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The Mental Simulation of a Human–Robot Interaction: Positive Effects on Attitudes and Anxiety toward Robots*

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***Abstract*—In the present study, we experimentally investigated whether the mental simulation of an interaction with the robot NAO would improve human–robot interaction (HRI) acceptance, and would reduce negative attitudes and anxiety toward robots in general. Participants were introduced to the robot NAO and were then instructed to imagine for two minutes either a cooperative or a competitive interaction with the robot or a neutral scenario that did not include an HRI. Our results showed that, independent of its content, imagining contact with NAO improved HRI acceptance. Moreover, after imagining contact with the robot, participants indicated less negative attitudes and less anxiety toward robots in general. These effects were strongest for cooperative imagined contact. Theoretical and practical implications for research on HRI will be discussed.**

I. INTRODUCTION

The rapid advancement of robot technologies has contributed to the fact that robots will soon be part of our everyday life, for instance, as assistance systems, as co-workers, or even as social interaction partners. This development, however, will not simply be accepted without reservation on the part of the human user. To illustrate, Bartneck, Nomura, Kanda, Suzuki, and Kato [1] have demonstrated that people report negative attitudes toward robots and perceive them as threatening. Moreover, in an intercultural comparison, this study has shown that even the Japanese, who might assumingly be more exposed to robots than most people in other countries (e.g., through direct experiences or the media, see [1]) hold negative attitudes toward robots and are concerned with the impact of robots on contemporary societies. Accordingly, it seems that the mere presence of robots in everyday life does not automatically increase acceptance of robots and the willingness to interact with them. Above and beyond, research findings demonstrate that humans not only hold negative attitudes toward technical systems; they often even react with anxiety toward them [2].

Importantly, attitudes and anxiety toward an attitude object strongly influence behavioral responses toward the respective object [e.g., 3, 4, 5]. Anxiety and negative attitudes lead, for instance, to avoidance behavior [6]. To illustrate, attitudes toward computers have been shown to be related to the frequency of computer usage [7, 8]: The more negative people's attitudes toward computers were the more often they evaded using computers. Moreover, research has demonstrated that anxiety toward newly developed technologies negatively impacts how students evolve their skills to effectively use those technologies [9].

Correspondingly, in the social robotics context, Nomura, Kanda, and Suzuki investigated the relationship between negative attitudes and people's communication behavior toward robots [10]. Their findings suggest that individuals who hold negative attitudes toward robots indeed tend to avoid talking to a robot during a human–robot interaction (HRI) compared to users with more positive robot attitudes. This negative impact of robot attitudes on communication avoidance has been confirmed repeatedly [11]. Moreover, anxiety toward robots shows similarly negative effects on the way in which users communicate with robots [11].

Taken together, attitudes and emotions seem to be important factors that influence people's willingness to interact and communicate with robots and that potentially have an impact on the success of HRI. However, to date, there is little research that focuses on strategies to improve humans' attitudes and emotions toward robots.

The current research addresses this gap in the literature: Specifically, we test a new strategy based on social psychological research on intergroup attitudes to improve humans' reactions toward robots. We investigated whether simply asking people to mentally simulate an interaction with a robot would increase acceptance of the robot, and would reduce negative attitudes and anxiety toward robots.

II. RELATED WORK

Humans' reactions toward robots are on some dimensions comparable to humans' reactions toward other human beings. Interactions between humans and robots thus are social in nature and need to be reflected from a social psychological perspective. To illustrate, people make gender-stereotypical inferences about robots using visual or auditory cues, such as a robot's hair length or a robot's voice [12, 13]. Moreover, humans perceive robots even as members of social in- and out-groups, which in turn affects subsequent evaluations of the robot [14, 15]. That is, when people perceive a robot as an out-group member, they evaluate this robot more negatively, are less willing to interact with the robot, and perceive it as less human. Furthermore, people show increased performance in easy tasks in response to the mere presence of a robot [16]. This so-called social facilitation effect is generally known as a typical reaction toward the presence of other humans [17]. These empirical findings demonstrate that robots represent social and not just technical entities.

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Against this background, we reason that particularly findings from social psychological research on human–human interactions can provide us with strategies to influence reactions toward robots. Specifically, a large proportion of social psychological work on attitudes toward and behavior between human individuals has been done in the field of intergroup relations and reactions toward social out-groups. Only recently, one new simple but effective method to improve attitudes and behavioral tendencies toward human members of social out-groups has received a great deal of attention—imagined intergroup contact. Imagined contact is defined as the mental simulation of a positive interaction with an out-group member [18]. Within this paradigm, participants are generally asked to imagine for a few minutes a positive and interesting chat [see 19] or a cooperative task [20] with an out-group stranger. Imagined contact with an out-group member has been shown to improve attitudes toward the out-group as a whole, to reduce anxiety toward the out-group, and to increase intentions to engage in future contact with the out-group [see 19]. Crisp, Husnu, Meleady, Stathi, and Turner have assumed that imagined contact is effective because it provides people with a behavioral script about out-group contact [19]. In this context, a behavioral script means a (imagined) sequence of expected behaviors for a given situation (i.e. a social interaction with a specific out-group target person). People are hereby provided with 'knowledge' about behavioral rules in such social situations so that they become more confident about intergroup contact.

In a similar vein, we suggest that the imagined contact paradigm could also help improve attitudes and emotions toward robots. Consequently, it could increase the likelihood of a pleasant HRI. In the present research, we therefore investigate the effects of imagined contact with the robot NAO (Aldebaran Robotics, [21], see Fig. 1) on attitudes and anxiety toward robots. Moreover, we test two different forms of imagined interactions: Cooperative vs. competitive. Research so far has only investigated the effects of an imagined cooperation with a target person because this type of interaction is assumed to be one of the most positive and effective forms of contact [22, 23]. However, similar to interactions between human beings, humans and robots will not always cooperate (e.g., at the workplace). Instead, robots might also be competitors in some cases. Imagining a competitive interaction with a robot might thus serve the function of preparing humans for these types of HRI.

The following hypotheses were tested: We predicted that the mental simulation of a cooperative interaction with the robot NAO as well as the mental simulation of a competitive interaction with NAO would decrease negative attitudes and anxiety toward robots, and would lead to greater HRI acceptance with the target robot. However, as cooperation compared to competition is generally perceived as the more positive and enjoyable form of social interactions, we further assume that imagining a cooperative interaction with NAO will have greater positive effects on the dependent dimensions relative to competitive imagined contact.

III. Method

A. Participants and Design

$N = 66$ German university students (34 men, 32 women) with a mean age of $M = 24.68$ years ($SD = 6.02$) participated in our experiment. They were randomly assigned to one of three experimental conditions: Accordingly, the participants evaluated the robot NAO either after imagining a cooperative interaction with NAO ($N = 26$) or after imagining a competitive interaction ($N = 21$) or, in the control condition, after imagining a neutral scenario that did not include an interaction with the robot ($N = 20$).

Figure 1. The robot platform NAO [21]

B. Procedure and Materials

Participants were tested individually in the laboratory. Before the actual experimental manipulation took place, we created a situation in which the participants perceived themselves and the target robot NAO as members of two different groups so that participants would categorize the robot as an out-group member. Real-world interactions between humans and robots generally take place in a specific social context (e.g., at the workplace) in which robots are probably ascribed a certain 'social role' (e.g., as a co-worker) during the interaction. In the laboratory, in contrast, it is highly likely that participants perceive the robot merely as a target of the study and thus associate no social meaning with the robot. Accordingly, in order to create a more socially meaningful and realistic situation between the participants and NAO, we induced out-group membership of the robot. To do so, we followed the procedure described in [14]. This procedure did *not* differ depending on our experimental condition:

At the beginning, all participants received written instructions about the alleged purpose and the procedure of the experiment. They learned that they would take part in a study on the development of two different language-learning trainings both for robots and humans. Importantly, participants were informed that there would be two groups in the study—each for testing one language-training program—that were labeled with colors: Blue and green. Crucially, participants were told that the robot NAO would belong to the blue group, but not to the green group. After reading the information sheet, all participants were informed that they were randomly assigned to the green group. Additionally, they were reminded that NAO would belong to the blue group to make the robot's out-group membership more salient.

Participants were then introduced to NAO, which served to ensure that all participants across the experimental conditions have comparable mental representations of the robot. Participants watched a short video clip in which the robot greeted them and thanked participants for taking part in the study. Moreover, the robot was physically present in the laboratory during the study but no additional HRI took place. After the introduction, the experimenter asked participants to complete several computerized tasks that were allegedly related to the upcoming language-training test. In fact, these tasks contained our experimental manipulation followed by the dependent measures; no actual language-training test took place. Finally, participants were reimbursed, debriefed and dismissed.

C. Experimental Manipulation

During the first computerized task, we realized our experimental manipulation: Participants read one of three short descriptions of a situation presented on a computer screen and were asked to imagine this situation for two minutes as detailed and lively as possible.

In the *cooperative interaction condition* participants were presented with the following description of a cooperative task with NAO:

You take part in a memory test. Your task is to memorize a series of numbers. NAO also participates in this memory task and is your ***team partner****. The aim of the task is to remember as many numbers as possible correctly in order to obtain a high score.* ***The team*** *with the highest score will be rewarded.*

Accordingly, this scenario emphasized that the participants and the robot would work together as team partners.

In contrast, the participants in the *competitive interaction condition* were asked to imagine that they would compete against the robot:

(…) *NAO also participates in this memory task and is your* ***opponent****. (...)* ***The competitor*** *with the highest score will be rewarded.*

In the *control condition* participants were also asked to imagine the same memory task. This time, however, NAO was not mentioned in the scenario:

You take part in a memory test. Your task is to memorize a series of numbers. The aim of the task is to remember correctly as many numbers as possible in order to obtain a high score. The participant with the highest score will be rewarded.

D. Dependent Measures

Manipulation Check: As a manipulation check, we asked participants to indicate on two 7-point Likert scales how cooperative and how competitive they perceived the situation they had imagined.

HRI Acceptance: To measure HRI acceptance, we asked participants to indicate on 7-point Likert scales how much they would like to meet, talk to, buy and own the robot NAO and whether they would prefer to do several activities (e.g., preparing meals, serving guests, guarding a house) either alone or together with NAO [24]. The nine items formed a reliable index (α = .87).

Negative Attitudes toward Robots: To assess attitudes toward robots in general, we used the Negative Attitudes toward Robots Scale (NARS, [25]). Participants rated the 14 statements that constitute the NARS (e.g., 'I would feel uneasy if I was given a job where I had to use robots.') on 7-point Likert scales. With α = .83 the items formed a reliable index.

Anxiety toward Robots: To measure anxiety toward robots, we adapted the Robot Anxiety Scale (RAS, [26]). On 7-point Likert scales, participants indicated to what extent they would worry about communication capabilities of robots (e.g., 'Conversation with robots may be inflexible'), about behavioral characteristics of robots (e.g., 'What power robots will have'), and about the discourse with robots (e.g., 'How I should talk with robots'). The 10 items formed a sufficiently reliable index (α = .79).

IV. Results

To test our hypotheses, we conducted a series of contrast analyses[1]. Unlike analyses of variance (ANOVA) that provide only an omnibus test of any difference between groups, contrast analyses allow for a more powerful testing, as they constitute significance tests of specific predictions [27]. Contrasts are linear combinations of two or more group means whose coefficients add up to zero. Statistically, a contrast is defined as the sum of each group mean multiplied by the coefficient of each group mean (contrast weight), whereas the contrast coefficients can take any number. However, the contrast coefficients are supposed to reflect the hypothesized structure of mean differences. When no difference between two or more means is assumed, they are assigned equal coefficients, meaning they are weighted equally. When means are assigned different coefficients, the contrast tests for the specified differences between those means. The linear combination of the weighted group means results in an estimated contrast value that can be transformed into a *t*-score. This allows testing for statistical significance of the contrast (for more details see [27]).

A. Manipulation Check

We first of all tested whether participants in the cooperative contact condition perceived the imagined situation as more cooperative compared to participants in the two other conditions. To test this, we conducted a

[1] Because of planned a priori contrasts, we report one-tailed *p*-values.

contrast whose coefficients were +2, -1, -1. The order for this contrast was *cooperation* vs. *competition* vs. *control*. As predicted, participants in the cooperative condition perceived the imagined task as more cooperative (M = 3.81, SD = 1.91) than participants in the competitive (M = 2.35, SD = 1.63) and in the control condition (M = 2.00, SD = 1.62), $t(63) = 3.64$, $p < .001$.

In a second step, we tested whether participants in the competitive contact condition perceived the imagined task as more competitive than the participants in the cooperative and the control condition. We conducted a contrast that was coded -1, +2, -1. The order for this contrast was cooperation vs. competition vs. control. As hypothesized, participants in the competitive condition perceived the imagined task as more competitive (M = 4.33, SD = 2.37) than participants in the cooperative (M = 2.42, SD = 1.86) and in the control condition (M = 2.25, SD = 1.21), t(64) = 4.07, p < .001.

B. Test of Main Hypotheses

For each dependent measure, we conducted a set of simple contrasts. For our three experimental groups, we obtained three contrasts that incrementally tested specified differences across the experimental groups. The order for all contrasts was *cooperation* vs. *competition* vs. *control*. The coefficients for contrast 1 were +1, 0, -1. With this contrast, we tested whether cooperative imagined contact with the robot NAO had a positive effect on the respective dimension relative to the control condition. Contrast 2 was 0, +1, -1, and tested the prediction that imagining competitive contact with NAO would have positive effects on the respective dependent measure compared to the control condition. Contrast 3 was coded +1, -1, 0. Accordingly, we tested the hypothesis that imagining cooperative contact with a robot would have greater positive impact on our dependent dimensions compared to imagining a competitive interaction.

HRI Acceptance: Regarding HRI acceptance, Contrast 1 turned out significant, $t(63) = 2.22$, $p = .02$, indicating that imagining a cooperative interaction with NAO resulted in significantly more HRI acceptance (M = 4.00, SD = 1.42) relative to the control condition (M = 3.08, SD = 1.38). Moreover, results of Contrast 2 demonstrate a significant difference between imagining competitive contact with NAO (M = 3.98, SD = 1.28) and the control condition, $t(63) = 2.12$, $p = .02$. Unlike our predictions, Contrast 3 showed that the effects of imagining cooperative contact on HRI acceptance did not significantly differ from the effects of imagining competitive contact, $t(63) = 0.01$, $p = .50$. That is, both forms of imagining an HRI with NAO equally increased the participants' willingness to get in contact with NAO (see Fig. 2).

Negative Attitudes toward Robots: For negative attitudes toward robots, Contrast 1 again yielded significant results, $t(63) = -2.52$, $p = .01$. That is, cooperative imagined contact with a robot significantly decreased negative attitudes toward robots in general (M = 3.63, SD = 0.84) relative to the control group (M = 4.36, SD = 1.19). Results of Contrast 2 show that competitive imagined contact (M = 4.00, SD = 0.92) did not significantly reduce negative attitudes toward robots compared to the control condition, $t(63) = -1.16$, $p = .13$. The pattern of means indicates, however, that also competitive imagined contact led to improved attitudes toward robots (see Fig. 2), but to a lesser extent than imagined cooperative contact. Contrast 3 yielded no significant difference in attitudes toward robots between the cooperative and competitive imagined contact condition, $t(63) = -1.28$, $p = .10$.

Anxiety toward Robots: With regard to anxiety toward robots, we obtained similar, but more pronounced results. The significant results of Contrast 1 demonstrate that cooperative imagined contact led to reduced anxiety toward robots (M = 3.57, SD = 1.00) compared to the control condition (M = 4.68, SD = 1.05), $t(63) = -3.68$, $p < .001$. Moreover, and in line with our hypotheses, Contrast 2 shows that also competitive contact significantly reduced anxiety toward robots (M = 4.11, SD = 1.01) relative to the control condition, $t(63) = -1.80$, $p = .04$. Contrast 3 demonstrates that cooperative imagined contact with a robot reduced anxiety toward robots more effectively than competitive imagined contact, $t(63) = -1.78$, $p = .04$.

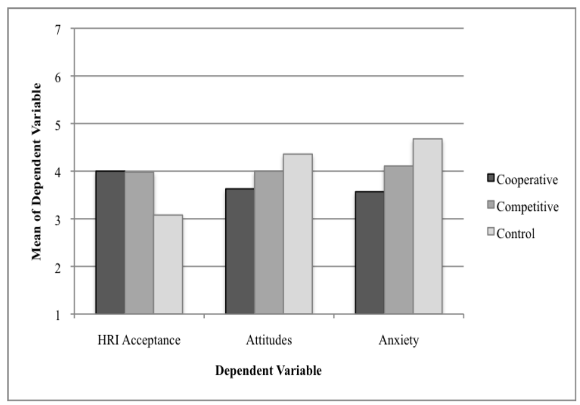

Figure 2. Means of HRI acceptance, negative attitudes and anxiety toward robots as a function of experimental condition.

V. CONCLUSION

In the present experiment we have tested a new psychological strategy to improve humans' reactions toward robots. To do so, we have asked participants to mentally simulate either a cooperative or a competitive interaction with the robot NAO. Moreover, in the control condition, participants imagined a scenario that did not include any interaction with the robot. In line with our hypotheses, results revealed that the mental simulation of both cooperative as well as competitive contact with a robot increased HRI acceptance with NAO compared to the control condition. Moreover, we found that both forms of imagined robot contact reduced negative attitudes and anxiety toward robots. As predicted, cooperative imagined contact had a greater positive impact on attitudes and robot anxiety compared to the competitive imagined contact condition.

Our experiment is the first that has applied this social psychological paradigm of imagined contact [18] to the field of social robotics. With this study, we provided a simple but effective strategy to positively influence psychological factors that are important for the acceptance of robots as part of our everyday lives as well as for the quality of HRI. Importantly, imagined robot contact did not only improve the acceptance of the target robot involved in the simulation task. The positive effects even transferred to attitudes and emotions toward robots in general. Our findings thus document that imagined contact with one specific robot can have a broader impact on human's general evaluative responses toward robots. However, follow-up studies need to investigate imagined robot contact with various robot prototypes to test whether the present positive effects can be obtained independent of the specific robot type and its characteristics (e.g., degree of humanlikeness) used in the simulation task.

Interestingly, although imagining cooperative and competitive robot contact equally affected HRI acceptance with NAO, our results indeed revealed that imagined cooperative (vs. competitive) contact was more effective in influencing attitudes and emotions toward robots in general. This is clearly in line with social psychological work on real and imagined intergroup contact [20, 22, 23] that has demonstrated that cooperation between members of different groups is one of the most effective forms of (real and imagined) intergroup contact. Accordingly, in order to improve attitudes and emotions toward robots in general, the mental simulation of a cooperative interaction between humans and robots would be the recommended strategy. Moreover, our findings give rise to the assumption that imagined cooperative contact with robots not only improves attitudes and emotions toward robots. Previous research has shown that negative attitudes and emotions toward different technologies prevent people from interacting with these technologies [7, 8]. Conversely, we assume that improving attitudes and emotions toward robots could at the same time increase people's general willingness to interact with robots.

However, to prepare users for a specific HRI, it might be useful to use either cooperative or competitive imagined contact depending on the type of the targeted interaction. As mentioned above, imagined contact is thought to provide people with a behavioral script about social interactions [19], which potentially increases people's feelings of self-efficacy and confidence for the upcoming interaction. Accordingly, when humans are supposed to engage, for instance, in a competitive interaction with a robot, mentally simulating a competitive instead of a cooperative interaction with a robot might be the preferred measure, despite the fact that both imagined contact forms equally increase the willingness to engage in HRI. Future studies should test such differential effects of various forms of imagined robot contact directly.

One potential shortcoming of the present research is that we have not investigated the effects of mentally simulating an HRI on participants' reactions in a real HRI. There is, however, evidence that the quality and success of real HRI could benefit from imagined robot contact. To illustrate, social psychological findings have demonstrated that the quality of social interactions is negatively influenced by feelings of anxiety and negative attitudes [28]. Moreover, Nomura et al. have shown that higher levels of robot anxiety are associated with communication avoidance behavior within an HRI [11]. According to these findings, improving attitudes and emotions toward robots by means of imagined robot contact could positively affect people's reactions in real HRI (e.g., their communication behavior) and thus ameliorate real HRI. In support of this assumption, Turner and West have documented that imagining an interaction with an out-group person actually resulted in positive behavioral consequences that are relevant for the quality of real intergroup interactions [29].

However, also other variables than attitudes and emotions potentially influence how humans behave in real HRI, such as anthropomorphic inferences about the robot [30, 31, 32], or expectancies regarding the robot. From our findings, we cannot conclude how these variables are affected by imagined contact with robots. Therefore, future studies investigating imagined robot contact should include further variables that are potentially relevant for the success of HRI. Moreover, further research should focus on long-term effects of imagined robot contact because so far it remains unclear how sustainable the effects of imagined HRI on evaluative reactions toward robots are.

Despite these limitations, the present experiment yielded first evidence that the mental simulation of an HRI is a useful and easy to apply method to improve attitudes and emotions toward robots. Our findings make us optimistic that imagined robot contact could be applied as an effective measure to increase people's willingness to actually engage in HRI and to heighten the acceptance of robots as part of our everyday lives. Further research, however, is underway in order to validate the present findings.

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