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'Human-Robot (Fast) Friendship' as a Tool to Improve Attitudes Towards Robots and Beyond

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Abstract
Drawing on an intergroup contact framework, we investigated the effectiveness of a new human-robot interaction (HRI) procedure—*human-robot (fast) friendship (HRF)*. HRF is a self-disclosure-based interaction between a human participant and a robot, designed to improve attitudes towards social robots and non-contacted secondary human outgroups (e.g., vegetarians, refugees, and individuals with disabilities). Study 1 tested HRF with a humanoid robot among university students ($N=103$), and demonstrated HRF to directly and indirectly improve attitudes towards social robots through greater trust and positive emotions (sympathy and respect). HRF was also indirectly associated with more positive attitudes towards some secondary outgroups. Study 2 replicated the same procedure in a community sample ($N=148$); participants in the HRF condition showed more positive attitudes towards social robots through increased trust and in turn sympathy, compared to both baseline (no contact) and mere exposure (being in the same room with the robot) conditions. In Study 2, we also observed indirect effects on attitudes towards some human outgroups through increased robot sympathy. Findings highlight the importance of friendship potential in HRI effectiveness and point to the potentially broader consequences of HRF in reducing generalized prejudice in humans.

Keywords Human-robot interaction (HRI) · Intergroup contact · Friendship · Self-disclosure · Outgroup attitudes

1 Introduction

Robots are becoming more and more present in our everyday lives, including 'social robots' that directly interact with humans [1], for example, by caring for the elderly, teaching language, or working in service sectors (e.g [2–4]). While the systematic use of robots in both industrial and social contexts stands as a critical asset for the development of societies, concerns regarding the quick integration of robots into daily life are increasing. Many express negative attitudes and avoidance tendencies towards robots, feelings of uncertainty and threat, as well as anxiety in the presence of robots, which may in turn create adversities against the acceptance of robots in various societal contexts (e.g [5, 6]). For example, research examining representative samples in 27 countries indicate that negative attitudes towards robots increased from 2012 to 2017 [7]. Therefore, to achieve a smooth transition into a new world where people are expected to cooperate further with robots and other machines, it is essential to explore effective strategies targeting the reduction of negative attitudes towards robots or the fear of potential harm from the extensive use of robotics (e.g., robophobia) [8–10].

One fruitful avenue to reduce potential negative responses to robots is to bring an intergroup perspective to the study of human-robot interaction (HRI), given that individuals' negative reactions or attitudes towards robots resemble how they would typically react towards human outgroups (e.g [11–13]). A prominent prejudice-reduction strategy in human ingroup-outgroup contexts is the *Intergroup Contact Theory*, which has been found to improve intergroup attitudes across a wide range of groups [14–16]. While a few studies examined HRI within an intergroup contact framework (e.g [12, 17, 18]), these studies mostly (a) used mere exposure or indirect contact rather than direct contact procedures, (b) tested student samples only, and

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(c) assessed a limited range of contact outcomes. We thus aimed to advance this new generation of research (e.g [12, 13]), by testing the 'human-robot (fast) friendship' (HRF) procedure that is designed to generate positive attitudes towards robots, which may even extend to attitudes towards non-contacted human (secondary) outgroups.

1.1 Robots as an 'outgroup' to Humans

Earlier theoretical accounts proposed that HRIs are similar to human-human interactions, since people respond socially to technological devices and attribute various human qualities such as gender, ethnicity, or politeness to non-human entities including robots (e.g [19–21]). However, despite their analogous look to humans, social robots are still evaluated as distinct entities apart from humankind [11], and can be viewed as an 'outgroup' that is similar to typically studied human outgroups such as ethnic minorities or immigrants [12, 13]. Smith et al. [22], for example, argued that "robots' differences from humans lead them to be regarded as members of a potentially competing outgroup" (p. 1). Growing empirical evidence corroborates the suggestion that robots form a distinct social category for humans. For example, compared to human-human interactions, HRI poses greater uncertainty [23] and competitiveness [24]. Similar to how ingroup members would react to outgroup members in traditional intergroup contexts (e.g., based on race and gender), individuals tend to avoid robots physically (e.g [25]), believe that robots hold different values and characteristics than the human ingroup [1, 26], and form a common ingroup identity with other human outgroups when the salience of robots increases [27].

People also experience negative emotions and threats from robots, as they do typically in human ingroup-outgroup interactions (see [28, 29]). For example, similar to how natives perceive realistic threats posed by increasing numbers of newcomers into a country (e.g [30]), individuals may fear that robots would take over their jobs. The increasing use of social robots may also imply threats to the human ingroup at a more symbolic level, by creating an identity or distinctiveness threat to human uniqueness [1, 29, 31]. At an individual level, humans may experience 'robot anxiety' [6, 32], a process similar to 'intergroup anxiety' known as a major precursor of avoidant attitudes and behaviours towards many outgroups (e.g [33]). Overall, these findings suggest that an intergroup relations perspective on HRI may provide useful explanations for understanding humans' attitudes towards robots [13].

Importantly, while the concept of an outgroup can refer to any social group perceived as different from the self or one's ingroup, it is not a uniform construct. Outgroups can vary in perceived distance from the self and ingroup, and people include different outgroups in the self-concept at varying levels of perceived overlap (e.g [34]). Intergroup HRI research has typically treated robots as an outgroup of humans, but as a non-human yet social agent, robots may occupy a qualitatively different or more distal position along this continuum of otherness. While robots elicit social and intergroup-like responses [22], they may not belong to the same psychological category as human outgroups. The present study therefore applies an intergroup framework not necessarily to equate robots with human minorities, but to examine whether a contact strategy effective in human intergroup contexts could result in similar outcomes through similar mechanisms (such as trust and emotions).

1.2 Intergroup Contact as a Theoretical Framework

Intergroup Contact Theory [14, 15] posits that direct contact between group members is likely to reduce prejudicial attitudes mainly through increased positive feelings such as empathy and reduced anxiety towards an outgroup [35]. Longitudinal (e.g [36, 37]), experimental (e.g [38]), and meta-analytic studies [16] provide robust empirical evidence for the effectiveness of positive intergroup contact in ameliorating intergroup relationships. While early research established the effectiveness of contact and the mediating processes that produce prejudice reduction [39], more recent theoretical developments in the field have been devoted to the understanding of how contact effects can be maximized.

1.2.1 Friendships as an Ultimate Form of Contact

The current work tests an enhanced form of intergroup contact by highlighting the '*friendship potential*' which has been suggested as a critical condition for increasing the effectiveness of contact on improving outgroup attitudes [15, 40]. Friendship potential is typically described as the extent to which contact provides a positive, high-quality, reciprocal, and intimate interaction that crosses group boundaries, and potentially maximizes the effects of contact (e.g [41]). When the friendship aspect is highlighted, for example by instigating interpersonal processes like reciprocal self-disclosure and trust between group members [42], such interactions commonly play a more powerful role than superficial contact [43, 44]. Thereby, the recent literature has conceptualized cross-group friendships as an ultimate form of contact that maximizes its benefits (e.g [45, 46]). Previous studies integrating intergroup contact to HRI research have

typically relied on either indirect forms of contact, which does not require a face-to-face interaction (e.g., imagined contact [47]), or more superficial interactions that include mere look or touch [12, 18], and little is known about how HRI could improve attitudes towards robots more effectively.

Studies using experimental methodologies suggest that the 'fast friendship' task, whereby group members gradually self-disclose to each other and interact in a positive environment [48], can effectively capitalize friendship potential in structured intergroup contact. A fast friendship procedure between White and Latino American participants was found to reduce intergroup anxiety in future encounters [38]. Similar research reports the benefits of the fast friendship procedure on improving relationships between Hungarian-Roma people [49], natives-refugees in Germany [50], as well as White (labelled as 'Caucasian' in the work) and African Americans [51].

In the present work, we highlight the role of friendships and reciprocal self-disclosure in the effectiveness of contact (e.g [44]), and examine the first research question: *whether a human-robot fast friendship (HRF) procedure that includes reciprocal self-disclosure*, *positivity*, *and intimacy leads to greater positivity towards robots* (RQ1). Building on previous research showing that friendship potential and self-disclosure foster more positive attitudes towards outgroups than superficial and casual contact (e.g [42]), we expected HRF to increase positivity towards social robots compared to the baseline (no contact) and mere exposure (just seeing the robot without interacting) conditions.

1.2.2 Effects on non-contacted Secondary Outgroups

Another aspect that has not been explored in HRI research is '*secondary transfer effects*'—the generalization of contact effects to non-contacted secondary outgroups. Pettigrew suggested that intergroup contact does not only generalize to the contacted outgroup, i.e., *primary transfer effects*, but it also extends to groups that are not even involved in the direct intergroup interaction [52]. For example, Italian children's contact with immigrants improved their attitudes towards two non-contacted outgroups (the homosexual and disabled) [53]. Similar research in eight European countries showed that contact with immigrants indirectly related to more positive attitudes towards secondary outgroups (homosexuals and Jews) via attitude generalization [54], demonstrating the potential of secondary transfer effects for various outgroups that are similar or dissimilar to the contacted outgroup. Based on these findings in human intergroup research, we formulated a second research question: *whether contact with a social robot improves attitudes towards proximal (such as industrial robots) and distal outgroups (such as migrants and people with disabilities)* (RQ2) and hypothesized that HRF would increase positivity towards secondary outgroups than do other control conditions.

1.2.3 Potential Mediators

We investigated potential mediational relationships whereby an HRF procedure improves attitudes towards social robots and asked *which social psychological processes explain the effects of HRF on attitudes towards social robots* (RQ3). First, we suggest that *trust in the outgroup*, i.e., a positive expectation about the intentions and behaviour of a specific outgroup towards the ingroup, would be a prominent mediator. The current work specifically examines the individual's trust in robots. Trust has been known to play an important role in the acceptance of and collaboration with robots [55], yet HRI research has rarely focused on relation-based trust towards robots [56]. Human contact literature established that intergroup contact, and particularly cross-group friendships, are likely to improve attitudes towards outgroups through increased trust (e.g [44, 57]). Intimate contact is particularly successful in promoting reciprocal self-disclosure and trust [42], and in turn, increased trust may function as a critical buffer against hostility towards outgroups (e.g [58]). HRF is likely to increase trust in robots and thereby result in more positive attitudes.

Second, we proposed *anthropomorphism* of robots as another process through which HRF may improve attitudes towards social robots. Anthropomorphism is the process of attributing human-like qualities and characteristics to non-human agents and objects [59]. Anthropomorphism may function similarly to the 'humanization' of the outgroup partner during contact, which has been suggested to be an important mechanism in traditional human intergroup contexts. For example, intergroup contact was found to reduce prejudice against refugees through increased humanization of outgroups (e.g [60]). Likewise, anthropomorphism may increase one's positive attitudes towards robots by facilitating HRI and creating a safe environment [61]. While too much human-likeness in robots may provoke negative emotions, as suggested by the 'uncanny valley hypothesis' [62], we introduce a humanoid robot as the optimum robot partner (see also [63]), because a typical member of an outgroup can allow the effects of contact to generalize more broadly [64]. We thus hypothesized that HRF would increase anthropomorphism, which is likely associated with more positive

attitudes towards social robots, highlighting a sense of reciprocity and commonality across humans and robots.

We also examined *intergroup emotions* as a potential mediator. While both positive and negative emotions play an important role in regulating intergroup relations and behaviours (e.g [65]), reduced *intergroup anxiety*, in particular, is a robust affective mediating process in the link between contact and attitudes [35, 40, 66]. HRI research consistently demonstrates that both direct and indirect forms of contact with robots decreases anxiety and other forms of negative emotions (e.g [17, 18]), and 'robot anxiety' is likely to predict negative attitudes towards robots [32]. Further, *positive emotions* such as *sympathy* and *excitement* towards robots were shown to function as even more critical predictors of attitudes towards robots [13]. Specifically, reciprocal friendship processes crossing group boundaries are likely to strengthen potential changes in both positive and negative emotions towards robots, and therefore we expected decreased anxiety towards robots, and increased positive emotions towards robots to be significant mediators between HRF and attitudes towards social robots.

Finally, we also explored *the potential mediators for the effects of HRF on attitudes towards non-contacted (secondary) outgroups* (RQ4). While it is plausible to expect direct effects of contact on improving attitudes towards non-contacted secondary groups, previous studies testing secondary transfer effects have typically relied on indirect associations between contact and attitudes towards secondary groups (e.g [67, 68]). Recent literature identified attitude generalization as a key mechanism that links contact with the primary outgroup and attitudes towards secondary outgroups (e.g [69, 70]). For example, White South Africans' cross-group friendships with coloured South Africans improved their attitudes towards the contacted outgroup as well as the non-contacted secondary outgroup of Black South Africans [71]. An indirect contact manipulation with an illegal immigrant also improved attitudes towards secondary outgroups such as homeless people and refugees/migrants through improved attitudes towards illegal immigrants (the contacted outgroup) [72], overall indicating attitude generalization to occur for a broad range of secondary outgroups.

1.3 Overview of Studies

We present two studies testing the effectiveness of an HRF procedure on various intergroup measures. Study 1 was designed as an initial proof-of-concept to test whether the novel procedure of HRF could change attitudes toward social robots relative to a no-contact baseline (not meeting or interacting with a robot), following the typical approach in intergroup contact research (e.g [49]), in a university student sample. This step was important to establish the basic efficacy and feasibility of the HRF task before introducing more nuanced control conditions. While this design necessarily conflates contact with exposure and interaction, its results provide initial evidence of attitudinal change and guided the refinement of Study 2, which incorporated the 'mere exposure' (just seeing the robot without interacting) condition to address this limitation, with a more generalizable community sample. Beyond addressing methodological confounds, the two-study design also serves an important function of replication. HRI research often tests new concepts and paradigms only once, but given broader reproducibility concerns in the behavioural and social sciences, we intentionally tested the HRF procedure across two independent studies. In both studies, we also evaluated specific intergroup processes (trust, anthropomorphism, and emotions) as potential mediators and attitude improvements for various non-contacted secondary outgroups.

Overall, we contribute to the rapidly growing field of HRI research by drawing on recent developments in contact theory [12, 13]. While previous research has benefitted from direct and indirect contact theories to improve attitudes towards robots (e.g [17, 18]), HRI research including actual interactions and conversations is rare [57], and does not focus on 'self-disclosure', which has been known as an effective tool to improve attitudes towards different social groups (e.g [41, 42]). Even brief exposures to robots can be effective, yet just being exposed to outgroup members with no actual contact can inadvertently intensify negative attitudes (e.g [73]). We also extend existing work in human-robot contact by examining the consequences to secondary outgroups. This extension provides important applied-level implications; if HRF can decrease individuals' general prejudice levels by making them less ethnocentric and more open to accepting outgroups, we can expect a wider application of HRF to help the reduction of prejudice against social groups in society. Our hypotheses are:

H1 Participants in the HRF condition would report increased positive attitudes, trust, positive emotions, anthropomorphism, as well as decreased anxiety towards social robots compared to participants in the control conditions.

H2a Participants in the HRF condition would show more positive attitudes towards non-contacted proximal outgroups

(such as industrial robots) compared to participants in the control conditions.

H2b Participants in the HRF condition would show more positive attitudes towards distal human outgroups (such as feminists, LGBTQI, refugees/migrants) compared to participants in the control conditions.

H3 Increased trust, anthropomorphism, and positive emotions, as well as reduced anxiety would mediate the effects of HRF on attitudes towards social robots.

H4 Improved attitudes towards social robots would mediate the effects of HRF on attitudes towards non-contacted (secondary) outgroups.

2 Study 1

2.1 Method

2.1.1 Participants

Based on the previous theoretically relevant studies [18, 74], we aimed for large effects. According to the a priori G*Power analysis, 98 participants would be required to detect large effects (f^2 = 0.16) with a power of 0.80. The study was advertised as examining how individuals could contribute to the development of a social robot, and 103 university students (M_{age} = 21.50, SD = 1.79, 72 Females, 31 Males) participated in return for course credits. Participants' previous contact with robots was rare ('Have you ever contacted a robot?' 9.7% Yes) and their general knowledge of robots (M = 3.08, SD = 1.27) and technology was both low to medium (M = 4.85, SD = 1.22; 1 = *not knowledgeable at all* to 7 = *extremely knowledgeable*). Both Studies 1 and 2 were approved by the ethics committee of Sabanci University in Türkiye (Protocol Number: FASS_2022-47).

Fig. 1 The Robot Doğa and Participant in the HRF Task

2.1.2 Procedure

Participants were randomly assigned to one of the two conditions: the baseline condition (n = 51) and the HRF condition (n = 52). In the baseline condition, participants filled out a computerized outcome survey without meeting or seeing our robot. In the HRF condition, one experimenter acted as a moderator of the HRF session, and the other experimenter teleoperated the humanoid robot Pepper (Softbank Robotics; Fig. 1) from a separate room (i.e., Wizard-of-Oz; [75]). The moderator first seated the participant in front of the robot and asked the participant and the robot 'Doğa' (a typical gender-neutral Turkish name) to introduce themselves to each other. Then, the participant completed the HRF task with Doğa (Fig. 1), in which they asked five questions to each other in turn (see Note S1 in Supplementary Materials for all questions). While the questions asked by Doğa were fixed across participants, designed to create a gradual self-disclosure process from the participant, the participant was instructed to choose any questions from a list of eight questions. For all questions asked to the robot, the robot answered in a previously prepared fixed format, teleoperated by the second experimenter. When it was the robot's turn to ask a question to the participant, it turned towards the question list on the table and recited one of the questions to give the impression that it was spontaneously choosing a question. After the HRF procedure, the participant filled out the outcome survey on a computer in a room next door, as did participants in the baseline condition (see the Measures section).

2.1.3 Measures

The outcome survey consisted of the measures described below, listed in the order in which they appeared.[1] The main outcome variable, i.e., *feeling thermometers*, was placed at the beginning of the survey, to avoid 'contamination' from the mediator questions, some of which were expected to prime participants with certain mindsets or beliefs (e.g., anxiety, anthropomorphism).[2] Note that unless indicated

[1] In the same experimental setting, other scales were also used for exploratory purposes (e.g., perceived robot threat, group representations).

[2] The practice of strategic sequencing of questions is common in survey-based research, and when a relatively specific question precedes a more general question, respondents tend to use the information gained in the specific question to answer the general question, i.e., assimilation effect [76–78]. In this study, the feeling thermometers and other mediator questions do not form the classic specific vs. general relationship, but mediator questions focus on a particular group (i.e., robots) and construct (e.g., trust), whereas the feeling thermometers ask more general question of warmth towards many different social groups [79].

otherwise, these scales were based on a 7-point Likert Scale ranging from 1 (*Strongly disagree*; *Not at all*) to 7 (*Strongly agree*; *Very much*). All data analysed here are available at OSF (https://osf.io/u57bq).

Attitudes towards social robots and other groups were assessed by *feeling thermometers* (e.g [80]). Participants were asked to rate the warmth they felt towards a list of 15 outgroups (see Tables S1-4) on a scale of 0 (*Extremely unfavourable*) to 100 (*Extremely favourable*). We tested not only minority groups typically tested in intergroup relations literature in Türkiye (e.g., Syrian and Afghan refugees [80–82], but also outgroups that shared characteristics typically attributed to robots (i.e., high competence and low warmth; [83]). We also included disadvantaged groups commonly tested in secondary transfer effects literature (e.g., people with disabilities, homosexuals; [53, 54, 72, 84]), and less disadvantaged groups that might be considered highly competent (e.g., Germans). The order of the groups was randomized across participants.

Anthropomorphism of Robots [85] was measured by a 9-item scale consisting of agency (e.g., 'can engage in a great deal of thought') and experience items (e.g., 'can experience pain'). The scale was previously adapted from prior research on mind attribution [86], and the overall reliability was high (α = 0.83).

Anxiety Towards Robots (adapted from [87], i.e., *intergroup anxiety*) was assessed by three items measuring the extent to which participants would feel awkward, anxious, and nervous if they were in a room with only robots (α = 0.85).

Emotions Towards Robots (i.e., *intergroup emotions*) were measured by three positive emotions from [13]: excitement, sympathy, and respect (e.g., 'To what extent do you feel sympathy towards robots?'; α = 0.71).

Trust in Robots (i.e., *outgroup trust*; adapted from [88]) assessed participants' willingness to self-disclose and trust a robot with personal information ('I would be able to trust a robot as much as any other person', $r = .51$, $p < .001$).

2.1.4 Results and Discussion

Manipulation checks. We checked participants' interactions with Doğa to make sure that the HRF procedure was found positive, pleasant, easy, and included self-disclosure. Overall, the procedure was rated as highly positive ($M = 6.02$, $SD = 1.15$) and enjoyable ($M = 5.56$, $SD = 1.55$), and resulted in willingness to meet Doğa again ($M = 5.56$, $SD = 1.83$). The HRF task was rated as relatively easy ($M = 5.79$, $SD = 1.40$), and participants rated their own self-disclosure as higher than the midpoint of 4 on the 7-point scale ($M = 4.77$, $SD = 1.23$). For all of these scales, one sample *t*-tests comparing the means to the midpoint of the scale (4.0) were significant (all *p*s < 0.05). We also asked how human-like Doğa was on a scale from 1 (*human-like*) to 10 (*machine-like*), and the responses showed that Doğa was at medium level of humanness ($M = 4.94$, $SD = 2.40$), as this score did not significantly differ from the midpoint (5.5) of the scale ($p < .05$).

Main effects of HRF. As hypothesized, on average, the HRF condition resulted in more favourable outcomes (higher ratings in attitudes towards social robots, anthropomorphism of robots, emotions towards robots, and trust in robots, and lower ratings in anxiety towards robots) than the baseline condition (Figs. 2 and 3). We conducted a MANOVA to test whether the differences between the two conditions were statistically significant. Note that trust was not included in this overall model and was analysed separately, since our final sample size was smaller ($N = 49$) for this measure due to a technical error.[3] The multivariate effect of Condition (HRF vs. Baseline) was significant, $F(4,98) = 3.63$, $p = .008$, $\eta_p^2 = 0.13$. As expected, the univariate effect of Condition was significant on attitudes towards social robots, $F(1,101) = 5.72$, $p = .019$, $\eta_p^2 = 0.05$, anthropomorphism, $F(1,101) = 8.26$, $p = .005$, $\eta_p^2 = 0.08$, and positive emotions towards robots, $F(1,101) = 11.17$, $p = .001$, $\eta_p^2 = 0.10$. However, unlike our hypothesis, there was no significant effect on anxiety towards robots, $F(1,101) = 1.41$, $p = .238$. A further univariate test also demonstrated that HRF significantly increased trust in robots, $F(1,47) = 5.55$, $p = .023$, $\eta_p^2 = 0.11$. Thus, supporting our initial assumptions, participants in the HRF group reported more positive attitudes towards social robots, anthropomorphism, trust, and positive emotions towards robots than did participants in the baseline group.

We also checked which specific positive emotions were particularly influenced by HRF. A MANOVA including three positive emotions as distinct outcome variables demonstrated that Condition had strong univariate effects on sympathy and respect towards robots, $F(1,101) = 13.84$, $p < .001$, $\eta_p^2 = 0.12$, and $F(1,101) = 10.53$, $p = .002$, $\eta_p^2 = 0.09$, respectively, whereas the univariate effect of Condition on excitement was not significant, $F(1,101) = 0.36$, $p = .552$, $\eta_p^2 = 0.004$ (Fig. 4).

Mediation analyses. We then tested a parallel mediation model with PROCESS Macro (Model 4; [89]). We included Condition as the independent variable, and anthropomorphism of robots and positive emotions towards robots as mediators. Since HRF was not effective on anxiety towards robots, this variable was not included here. Findings of this first model indicated that HRF effects on attitudes were mediated by positive emotions, $B = 6.99$, $SE = 2.39$, 95%

[3] Due to a technical error, the trust in robots scale was added later during the data collection phase, resulting in a smaller sample size for the particular measure.

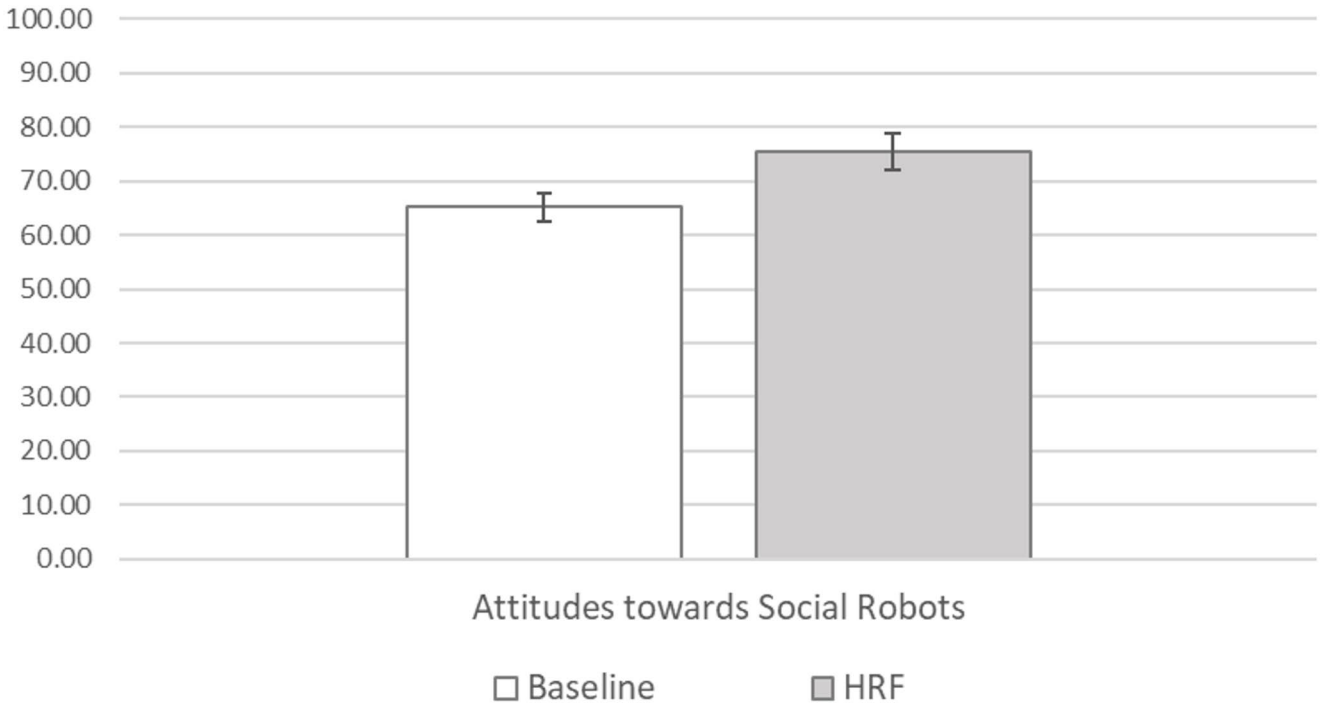

Fig. 2 Attitudes Towards Social Robots in Study 1. The ratings were on a scale of 1-100. The error bars indicate standard errors (SE). $N_{Baseline}$ = 51 and N_{HRF} = 52

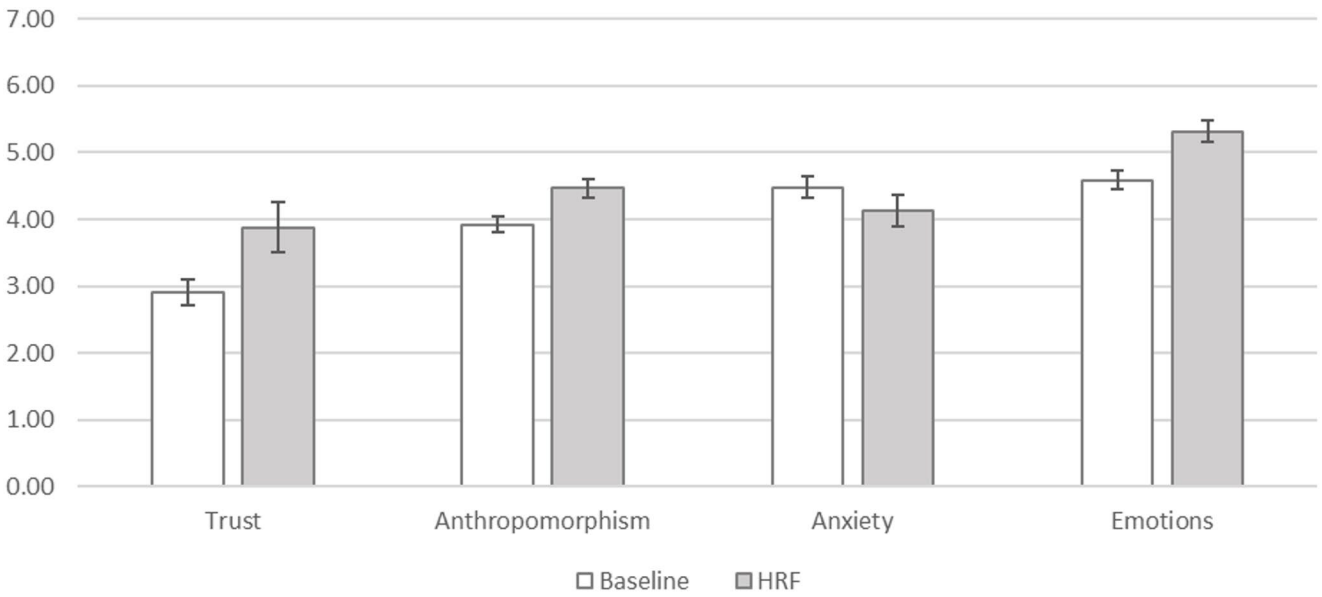

Fig. 3 Trust in Robots, Anthropomorphism of Robots, Anxiety Towards Robots, and Emotions Towards Robots in Study 1. All ratings were on a scale of 1–7. The error bars indicate standard errors (SE). $N_{Baseline}$ = 25 and N_{HRF} = 24 for Trust in Robots, $N_{Baseline}$ = 51 and N_{HRF} = 52 for all other scales

CI [2.71, 12.01], but not by anthropomorphism, B = 0.37, SE = 1.16, 95% CI [-1.69, 3.06]. A further model with trust as the mediator also confirmed that HRF was positively associated with attitudes towards social robots through increasing trust, B = 7.55, SE = 3.48, 95% CI [1.24, 14.89] (see Figure S1 and S2 for these mediational associations).

Effects on secondary outgroups. As we tested 15 outgroups on the feeling thermometer, we first factor analysed the outgroups to see whether there was a meaningful group structure (see Table S1 for results regarding each outgroup). An exploratory factor analysis with a Varimax rotation extracted four different categories which we classified based

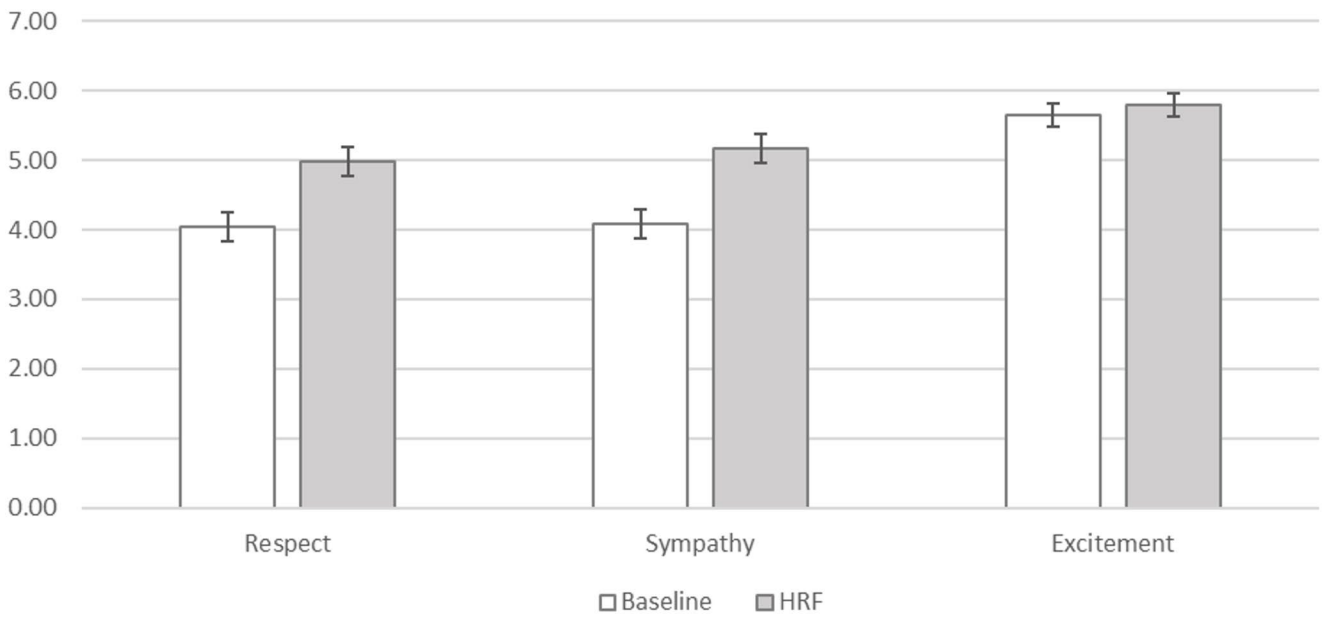

Fig. 4 *Positive Emotions Towards Robots (Respect, Sympathy, and Excitement) in Study 1. Note*. The ratings were on a scale of 1–7. The error bars indicate standard errors (SE). $N_{Baseline}$ = 51 and N_{HRF} = 52 for all scales

on stereotypes of *warmth* and *competence* as (1) Robotic outgroups: industrial robots and (general) robots, (2) Low Competence-High Warmth (LC-HW) human outgroups: feminists, LGBTQI, homeless, elderly, disabled, (3) Low Competence-Low Warmth (LC-LW) human outgroups: Syrian refugees, Afghan refugees, and criminals, (4) High Competence-Low Warmth (HC-LW) human outgroups: Germans, vegetarians, Spaniards, Jews, and Asians. These categories by no means represent the actual characteristics of these human outgroups, yet such a social categorization is consistent with cross-cultural stereotype content models [83, 90], and the social group mappings in Türkiye [91, 92]. Table S2 presents the factor loadings for different groups.[4]

Next, we conducted an initial MANOVA to test if Condition influenced participants' warmth towards the four outgroup categories extracted. The multivariate effect was not significant $F(4, 98) = 0.270$, $p = .897$, $\eta_p^2 = 0.01$, and Condition did not significantly influence how warm participants felt towards the four groups differing in warmth and competence levels (LC-HW ($p = .843$), HC-LW ($p = .624$), LC-LW ($p = .959$), and the Robotic group ($p = .522$)). Participants in the HRF condition felt comparable levels of warmth towards the LC-HW ($M = 76.00$, $SD = 17.20$), HC-LW ($M = 72.27$, $SD = 19.73$), LC-LW ($M = 34.34$, $SD = 19.45$), and Robotic groups ($M = 65.56$, $SD = 27.38$) to those in the control condition ($M = 76.66$, $SD = 16.32$ for LC-HW; $M = 70.50$, $SD = 16.66$ for HC-LW; $M = 34.12$, $SD = 22.49$ for LC-LW; $M = 62.50$, $SD = 20.38$ for Robotic group).

Mediation analyses. We then tested separate mediation analyses with PROCESS (Model 4) to test the effects of HRF on secondary outgroups, including Condition as the independent variable, attitudes towards social robots as the mediator, and attitudes towards each of four outgroup categories as the dependent variable. Significant mediations were found towards social robots to the Robotic category ($B = 8.78$, $SE = 3.77$, 95% CI [1.22, 16.13]), the outgroups in the Low Competence-High Warmth (LC-HW) category (e.g., individuals with disabilities), ($B = 2.28$, $SE = 1.44$, 95% CI [0.23, 5.57]), and the outgroups in the High Competence-Low Warmth (HC-LW) category (e.g., vegetarians; $B = 1.76$, $SE = 1.14$, 95% CI [0.03, 4.48]). However, no indirect effect was observed for the outgroup in the Low Competence-Low Warmth (LC-LW) category (e.g., criminals; $B = -0.03$, $SE = 1.05$, 95% CI [-2.50, 1.85]). Figures S3-S6 depict these mediational associations.

In summary, the HRF procedure significantly improved attitudes towards social robots, led to greater trust in robots and anthropomorphism of robots, as well as more positive emotions towards robots (particularly sympathy and respect), though anxiety and anthropomorphism were not significant mediators on this link. The mediation analysis also suggested indirect effects of HRF on proximal outgroups (e.g., industrial robots), and more distal LC-HW and HC-LW outgroups, implicating that contact with social robots may relate to decreases in generalized prejudice levels.

Study 1 presented initial evidence for the effectiveness of the HRF procedure, which not only improved attitudes, emotions, and trust towards robots, but also indirectly

[4] Note that attitudes towards social robots were also measured with the feeling thermometer. Tables S3 and S4 report factor analysis for the secondary outgroups and thus do not include social robots.

associated with more positivity towards (some) secondary outgroups. Although Study 1 alone cannot distinguish whether the effects were due to exposure to the robot or specifically to the reciprocal self-disclosure process, it offers a critical demonstration that structured human-robot contact can elicit measurable attitudinal change. Such initial findings are quite valuable as (1) they confirm that the HRF task is engaging and effective enough to influence the participant's perceptions in a controlled setting, and (2) they provide effect-size benchmarks and empirical justification for introducing additional control conditions in the next study, and (3) they demonstrate the feasibility of applying intergroup contact paradigms to human-robot contexts, thereby informing future methodological refinements.

3 Study 2

Study 1 compared HRF to a no-contact baseline condition, and thus does not reveal whether the procedure is substantially more effective than less intimate 'mere exposure' forms of HRI, typically used in previous research (e.g [18]). This distinction is theoretically critical, as increased exposure to outgroups without actual contact can instigate negative attitudinal outcomes [73]. Therefore, Study 2 compared the same intergroup outcomes across three conditions: HRF, mere exposure (being in the same room with the robot for a brief time), and baseline (no contact) conditions. Regarding samples too, Study 2 extends the generalizability of the Study 1 findings, which were based on a university student sample (who were relatively young and tech-savvy and more familiar with the robotic industry [93]), by testing a community sample.

3.1 Method

3.1.1 Participants and Procedure

Following the per-condition sample size of Study 1, Study 2 collected data from 148 participants (M_{age} = 35.64, SD=12.87; 95 Females, 51 Males, 1 Other, and 1 Did not want to report) through convenience sampling. The average education of participants ranging from 1 (primary school) to 7 (post-doctoral degree) was 3.30 (SD=1.16). The average income ranging from 1 (0-2.500 TL) to 5 (15.000 TL and above) was 3.38 (SD=1.42), demonstrating that the sample was generally formed of middle-class individuals. As in Study 1, previous experience with social robots was minimal (only 4.7% having a previous interaction with a robot). While general knowledge about robots appeared low (M=2.86, SD=1.42), general knowledge about technology was above the midpoint score on the scale (M=4.74, SD=1.20).

The procedure was largely similar to Study 1. The study was advertised as a study about communication for anyone who is over age 18 years (thus no mention of robots) on social media and the network of our research assistants. The baseline (n=50) and HRF conditions (n=49) were the same as in Study 1. In the *mere exposure* condition (n=49), the participant was invited to the lab space in which the robot was standing quietly, facing the participant. The participant filled out the informed consent for a couple of minutes in that space with no interaction with the robot and then proceeded to another testing room to fill out the main survey. At the end of the study, participants were rewarded with 150 TL for their time and effort.

3.1.2 Measures

We used the exact same scales used in Study 1. Reliabilities were again satisfactory for all scales (Anthropomorphism of robots: α=0.85; Anxiety towards robots: α=0.86; Positive emotions towards robots: α=0.78; Trust in robots: r = .59, p < .001).

3.1.3 Results and Discussion

Manipulation checks. Using the same manipulation checks as Study 1, we found that the interaction was perceived to be positive (M=5.88, SD=1.58), pleasant (M=5.67, SD=1.68), and easy (M=5.68, SD=1.65). Participants' self-disclosure (M=4.69, SD=1.43) and willingness to meet Doğa again in the future (M=5.37, SD=1.88) were also generally high. A series of one-sample t-tests comparing these values to the midpoint of 4 on the 7-point scale were highly significant (all ps < 0.001). Moreover, Doğa was found to be slightly more humanlike than machinelike (M=4.63, SD=2.71, p = .03), compared to the midpoint of 5.5 on a scale from 1 to 10, unlike Study 1.

Main effects of HRF. As shown in Fig. 5, the average values in the HRF condition appeared more favourable (higher ratings in attitudes towards social robots, anthropomorphism, emotions towards robots, and trust in robots, and lower ratings in anxiety towards robots) than in the baseline or mere exposure condition. As in Study 1, we first conducted a MANOVA with all the outcome variables to test the statistical significance of the observed pattern. The multivariate effect of Condition was significant, F(10, 282)=1.88, p = .048, η_p^2=0.06. The univariate effects of Condition on attitudes towards social robots was not statistically significant, F(2, 145)=1.86, p = .160, η_p^2=0.03. Pairwise comparisons through Tukey HSD post-hoc tests indicated that the comparison of the baseline group to either

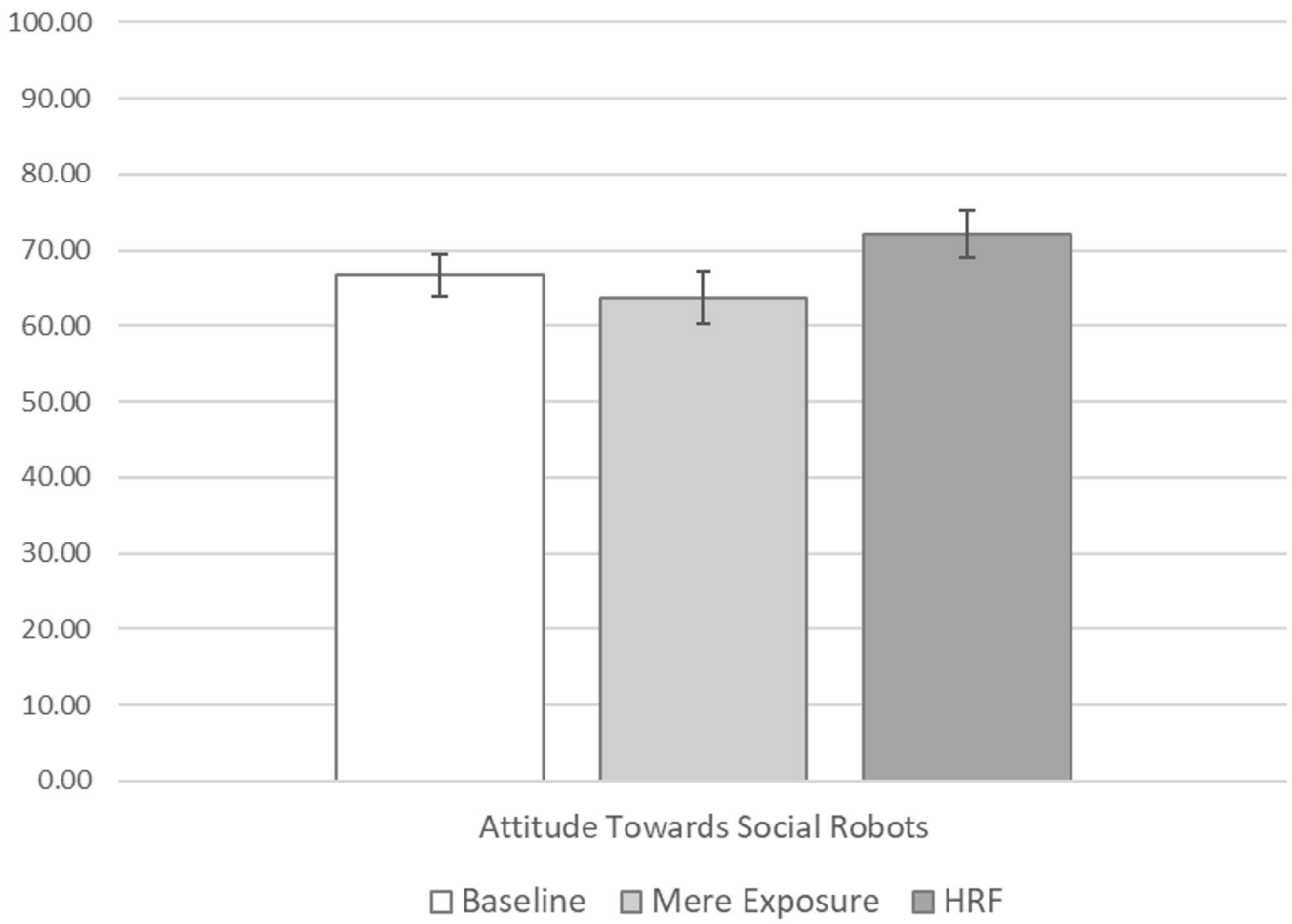

Fig. 5 *Attitudes Towards Social Robots in Study 2. Note*. The ratings were on a scale of 0-100. The error bars indicate standard errors (SE). $N_{Baseline}$ = 50, $N_{Mere\ Exposure}$ = 49, and N_{HRF} = 49

the HRF condition (p = .435) or the mere exposure condition was not significant (p = .777). Similarly, the comparison between the HRF and mere exposure conditions was not significant (p = .142).

However, as expected and in line with Study 1, the univariate effect of Condition on trust was significant, $F(2, 145) = 7.92$, p = .001, $\eta_p^2 = 0.10$. Tukey HSD pairwise comparisons demonstrated that, while trust was not significantly different between the baseline and mere exposure conditions (p = .935), the HRF procedure resulted in greater trust in robots compared to both baseline (p = .001) and mere exposure conditions (p = .004). The univariate effects of Condition on anthropomorphism, anxiety, and positive emotions were not significant. Figures 5 and 6 indicate the means and standard errors for all conditions.

As in Study 1, we further tested whether HRF affected positive emotions towards robots differentially, by testing the effect of condition on each emotion separately. A further MANOVA demonstrated a significant multivariate effect of Condition on positive emotions (respect, sympathy, and excitement). The univariate effects indicated that Condition led to changes in sympathy only, $F(2, 145) = 4.85$, p = .009, $\eta_p^2 = 0.06$. According to the Tukey HSD post-hoc tests, while there was no difference between the baseline and mere exposure conditions (p = .858), individuals reported significantly more sympathy towards robots in the HRF condition compared to both baseline (p = .045) and mere exposure conditions (p = .011), replicating the findings in Study 1. Figure 7 indicates means and standard errors for sympathy, respect, and excitement.

Mediation analyses. We tested a parallel mediation model on PROCESS (Model 4) by testing trust in robots and outgroup sympathy as the mediators of the link between Condition and attitudes towards social robots. We did not include anthropomorphism, anxiety towards robots, and the other positive emotions (excitement and respect) measures in the final model, since the main effect of Condition was not significant on these variables. We defined Condition as a multicategorical independent variable whereby the baseline condition was considered the reference category (see Figure S7). Findings demonstrated that the HRF procedure significantly increased trust ($B = 1.05$, SE = 0.29, $p < .001$),

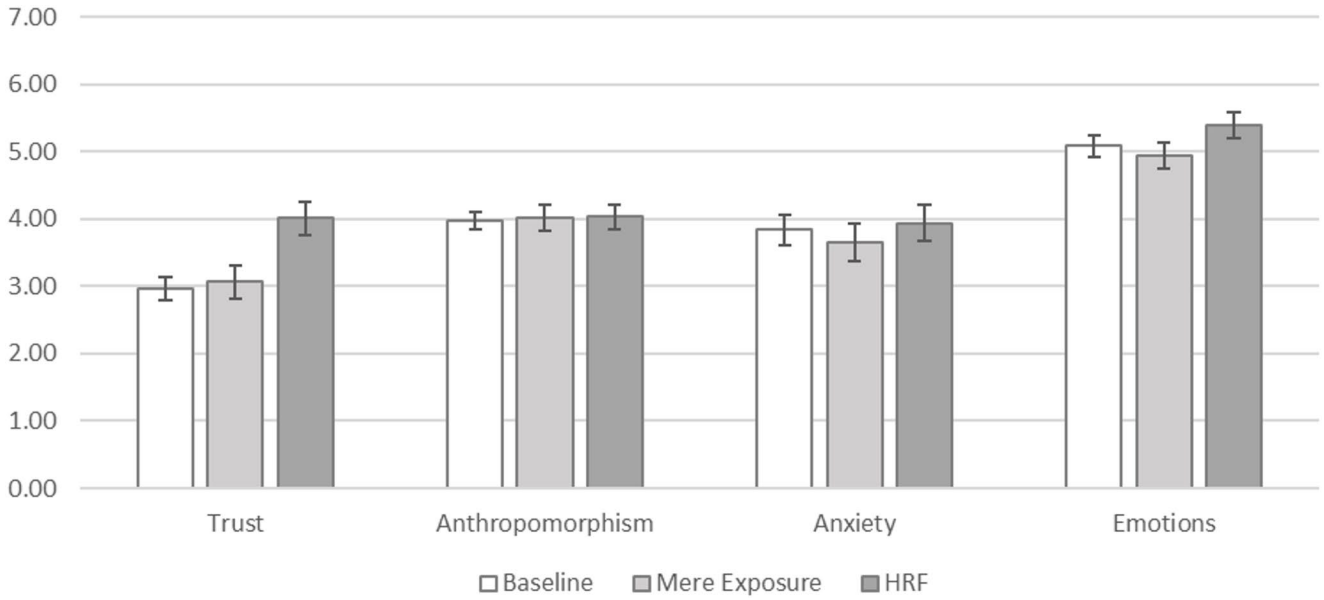

Fig. 6 Trust in Robots, Anthropomorphism of Robots, Anxiety Towards Robots, and Emotions Towards Robots in Study 2. All ratings were on a scale of 1-7. The error bars indicate standard errors (SE). $N_{baseline} = 50$, $N_{Mere\ Exposure} = 49$, and $N_{HRF} = 49$

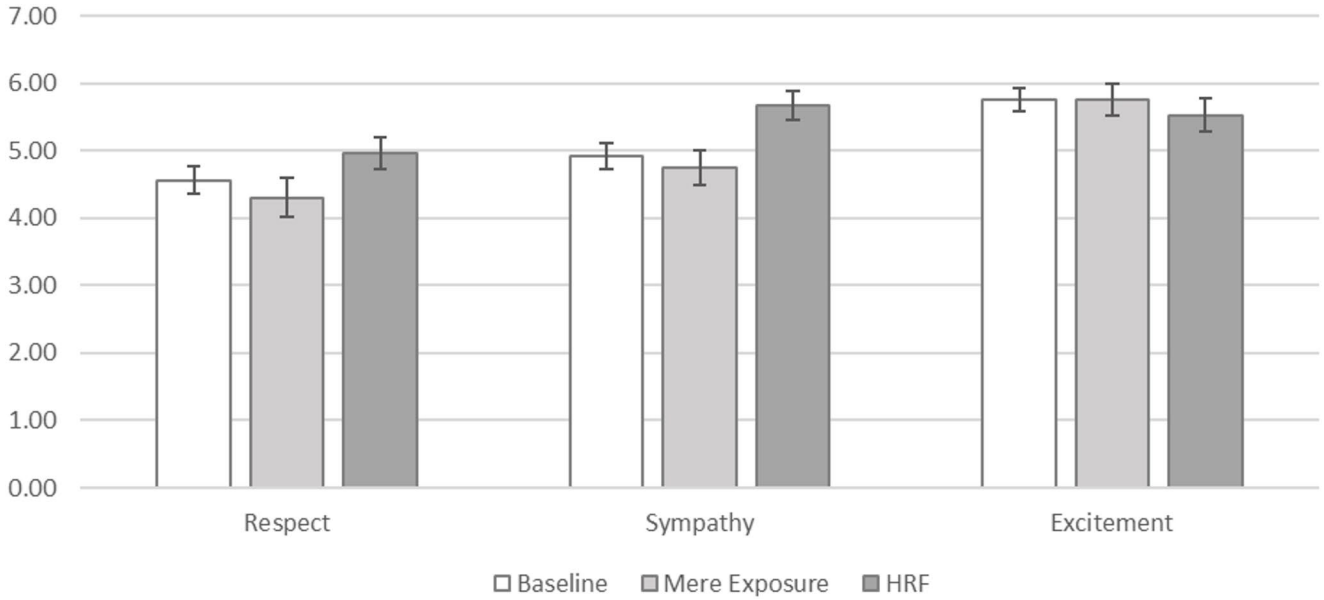

Fig. 7 Positive Emotions Towards Robots (Respect, Sympathy, and Excitement) in Study 2. The ratings were on a scale of 1–7. The error bars indicate standard errors (SE). $N_{Baseline} = 50$, $N_{Mere\ Exposure} = 49$, and $N_{HRF} = 49$

as well as sympathy in robots ($B = 0.75$, $SE = 0.31$, $p = .017$). Trust was not significantly associated with more positive attitudes ($B = 1.98$, $SE = 1.09$, $p = .072$), whereas sympathy was associated significantly with more positive attitudes ($B = 7.30$, $SE = 1.01$, $p < .001$). While trust was not a significant mediator of the effects of Condition on attitudes ($B = 2.08$, $SE = 1.55$, 95% CI [-0.70, 5.42]), sympathy was a significant mediator in this association ($B = 5.50$, $SE = 2.27$, 95% CI [1.28, 10.32]).

As an exploratory analysis, we further checked whether there might be a serial mediational process rather than a simultaneous mediational process, given that trust and sympathy are likely to have potential covariance and sympathy likely emerges from reciprocal disclosure and understanding (e.g [94]). A PROCESS analysis with Model 6 (serial mediational process) revealed a significant serial mediation linking the effect of Condition on attitudes (Figure S8). Accordingly, the HRF procedure seemed to increase trust and trust was associated with more positive attitudes

through increased sympathy (B=2.38, SE=1.10, 95% CI [0.66, 4.96]).

Effects on secondary outgroups. We again grouped the secondary outgroups the Low Competence-High Warmth (LC-HW), Low Competence-Low Warmth (LC-LW), High Competence-Low Warmth (HC-LW), and the Robotic groups (see Table S3 for the means and SDs for the 15 secondary outgroups). An exploratory factor analysis yielded similar categories as in Study 1, except for minor differences (feminist and LGBTI were classified together with the HC-LW outgroups instead of the LC-HW outgroups; see Table S4 for factor loadings). We then conducted a MANOVA with the four categories of outgroups as the dependent variables and the Condition as the independent variable. The multivariate effect of Condition was not significant, $F(8, 284)$ = 0.435, p = .899, η_p^2=0.01. Similar to Study 1, the means were comparable across the HRF condition (M_{LW-HC} = 65.13, SD=20.62; M_{HW-LC} = 83.35, SD=15.27; M_{LW-LC} = 33.48, SD=24.74; $M_{Robotic}$= 68.95, SD=21.96), the mere exposure condition (M_{LW-HC} = 64.51, SD=20.56; M_{HW-LC} = 80.39, SD=15.72; M_{LW-LC} = 34.83, SD=22.05; $M_{Robotic}$ = 65.67, SD=21.58), and the baseline condition (M_{LW-HC} = 63.65, SD=18.22; M_{HW-LC} = 81.21, SD=17.48; M_{LW-LC} = 29.31, SD=21.54; $M_{Robotic}$ = 64.17, SD=19.10), and we did not observe any direct effects of HRF on attitudes towards the LW-HC (p = .933), HW-LC (p = .647), LW-LC (p = .791), and the Robot group (p = .511).

Because our initial analyses demonstrated condition to have no effects on attitude change towards social groups, we tested whether increased trust and sympathy towards robots would play a role in increased positive attitudes towards secondary outgroups, as emotions and trust have been shown to generalize towards other groups (e.g [53, 71, 95]). Separate mediational models (Model 4) including trust and sympathy in robots as parallel mediators revealed a significant mediation effect through both robot trust and sympathy as regards the Robot outgroup and the LC-HW groups (Figures S9 and S10). Accordingly, HRF resulted in more positive attitudes towards the Robot group through both increased trust and sympathy (B=2.79, SE=1.50, 95% CI [0.28, 6.20] and B=4.27, SE=1.92, 95% CI [0.86, 8.38], respectively). A further mediation was found as regards the LC-HW group; as expected, HRF increased sympathy for robots and sympathy was associated with more positive attitudes towards the LC-HW group (B=1.89, SE=1.28, 95% CI [0.11, 4.94]). However, HRF also increased trust in robots, which was negatively associated with attitudes towards the LC-HW group (B = -2.87, SE=1.45, 95% CI [-6.16, −0.62]), suggesting opposite indirect effects through different mediators. There were no effects of the HRF procedure on attitudes towards the HC-LW or LC-LW groups (Figures S11 and S12; see also Note S2 for analyses based on the pooled data from Studies 1 and 2).

In summary, we partially replicated the findings of Study 1; although there was no direct effect of Condition on attitudes, we observed a serial mediation whereby HRF produced greater trust in robots and sympathy towards robots, which were associated with more positive attitudes towards robots compared to both control conditions. HRF also resulted in more positive attitudes towards proximal outgroups (Robotic group) through increased trust and sympathy, and distant outgroups (Low Competence-High Warmth [LC-HW] groups) such that increased sympathy in robots was related to more positive attitudes towards the outgroup, whereas trust was related to more negative attitudes.

4 General Discussion

We tested a novel procedure of HRF that involved a self-disclosure-based face-to-face interaction between a human participant and a humanoid robot. We specifically investigated whether this procedure would promote positivity towards social robots (higher positive attitudes, trust, positive emotions, and anthropomorphism, as well as lower anxiety), and whether such attitude improvement would be also observed in relation to non-contacted secondary outgroups. Both studies showed that, compared to the control groups, HRF resulted in more positive attitudes towards social robots through increased trust and positive emotions (sympathy and respect in Study 1 and sympathy in Study 2). We also found some evidence for attitude improvement towards non-contacted secondary outgroups including proximal outgroups such as industrial robots, as well as more distal outgroups that range from low to high competence and warmth.

4.1 Direct and Indirect Effects of HRF on Attitudes Towards Social Robots

The first critical finding from both studies is related to how HRF directly and indirectly led to more positive attitudes towards social robots. Specifically, Study 1 demonstrated the direct and indirect effects of HRF on attitudes through increased trust and positive emotions towards social robots (providing partial evidence for H1 and H3). This was largely supported in Study 2 with a more general community sample and showed HRF to result in more positive attitudes through increased trust and particularly sympathy towards robots. These findings are in line with previous research demonstrating that various contact procedures based on physical touch, mental simulation, or direct exposure improve participants' attitudes towards robots (e.g [17, 18, 63, 96]). Extending these studies, HRF procedure capitalized on reciprocal

self-disclosure, highlighting the importance of friendship potential previously suggested in contact research [40, 45]. We also demonstrated that such an interpersonal interaction was critical for HRI to effectively change attitudes towards social robots, since the 'mere exposure' procedure, in which the participant just stayed in the same room with the robot, did not lead to significant changes in the outcome variables.

Our studies also consistently demonstrated the mediating role of both trust and positive emotions, highlighting the importance of positive affective mechanisms in HRF. In line with our findings, the contact literature has shown trust and positive emotions to function as critical mediators of the contact-attitude link (e.g [44, 94]). However, not all positive emotional responses changed significantly through HRF. Both Studies 1 and 2 showed that sympathy towards robots increased after HRF; although sympathy as a specific emotion has not been highlighted in previous HRI research, positive emotions have been found to play a stronger role in predicting people's willingness to interact with social robots than negative emotions or anxiety [13]. One possibility is that specific emotions can increase after positive contact with certain groups, and in fact, recent research showed that distinct emotional responses may explain contact effects depending on the target group [97]. Interestingly, excitement, previously identified as a strong predictor of positive attitudes towards robots [13], was not a significant mediator of the link between HRF and attitudes in the present studies. This may be because baseline excitement about robots was high in all conditions, leaving limited room for further change.

Unlike our initial predictions, anxiety, which has been consistently shown to decrease through intergroup contact (e.g [35]), and fast friendship procedures [38], was also not effectively reduced through HRF. The sustained level of anxiety observed may partly reflect participants' heightened arousal from meeting a real robot for the very first time. Further, the self-disclosure component of the HRF task might have maintained a certain level of anxiety, as sharing personal information can be intrinsically anxiety-provoking even in positive interactions. Also, to decrease potential demand effects, participants in both studies were uninformed about the specific aim of the study before or during the experiment. This might have caused some unpredictability preventing HRF to reduce anxiety towards robots. In fact, some contact procedures (such as text-based electronic contact with an ethnic outgroup member following a preprogrammed algorithm) intended to instigate self-disclosure also resulted in sustained anxiety (e.g [74]). Hence, anxiety may have persisted due to the self-disclosure task or the unfamiliarity of interacting with a machine. Future research is needed to devise strategies that could effectively reduce anxiety during HRF, by creating a more familiar naturalistic context.

Also opposing our initial suggestions, anthropomorphism did not function as a significant driver of contact effects on attitudes. While in Study 1 (but not Study 2), s participants in HRF anthropomorphized the robot more, this was not associated with more positive attitudes. One possible explanation is the relatively small effect size as reflected in the non-significant difference in anthropomorphism across the conditions in Study 2 (though in Study 1 and the analysis with the pooled data yielded significant differences). Another potential reason might be linked to the 'uncanny valley' hypothesis, suggesting that more humanlike AI tools trigger feelings of threat in individuals (e.g [63]). While our robot (Pepper) was generally rated in the middle of the machine- or human-likeness scale (but more human-like than machine-like in both studies), a more general humanness evaluation of robots—anthropomorphism—was not associated with attitudes. Attributing mind and agency to robots may not directly promote positive attitudes, and future research may examine whether the effectiveness of HRF depends on the anthropomorphic characteristics of the contacted robot.

4.2 Effects of HRF on non-contacted Outgroups

Regarding non-contacted secondary outgroups, although HRF did not result in more positive attitudes towards secondary outgroups directly (since the main group differences across conditions were non-significant in both studies), we observed indirect mediation, similar to previous studies on secondary transfer effects (e.g [54, 67, 68, 98]). While these studies did not test secondary transfer effects in the context of HRI, we suggested that contact with a social robot can lead to positive attitudes towards proximal and distal human outgroups. In line with H2a and H4, both studies provided empirical evidence for attitude improvement towards proximal outgroups such that HRF generated more positive attitudes towards the general robot category (e.g., industrial robots) through more positive attitudes towards social robots (Study 1), as well as through increased sympathy and trust in robots (Study 2). More importantly, Study 1 also showed improved attitudes towards Low Competence-High Warmth (LC-HW) groups, as well as High Competence-Low Warmth (HC-LW) groups. This was partially replicated in Study 2, and HRF increased sympathy for robots and this was associated with more positive attitudes towards the LC-HW group.

In both studies, HRF did not show any indirect effects on attitudes towards the Low Competence-Low Warmth (LC-LW) groups, which are typically the most negatively stereotyped groups in society. One reason might be the high

levels of dissimilarity between social robots, which are typically evaluated as highly competent and warm (e.g [99]), and the particular LC-LW outgroups we included. Study 2 also demonstrated that increased trust in robots was negatively associated with attitudes towards LC-HW groups, potentially because trust in robots made competence considerations more salient, leading to less favourable evaluations of this secondary outgroup.

In other words, a 'contrast effect' may have occurred such that, through HRF, robots were evaluated as more competent, thereby amplifying perceived differences relative to LC-HW groups. Further research may investigate additional mediators, such as ingroup reappraisal (re-evaluation of the ingroup) and generalized empathy [71, 100], as well as moderators such as group similarity (e.g [98]), to better understand these indirect effects. Also, the current studies did not assess the effects of HRF on high warmth and high competence outgroups, as our focus was on groups that are typical targets of prejudice; however, it might be valuable to investigate whether attitudes towards high warmth, high competence human outgroups (who generally elicit positive emotions such as pride and admiration; [83]), also become more favourable after the HRF procedure.

4.3 Limitations and Future Directions

Although our research makes significant contributions to the existing literature by testing the effectiveness of an HRF procedure on various attitudinal outcomes across different samples and control conditions, its limitations should also be considered. One methodological limitation was the use of a single interaction session which might not have allowed enough time for participants to fully self-disclose and/or develop intimacy. While our manipulation checks demonstrated that self-disclosure was achieved to some extent even with a single session, multi-session fast-friendship meetings may extend the effectiveness of the HRF procedure, providing a more gradual, but stable development of friendship (e.g [38]). A longitudinal approach would also be useful in addressing the question of whether 'mere exposure' without meaningful contact may result in more negative outgroup attitudes over time.

It would also be ideal to include another manipulation check to assess the extent to which people perceived the presence of the robot in the mere exposure condition. Our conceptualization of the mere exposure condition was that participants could see the robot but did not interact with it. However, some participants may not have perceived the presence of the robot, which may make this condition similar to the baseline condition where the robot was not present. Future studies may induce a more active mere exposure condition, where the presence of the robot is more salient. Moreover, although the testing of HRF against the mere exposure condition in Study 2 could partly solve one of the confounds involved in Study 1, namely the exposure effects, it does not rule out the potential effect of another critical confound—'interaction.' For example, would a simpler interaction with a social robot, without necessarily engaging in a reciprocal self-disclosure process, still provide improvements in individuals' attitudes? While the current studies cannot empirically answer this question, previous research suggests self-disclosure to be an important aspect of cross-group interactions [41]. Future research may test HRF against other control conditions whereby the participant and a robot engage in interactions, but do not self-disclose to each other, for example, by sharing only factual information (e.g [101]). Further studies may also elaborate the current HRF task by inducing various other elements that facilitate positive intergroup interactions such as increased cooperation, common goals, and similarity (e.g [15]).

In both studies, we examined the HRF effects in relation to non-contacted secondary outgroups using aggregate scores rather than raw scores for each outgroup. The approach was adopted because drawing meaningful conclusions about each of the 15 outgroups is challenging and focusing on individual social groups falls outside the objectives of the study. Moreover, our factor analyses revealed social categories that are generally consistent with previous research using the stereotype content model (e.g [102]). Our findings were mostly in line with the limited research conducted in Türkiye [103]. For example, previous studies have similarly demonstrated refugees to be in the same (low competence and low warmth) social group with criminals and beggars (e.g [91, 92]). Nevertheless, it is important to acknowledge that we relied on feeling thermometers to derive these stereotype categories, instead of directly measuring competence and warmth. Moreover, although these two dimensions have been suggested to form universal dimensions of stereotypes, there may be distinctions across cultures in terms of how different groups are evaluated (e.g [104]). Further research is needed to understand whether the effects on secondary outgroups were dependent on perceived warmth and competence of the outgroups.

Unlike many HRI studies, we conducted our research among both university students (Study 1) and a community sample (Study 2) to enhance the reproducibility and generalizability of our findings. Yet, both studies were conducted in the same city in Türkiye following convenience sampling, and thereby may not be fully representative. Cross-cultural data demonstrate that people's perceptions of robot appearance and abilities may change across cultures (e.g [5, 105]). For example, a study reported that Turkish participants have diverse opinions about robots and prefer machine-like and human-like robots equally, with moderate attitudes that

fall in between Korean and US participants [106]. Consistently, our participants generally showed positive emotions towards social robots. Given that contact interventions tend to be most effective in more conflictual intergroup settings [107], HRF may be more effective in settings where attitudes towards robots are rather hostile.

We should also note that, while there has been a growing interest in studying HRI using an intergroup approach, with empirical studies demonstrating intergroup dynamics, such as anxiety, threat, and contact, to play a major role in the formation of attitudes towards robots (e.g [63, 108, 109]), and robots to stand as an outgroup similar to humans [11], the current research does not assess specifically whether participants perceived robots as a distinct outgroup. As discussed in the Introduction, outgroups can vary in their degree of separation from the ingroup. As human-like machine agents, robots may represent a qualitatively distinct level of outgroupness, and this difference might have influenced the dynamics of trust, anxiety, and attitude changes observed here. While our findings demonstrate a promising application of intergroup contact framework to improving human-robot relations, our study does not fully capture whether attitudes towards robots and attitudes towards human outgroups operate similarly and whether they employ the same emotional and cognitive processes. Indeed, existing prejudice literature suggests that even attitudes towards different human outgroups are characterized by distinct negative emotions that guide different behavioural responses [110]. Future research may further investigate the conceptualization of robots as an outgroup of humans and test whether and how perceptions of robots as a different social category from the self may modulate the efficacy of the HRF task.

Lastly, in both studies, all outcome measures were presented in a fixed order. For example, we presented the feeling thermometers, which included attitudes towards both social robots and non-contacted outgroups, before the suggested mediators, with the intention of keeping relatively more general and neutral scales earlier than less neutral ones. While there has been no consensus in the field on whether potential mediators should come before or after the main outcome variables, research suggests that the results remain largely the same across the two designs (though the relative contributions among mediators may change) [111]. Nevertheless, the path between the mediators and feeling thermometers in our studies is supported only theoretically, and although the reverse relationship (i.e., feeling thermometers affecting the mediators) seems very unlikely, we cannot technically assume causal links. Future research may apply more stringent study designs whereby mediators are also manipulated experimentally to provide a more thorough understanding of the relationships between the proposed variables.

5 Conclusion

Through two experimental studies, we demonstrated that participants who engaged in HRF generally reported more positivity towards social robots through increased trust and positive emotions. In a progressive design logic, Study 1 established a baseline effect of HRF contact relative to no contact, and Study 2 extended the work by isolating exposure and interaction. The results suggest that a structured, positive interaction with a social robot can foster attitude change that extends beyond the immediate contact target. The current work offers preliminary yet promising evidence that human-robot contact can engage intergroup-like social mechanisms, inviting future research to delineate where robots lie within the broader landscape of social categories and how varying degrees of perceived outgroupness shape these dynamics.

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Data Availability The datasets analysed and reported are available at OSF (https://osf.io/u57bq).

Declarations

Ethical Approval The studies reported here have been approved by the ethics committee of Sabancı University (Protocol Number: FASS_2022-47).

Conflict of Interest The authors declare that they have no conflict of interest.

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