2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
Madrid, Spain, October 1-5, 2018

The Power of a Hand-shake in Human-Robot Interactions

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Abstract— **In this paper, we study the influence of a handshake in the human emotional bond to a robot. In particular, we evaluate the human willingness to help a robot whether the robot first introduces itself to the human with or without a handshake. In the tested paradigm the robot and the human have to perform a joint task, but at a certain stage, the robot needs help to navigate through an obstacle. Without requesting explicit help from the human, the robot performs some attempts to navigate through the obstacle, suggesting to the human that it requires help. In a study with 45 participants, we measure the human's perceptions of the social robot Vizzy, comparing the handshake vs non-handshake conditions. In addition, we evaluate the influence of a handshake in the prosocial behaviour of helping it and the willingness to help it in the future. The results show that a handshake increases the perception of Warmth, Animacy, Likeability, and the tendency to help the robot more, by removing the obstacle.**

I. INTRODUCTION

Handshaking is the default greeting ritual between humans in western civilizations, and frequently the first form of interaction between people. It is a powerful non-verbal behaviour that can influence how individuals perceive social interaction partners and even their interest in future interactions [1]. In fact, studies [2] have shown that people make personality judgments based on handshakes and that the way one performs a handshake has a strong impact on the perceived employment suitability [3] in recruitment tasks. Other studies [4] have also claimed that handshakes influence negotiation outcomes and promote cooperative behaviour.

In our view, social robots should be able to perform and understand human norms and social rituals if they are to be acknowledged as influential parts of society. Applications of robot assistants include those of guides, negotiators, and coaches, roles where trust is critical. Furthermore, current applications for social robots go towards human-robot collaboration as it allows the exploitation of the complementary skills that humans and robots have through an optimal division of tasks. Interestingly, non-verbal cues seem to have an important role in human-robot teamwork [5], not only do people expect these social cues to convey the mental model of the robot, but also the robot should understand the same cues in humans.

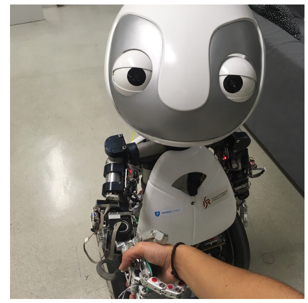

Fig. 1. Vizzy greeting a participant with a handshake.

As a result, we have conducted a user study that attempts to measure the impact of handshakes by the Vizzy robot (Fig. 1) in a task-based scenario. To our knowledge, this constitutes the first investigation of how the perception of a social robot is influenced by a handshake. This is evaluated in the context of finishing a task by the person and the robot. Moreover, we also analyse the helping pro-social behaviour [6], which is not mandatory for the success of the person's task. We believe that this is the first attempt at studying the effects of a robot handshake in a situation were people do not need to cooperate with the robot to succeed.

The results revealed that participants in the Handshake condition evaluated the robot as more warm, animated and likeable and were more willing to help it in the future compared to participants in the No Handshake condition. Overall, this paper contributes to the Human-Robot Interaction (HRI) community by reporting some of the effects a handshake might have and emphasizes the urge to explore further questions related with this powerful non-verbal behaviour.

The remainder of this paper is organized as follows. In Section II we discuss several works that focus on human-robot handshakes from technical and user study perspectives. Section III discusses the hand design of our robot and the necessary steps we took in order to implement a simple, yet reliable and comfortable handshake for users. Our user study is described in Section IV. We formulate our hypotheses, describe the experimental procedure and present the results. We then analyse the results in Section V. In Section VI we present our conclusions and ideas for future work.

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Work supported by Portuguese funds (FCT) through projects UID/CEC/50021/2013, AMIGOS (PTDC/EEISII/7174/2014), AHA (CMUP-ERI/HCI/0046/2013) and PhD grants SFRH/BD/133098/2017, SFRH/BD/118031/2016, and by European projects RAGE (H2020-ICT-2014-1/644187), and LAW TRAIN (H2020-FCT-2014/653587)

II. RELATED WORK

A. Willingness to help a robot

Currently, social robots have limitations that hinder the attainment of objectives (like navigating to a point in space) in non-structured scenarios. A way to overcome these limitations is to have a human helping the robot. Both humans and robots can benefit from helping each other since their strengths and weaknesses might be complementary, resulting in "*symbiotic relationships*" [7].

Several works study humans' willingness to help robots. On [8] a receptionist robot leads people through a building and brings them coffee, asking for help when there is a low probability of completing a task successfully. The robot's navigation capabilities are thus improved by shortening planning times and allowing it to use elevators. The study states three variables that affect the willingness to help: interruption of busy people, the frequency of requests to the same person, and whether there is anyone else available nearby. [9] attempts to increase the willingness of humans to help a robot by making participants perceive the robot's emotional state as similar to their own. The robot adapts to the participants' emotional state using verbal utterances and facial expressions. Results show that adapting to users emotional state significantly increases their willingness to help the robot. The study of [10] tested factors that might impact the eagerness to help a robot. Users demonstrated significantly more willingness to help with smaller requests, when they were more familiar with the robot and when the robot was more polite.

B. Touch and its role in HRI

Touch is one of the primary forms of interaction between humans, and is essential for social communication and well-being. With such a role in human relationships, it comes as no surprise that researchers are studying the possibilities of using touch in human-computer and human-robot interaction. Touch has such a powerful effect on people that it has been shown to increase trust and affection, improve bonds between humans and robots, and even affect physiological responses [11]. For instance, during a study with an animal like social robot [12], participants showed decreased levels of anxiety, respiratory rate, and heart rate while touching it. However, given its power, one can not tackle the usage of touch on robotics naively. For example, a study [13] showed that people displayed increased electrodermal arousal and slower response times if they had to touch a robot in a more private and socially restrictive body part, noting that people apply social norms in human-robot touch. To make educated decisions on where to place touch sensors and to study similarities between human-human and human-robot touch interaction [14] reports a user study with the NAO robot that maps touch behaviours and areas to people's emotions.

Some studies also evaluated the power of touch on pro-social behaviours [6]. A recent study [15] weakly suggests that participants hugged by a robot donate more money than participants that did not receive a hug. Another study [16] showed that touching and getting touched by a robot during a simple and monotonous task facilitated participants' efforts.

These examples show the potential of touch in Human-Robot Interaction but also warn researchers that haptic devices and haptic capable robots must be carefully designed.

C. Human-Robot handshaking

Besides being an exciting challenge from a technical point of view [17], [18], human-robot handshakes are also important from an interaction perspective. For instance, [19] has shown that human-robot handshakes affect the perceived arousal and dominance.

An earlier study [20] analysed the performance of a remote handshake through a telepresence device (with audio and video). Results showed a significantly stronger feeling of closeness and friendliness when the handshake was involved compared to a situation with no handshake. Another study [21] examined the effect of performing a handshake before engaging in a single issue distributive negotiation, where a negotiator performed their role through "Nao" humanoid robot. The study reports that the shaking of hands resulted in increased cooperation and economic results that were more beneficial to both.

These studies provide valuable information about human-robot handshakes. However, to our knowledge, no study exists addressing how a human-robot handshake before a task affects the participants' perceptions of the robot's social and physical attributes, their help behaviour, and their willingness to help in the future.

III. DESIGNING THE ROBOT'S HANDSHAKE

A. The robot: Vizzy

In the experiments, we used Vizzy (Fig. 1) [22], a differential drive mobile robot with a humanoid upper torso and 1.3 m height, built at ISR-Lisboa/IST with a total of 30 Degrees of Freedom (DoF). Using biologically inspired control algorithms for the head [23], Vizzy is able to perform human-like gaze actions through head pan & tilt movements and eyes tilt, vergence and version motions. Vizzy's arms and torso have a total of 23 DoFs. Its hands have four subactuated fingers controlled as follows: one motor for the thumb, other for the index finger, and one motor for both remaining fingers. Twelve tactile force sensors [24] are distributed as shown in Fig. 2: one sensor per phalange and two at the fingertips. The force sensors are composed of a Hall effect sensor and an elastometer cover with an embedded magnet that provides a skin-like touch feeling. Readings from these sensors are not used on this work. Each one of Vizzy's eyes has an RGB camera used for perception of the environment. The two laser scanners on Vizzy's base allow it to detect obstacles and localize itself during navigation. The loudspeaker and microphone also improve Vizzy's HRI capabilities.

B. Vizzy's handshake design

Execution of a comfortable handshake in an autonomous way is a challenging task. Humans use visual, haptic and

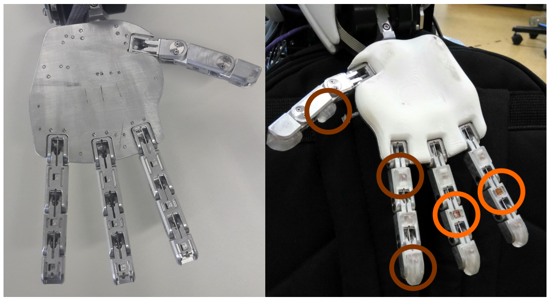

Fig. 2. (Left) Vizzy's initial hand design, without the 3D printed palm. (Right) Vizzy's tactile sensors distributed on its right hand. The image highlights with circles the hall effect sensors without the elastometer and cover (orange) and the of full tactile sensors (brown).

proprioceptive data to perform a proper handshake. Additionally, the touch sensation should be similar to the human skin. In a previous study, we designed a handgrip position controller focusing on user comfort [25]. We asked 35 participants to handshake the robot and verbally told the researchers on how to adjust each of the robot's fingers. We extracted proprioceptive and haptic data in the form of the joint positions (from motor encoders) and force distributions (from finger force sensors). In the current work, we use the handgrip position controller with the mean value of user-chosen finger positions as the desired set-point. To enhance handgrip comfort, we also use a 3D printed plastic cover for the robot's palm after participants reported that touching the metallic palm was slightly uncomfortable. The plastic palm will be replaced by an elastomer one later on. As Vizzy's arm does not have a force and torque sensor, we generate an open-loop signal for the shaking motion of the arm: we generate a sinusoidal signal for the elbow joint and another one with opposing phase on Vizzy's wrist to keep a constant hand orientation. The wrist position had a mean position of $0.84m$, an amplitude of $2cm$ and a frequency of $1.7Hz$. It is worth noting that the arm movement was not subject to study in [25] and was empirically designed. We intend to tackle the arm motion of the handshake in future works.

In summary, the robot's handshake in this work is composed of three sequential primitives which are:

Stretch arm: the robot stretches its arm in the direction of the participant with its fingers slightly flexed,
Handshake: upon receiving the handshake command from the "wizard", the robot closes its fingers in an attempt to grab the user's hand. When finger joints achieve the handshake predefined values, the robot performs the shaking motion by oscillating three times, releasing the user's hand afterward,
Home position: the robot's arm returns to its home position (arm pointing down side-by-side with the robot torso).

Although [17] and [18] have developed handshakes capable of following users' hands and produce compliant shaking motions, our approach based on comfort assessed previously by participants is appropriate in this study's context.

IV. USER STUDY

We conducted a user study to analyse the impact of a handshake from a social robot during a collaborative interaction. We have manipulated how the robot introduced itself to participants, with or without a handshake, in a between-subjects design.

Current findings from the cognitive neuroscience have shown that people evaluate more positively and have different neural responses to interactions that are preceded by a handshake compared to without a handshake [1]. Therefore, we have hypothesized a similar effect in HRI interactions: **H1 - Participants will have a more positive perception of a robot that greets them with a handshake.**

Additionally, touch behaviours have relevant effects on interpersonal relationships at a sociological level, including pro-social behaviours [26]. There are findings showing a simple touch can indeed increase the compliance with different types of requests [27], [28], revealing its positive effect on altruistic behaviours. In HRI, results suggest that the touch of a robot increases motivation to perform the task [29] and improves the emotional state [14] compared to interactions where the robot did not touch the participants. Regarding the effect of handshakes in HRI, literature is still scarce, which has motivated us to further extend it. For instance, a recent study showed that when a telepresent negotiator (by a humanoid robot) performs a handshake, the cooperation level increases [21]. Consequently, we have hypothesized that: **H2 - Participants will be more willing to help a robot that greets them with a handshake.**

A. *Procedure and Task*

The experiment took place at a large "L" shaped open-space room. Participants and different stages of the experiment were placed at two opposite edges of the room without visibility of each other. One area simulated a living room and was used to perform the task with the robot, while the secondary area was used for the briefing, questionnaire, and debriefing. We warned people in the open space not to stare nor come closer to the participant during the experiment.

Each participant started by reading the consent form in the secondary area, while a researcher initiated the video recording in the living room area. After having signed the consent form, the researcher accompanied the participant to the living room area (Fig. 3) and introduced Vizzy, that gazed and greeted with a handshake or just gazed, depending on the experimental condition. Then, the researcher pointed to the sheet with the task instructions, and asked the participant to return to the secondary area when the task was finished. The researcher left the participant alone and came back to the secondary area. The experiment ended with the final questionnaire and a debriefing.

The task consisted of four steps: (1) stand in the initial position and say out loud the voice command "I am going to start"; (2) move to the target position where a picture with several geometric shapes is; (3) count how many triangles there is on the picture; (4) return to the initial position and say out loud "I saw [N] triangles". The instructions sheet

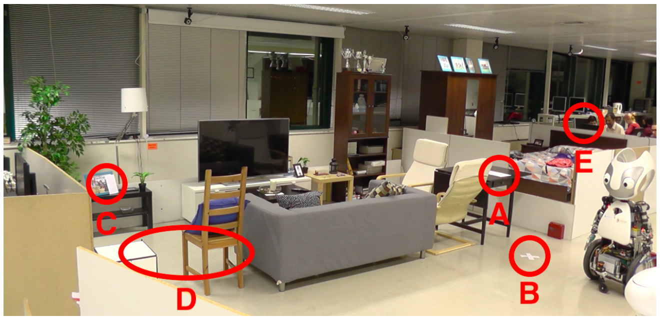

Fig. 3. Setup of the user study. A - Task instructions; B - Initial Position; C - Target picture with geometric shapes; D - Two obstacles for the robot, a box and a chair; E - Researcher controlling the robot

also mentioned the robot would perform the task in parallel. However, the robot was unable to complete the exact same task due to the obstacles in the way.

B. Robot's Behaviours

During the whole experiment, a researcher controlled the robot through a Wizard-of-Oz (WOz) interface. We used this setup instead of a fully automated system since the robot's sensing capabilities are still under development. This way, we avoid erratic behaviours resulting from the robot's sensors and can cope with unforeseen actions of the users.

The WOz controls the robot's movements using Rviz with a set of custom plugins and the robot's speech through a web interface with predefined speech actions. The robot only uses speech if it succeeds in counting the triangles, reporting in the end the number of triangles it saw. Through Rviz and our custom plugins, the WOz can see through one of the robot's cameras and choose fixation points by clicking on the image, controlling the robot's gaze. Gaze movements are biologically inspired and implemented using the control methodologies described in [23]. During the experiment, the robot's gaze obeys some patterns. First, when the robot greets the participants, it gazes at the participants face. While navigating, the robot does not move its head, continuously looking forward. Upon a successful arrival at the objective, the robot will move its head down to simulate the counting of triangles on the picture. Using keyboard WASD keys the WOz sends direct velocity commands to the robot's base. To control the different stages of the handshake we have developed a gestures panel with buttons. These buttons command the robot to stretch its arm, execute the handshake and return the arm to its initial position.

1) Indirect Help Request: While doing its own task and encountering the obstacles, the robot performs an indirect ask for help. To maximize the probability that participants would notice that the robot was struggling, we devised a three-phase behaviour for this situation:

Phase 1: the robot moves back, forth and sideways near the obstacles, simulating the it is trying to pass through them;
Phase 2: if the participant does not help the robot, it stretches its arm forward in the direction of the obstacle while moving back, forth and sideways near the obstacle;
Phase 3: the robot's arm returns to its home position, and the robot repeats the phase 1. If the participant does not help the robot in any way, it returns to the initial position.

C. DEPENDENT MEASURES

As our hypotheses involve perceptions of the robot and help behaviours, we use the following dependent measures:

Robotic Social Attribute Scale (RoSAS) Questionnaire [30] using its three dimensions of Warmth (e.g., "feeling"), Competence (e.g., "capable"), and Discomfort (e.g., "awkward") in a scale from 1 ("Definitely not associated") to 7 ("Definitely associated");
Godspeed Questionnaire [31] using the dimensions of Anthropomorphism (e.g., "fake/natural"), Animacy (e.g., "stagnant/lively"), and Likeability (e.g., "unpleasant/pleasant") in a 7-point semantic differential;
Perceived Closeness based on [32], using a 7-point scale;
Help behaviour was assessed through an objective video analysis, and confirmed with the questions "During the task, did you help Vizzy?" ("Yes/No" answer) and "Why?";
Perception that the robot needed help using the single item question "During the task, did you feel Vizzy needed help?" and a "Yes/No" answer;
Willingness to help the robot in the future using the single item question "In a hypothetical future interaction with Vizzy, in which it needed help, how willing would you be to help it?" and the same 5 possible answers of [10].

D. SAMPLE

We recruited 45 university students, but excluded 2 that, in the Handshake condition, did not touch the robot's hand at all. This decision was made due to our view of the handshake as a touch modality, and left us with 43 participants (23 female, and 20 male) with ages from 18 to 27 years old ($M = 19.86, SD = 1.54$). The Handshake and No Handshake conditions had 21 and 22 participants, respectively.

E. RESULTS

After conducting a normality analysis using the Shapiro-Wilk test, we used the parametric Student's t test for dependent variables with normal distributions, and the nonparametric Mann-Whitney U test otherwise.

1) Perception of the robot: Within the three dimensions of the RoSAS Questionnaire (Fig. 4), we did not use the Discomfort as it presented an extremely low internal consistency (Cronbach's $\alpha = 0.455$). A possible explanation may be the inaccurate translation as the questionnaire was validated in English and applied in Portuguese, the native tongue of the participants. The Warmth and Competence dimensions revealed good internal consistencies (Cronbach's $\alpha = 0.867$ and Cronbach's $\alpha = 0.835$, respectively). Participants in the Handshake condition attributed significantly higher levels of Warmth to the robot ($M = 3.734, SD = 1.124$) compared to participants in the No Handshake condition ($M = 3.038, SD = 1.063$), $t(41) = 2.148, p = 0.038, r = 0.311$. However, there was a non-significant difference between the levels of Competence attributed to the robot in both conditions, $t(41) = 1.733, p = 0.091, r = 0.255$.

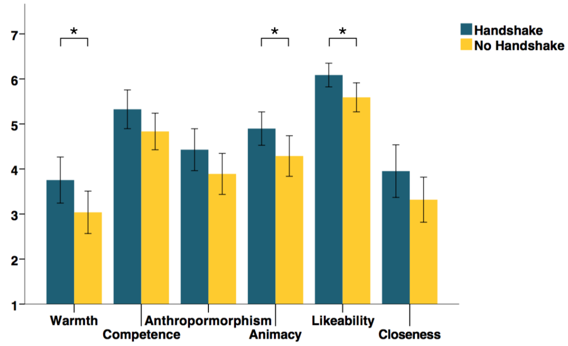

Fig. 4. Averages and standard deviations per condition for Godspeed, RoSAS and closeness measures. $^*p < 0.05$

Regarding the three dimensions of the Godspeed Questionnaire (Fig. 4), Anthropomorphism and Animacy revealed a good internal consistency (Cronbach's $\alpha = 0.838$ and Cronbach's $\alpha = 0.838$, respectively), while Likeability showed only an acceptable internal consistency (Cronbach's $\alpha = 0.790$). There was a non-significant difference between the levels of Anthropomorphism, $t(41) = 1.72, p = 0.093, r = 0.254$, but the difference between the levels of Animacy and Likeability were statistically significant, $t(41) = 2.163, p = 0.036, r = 0.314$ and $t(41) = 2.464, p = 0.018, r = 0.353$ respectively. Participants in the Handshake condition rated the robot with higher values of Animacy ($M = 4.897, SD = 0.814$) compared to the No Handshake condition ($M = 4.288, SD = 1.016$). Similarly, they rated the robot as more likeable in the Handshake condition ($M = 6.086, SD = 0.578$) compared to the values attributed in the No Handshake condition ($M = 5.591, SD = 0.726$).

The difference between the levels of Perceived Closeness attributed to the robot in both conditions was not statistically significant (Fig. 4), $U = 172, p = 0.139, r = -0.225$.

2) Willingness to help: The first measure related with the willingness to help the robot was the objective helping behaviour during the task, which we evaluated in a video analysis. Although in a previous pilot we have found out that people would help differently the robot (e.g. to remove one of the obstacles, to inform the robot out loud the number of triangles, or to show the picture to the robot), in this study the only observed helping behaviour was to remove one of the obstacles. Moreover, we double-checked the objective analysis with the subjective single item question "During the experiment, did you help the robot?", which matched for all participants except one. He considered saying the final command as helping the robot, which was not as it was part of the task and all the remaining participants did it as well.

There was no statistically significant association between the condition (Handshake or No Handshake) and the helping behaviour, $\chi^2(1) = 1.865, p = 0.172, r = 0.208$. Although non-significant, the tendency suggests that more participants helped the robot when it greeted with a handshake (57.1%), compared to when it did not greet with a handshake (36.4%).

Additionally, there was no statistically significant association between the condition (Handshake or No Handshake) and the perception that the robot needed help, $\chi^2(1) = 2.751, p = 0.097, r = 0.253$. Although non-significant, the tendency suggests there were more participants in the Handshake condition that understood the help request (85.6%) than in the No Handshake condition (63.6%).

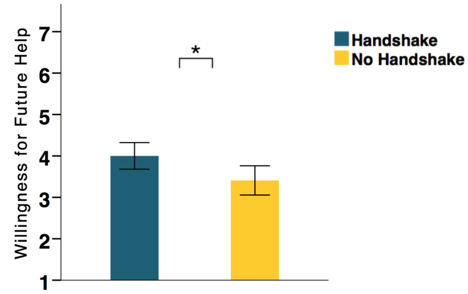

Fig. 5. Averages and standard deviations per condition for the willingness for future help. $^*p < 0.05$

Furthermore, among the 32 participants that understood the robot was in trouble, we also analysed the association between the condition (Handshake or No Handshake) and their helping behaviour, which was not statistically significant, $\chi^2(1) = 3.030, p = 0.082, r = 0.308$. Again, the tendency suggests when the robot was perceived as in need of help, participants in the Handshake condition helped it more (12 out of 18, 66.7%) than participants in the No handshake condition (5 out of 14, 35.7%).

Finally, there was a statistically significant difference between conditions in the willingness for future help (Fig. 5), $U = 138, p = 0.015, r = -0.369$. When asked about a hypothetical future situation where Vizzy was in need of help, participants in the Handshake condition reported significantly higher values ($M = 4.00, SD = 0.154$, "4 - Yes, I would help even if I was busy") than participants in the No Handshake condition ($M = 3.409, SD = 0.170$, "3 - Yes, I would help even if I was somewhat busy").

V. DISCUSSION

Our results support **H1**, which predicted that a robot greeting participants with a handshake would be perceived more positively. Indeed, the handshake had a positive effect on the levels of Warmth, Animacy and Likeability. Although we cannot claim a similar effect on the remaining measures used to assess the robot's perception, i.e. Competence, Anthropomorphism, and Perceived Closeness, we believe their considerable effect sizes and tendencies cannot be ignored.

According to **H2**, we expected the handshake would have positively influenced the willingness to help of the participants. Our results partially support this hypothesis as we can only claim the handshake had a positive effect on participants' willingness for future help. The pro-social behaviour of helping the robot during the task was not statistically significant between conditions. However, the considerable effect sizes and tendencies seem to suggest the handshake might have had a small impact, especially among the participants that understood the robot was needing help.

VI. CONCLUSIONS

In this paper, we explored the impact of the social engagement behaviour of handshaking. The study takes into account the robot's skills match to the challenge of the task. Results show that people greeted with a robot handshake improve their perception of the robot and willingness to help it. These results are relevant for roboticists willing to improve robot's acceptability via different engagement behaviours. Our results provide insights about the power of a handshake on future behaviours, which will play an important role in the accomplishment of regular and symbiotic collaboration.

Nonetheless, the present study has some limitations. First, the handshake behaviour is the most adequate taking into account the design, sensing and control constraints of the robot. We are currently implementing improvements that may provide a more comfortable and warmer handshake, which we believe will have more influence in the perception of the robot and willingness to help. Furthermore, if our robot displayed a highly elaborate and lifelike handshake, we think that participants would not expect it to get stuck during a minor navigation task, given the big discrepancy between the sensed handshake behaviour and the expected robot's skills. Finally, all the participants are from western countries, where handshakes are a standard greeting behaviour, share similar cultural backgrounds and are from the same age group. A more diverse sample is needed to generalize the results.

For future work, we consider that the effects of verbal greeting with a handshake should also be studied. Moreover, we think that handshaking and other forms of social engagement and greeting (for instance waving, fist bumps, high five) should be compared, to better guide roboticists during the process of behavioural design.

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