Avg: 4.67 S.E.: 0.42	Avg: 4.83 S.E.: 0.56	Avg: 4.42 S.E.: 0.42

between direction and timing ($F(2, 58) = 0.665, p=0.518, \eta^2 = 0.022$), the simple interaction effect between cue and timing ($F(2, 58) = 0.326, p=0.723, \eta^2 = 0.011$), and the two-way interaction effect ($F(2, 58) = 1.195, p=0.310, \eta^2 = 0.040$).

In summary, the statistical analysis only showed a significant difference in the direction factor in the measurement of warmth perspective (Right > Left), which is illustrated in Figure 8. Thus, predictions 1 and 2 are not supported; prediction 3 is partially supported.

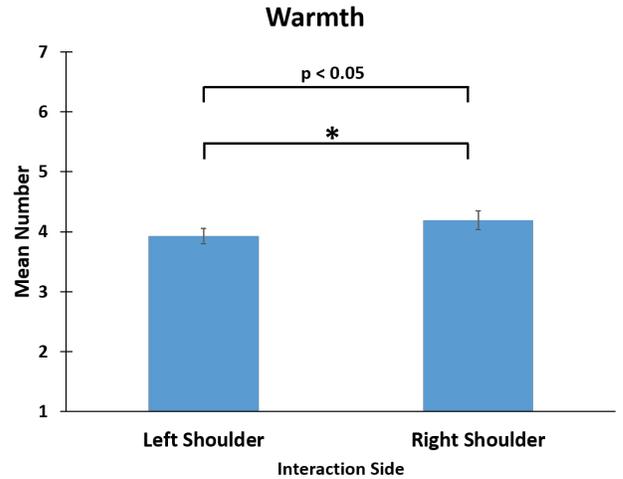


Fig. 8. This diagram illustrates the difference in perceived warmth between an interaction with the participant's left and their right shoulder ($p < 0.05$).

VI. DISCUSSION

A. Design Implications

The experiments in this study could result in insights into our predictions on the effect of salutation timing and social cues on robot-initiated touch interaction. For our robot, the Sciurus17, we could show that neither timing nor an optional social cue in the form of a waving motion caused statistically significant changes in the answers to our survey. However, we could observe a relevant change to the answers regarding the RoSAS Warmth scale depending on the shoulder the robot interacted with. In our experiment, this effect expressed

itself in a preference of our participants to be touched on their right shoulder.

Earlier studies described the influence of timing in touch interaction on the conveyed emotion [22], [23], [24]. Based on the results of our experiments, we could not infer that in the case of touch interaction as part of a greeting, the timing has an influence on the emotional state of our participants. The initially assumed transferability of the mentioned results could not be observed in our experiment. This could be caused by the situational difference of the interaction in our experiment as well as the more machine-like visual appearance of our robot, which in combination, could be less effective in conveying positive emotions by the same means.

B. Limitations and Future Work

A possible generality of our results regarding greeting behaviors should be scrutinized. It needs to be investigated if the discrepancy between our results and previous research about the effect of differences in touch timing could result from the shape of the robots used for the experiments. The reported naturalness of greeting behavior as an elementary part of the establishment of physical interaction could be sensitive to the perceived equality of the involved parties. This could cause variations in the effectiveness of touch timings based on the chosen morphology of the robot. Our robot is arguably relatively neutral in its appearance. It could be considered the middle ground between a traditional robot with a focus on task execution and a realistic android with an emphasis on conveying a natural human image. Therefore it should be considered to repeat the experiment with more robots with different positions on the spectrum of physical appearance. It remains assumed that the response to specific social interactions will vary in this case. Besides this aspect, the pool of participants was also homogeneous in several aspects, such as ethnicity and cultural background. The terms for physical contact and the rules for acceptable greets can change drastically between cultures; thereby, a more culturally diverse pool could result in deviating results.

VII. CONCLUSION

In this study, we investigated the relationship between touch timings, usage of social cues, and choice of the body part on the perceived likeability, safety, warmth, competence, and discomfort for a greeting behavior, which included physical contact. Albeit social interactions between humans and robots are of increasing interest in the domain of social robots, fundamental research about the aspect of robot-induced physical interaction is still sparse. Therefore, we selected this realistic scenario of a robot-initiated interaction.

We found that for our robot, the timing and the usage of a social cue in the form of a waving motion have no significant influence on the perceived naturalness in our test group. However, we found that participants generally preferred their right shoulder when being touched by our robot. Based on these analyses, we could conclude that, at least for our type of robot and interaction, timing and social cue do not convey

a more natural perception to the participants but that the selection of where to touch them can make them feel more comfortable.

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