Observing Robot Touch in Context: How Does Touch and Attitude Affect Perceptions of a Robot's Social Qualities?

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ABSTRACT

The complex role of touch is an increasingly appreciated horizon for HRI research. The explicit and implicit registers of touch, both human-to-robot and robot-to-human, have opened up pressing questions in design and HRI ethics about embodiment, communication, care, and human affection. In this paper we present results of an MTurk survey about robot-initiated touch in a social context. We examine how a positive or negative attitude from the robot, as well as whether the robot touches an interactant, affects how a robot is judged as a worker and teammate. Our findings confirm previous empirical support for the idea of touch as enhancing social appraisals of a robot, though the extent of that positive tactile role was complicated and tempered by the survey responses' gender effects.

KEYWORDS

robot touch; gender effects; observation study

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1 INTRODUCTION

The complex role of touch is an increasingly appreciated horizon for HRI research. The explicit and implicit registers of touch, both human-to-robot and robot-to-human, have opened up pressing questions in design and HRI ethics about embodiment, communication, care, and human affection. As products like Paro find their way into therapeutic use, researchers are finding positive effects of tactile human-robot interaction on people's emotional state and performance. Yet there are charged debates around human-robot intimacy, especially around sexuality, that are becoming more circumspect about what such touch might bring with it. It is a critical project within HRI to anticipate and prepare for the risks and opportunities that tactile interaction will present, as social interaction on the whole gets more sophisticated and varied. HRI as a field must offer its distinctive insights in a technological environment where haptic developments in AR and VR, for instance, are complicating notions of what touch in "real-life" is and could be.

The last decade has seen a number of interesting and engaging efforts to tackle the varied dimensions of touch. From providing anxiolytic comfort to lending encouragement and motivation, these approaches have shown that a robot's vocal and facial presentation is just part of the story of how human-robot interaction can meet human needs and promote human abilities. As areas of practical robotic applications grow, it is all the more apparent that the social context and complexity in which touch might feature will need to be studied as constitutive of how touch is interpreted, experienced, and reshaped. In addition, these applications will need to account for how different social locations and roles may condition how touch should best be employed.

In this paper, we attempt to build on this trajectory of research in tactile HRI by presenting a concrete example of touch and surveying how observers judge a robot touching a person. We present results of an MTurk survey testing different conditions for this touch, situated in an office-like task environment. We are interested in how the evaluation of a robot unfolds in cases where the robot's touch is accompanied by positive or negative attitude via verbal response, as well as what difference it may make when the robot touches a female or male actor in the scenario. Our findings confirm previous empirical support for the idea of touch as enhancing social appraisals of a robot, though gauging that positive role of touch was complicated and tempered by gender effects in the survey responses. The degree to which the robot's performance was appraised positively had intriguing dependencies on whether a male or female was being touched and with what attitude, and the results suggest that gender roles and workplace expectations can shape how social robots' touch bears on evaluating the robot itself.

2 BACKGROUND AND MOTIVATION

It is not a new observation that HRI work needs to incorporate richer research into touch as a facet of interaction [13]. The last decade has seen a steady increase of inquiries into human touch of robots, mutual touch, and robot-initiated touch of people [2] – recently given a thorough mapping by Hoffmann [18]. The emergent attention of "implicit interaction" [20] has only drawn further attention to how shared space and various shades of contact can connect physiological reactions with social aspects of robotic function [23]. More explicit, hot-button issues such as sex robots bring touch to

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the fore as a potential threat to human intimacy and indeed a possible model for abuse [16, 28]. The broader ethical implications of designing robots for tactile interaction are receiving closer scrutiny and clearer articulation [4, 38].

Understandably, research in HRI has explored the many questions that robot touch raises with a corresponding range of methods. The prospect of robots whose purpose is chiefly tactile has led researchers to test whether a robot's touch, whether active or passive, is as effective as a human being's touch, or at least qualitatively similar: for example, for a head massage [40] or other stimuli [37]. Beyond how users report about how the robot feels, tests of therapeutic products like Paro have examined its physiological effects on those who touch it [39]. The possibility of humanoid robots being able to convey affection through touch, or enact a cultural practice, continues to garner empirical evidence [1, 12], and human performance itself on a task-oriented activity has recently been measured to gauge how a robot touch might provide encouragement [32].

While pleasant or tactile feedback characterizes many robots meant for human touch, robot-initiated touch has also, by and large, been found to improve receptions of social robots by their interactants [13, 18, 25]. This holds not just for pure affection or friendly touch, but more functional touch as well (e.g. where the human interactant sees a direct purpose for it, such as taking pulse). Even warmth [26] can yield positive effects for how a human being evaluates being touched by a robot.

The context in which a robot touches a human being can frame how it is being evaluated and measured for effects. A nursing home implementation [11] will have different expectations and priorities than those in domestic or school settings [42]. Recent work has examined how communication cues like gaze and style of touch can affect the perception of the robot's touch itself [17]. One of the research challenges moving forward, then, is to yoke tests of touch to plausible, practical, and robust settings where robots seem likely to be present, operational, and reasonably appropriate. This is all the more challenging given the mechanical and logistical subtlety of touch in a live setting, whether lab or "in the wild." Consistently administering or receiving touch is crucial for having a legitimate comparison across participants for what they are experiencing.

Helpfully, the literature on interpersonal touch suggests how reactions to robotic touch might still be tested without live, in-lab touch. The "social meaning model" of touch [9] registers how observers can interpret touch in a manner quite similar to the person and person being touched. Based on such a model, bare descriptions in language of touch scenarios, or pictures representing such touch, have been used to elicit reactions and judgements from study participants [18].

Given the many complex and increasingly nuanced social issues that HRI presents, and the public debates about robots and AI in which those issues have featured, what HRI touch research can expand upon is more than just positive or negative ratings of a robot, feelings of affection, or experiential similarity to human touch. Robot-initiated touch in particular may be a key leading edge to how robotic autonomy and/or agency is interpreted in shared spaces. Thus, evaluating the robot on the basis of tactile action will need to involve a broader set of attributions than typically employed [5], opening onto notions of social competence, responsibility, companionability, and dependability.

The present study attempts to advance HRI touch research along these lines, situating robot-initiated touch in a plausible task-oriented context and then examining how third-party observers evaluate the robot as a social agent after seeing the tactile interaction. Embedding touch into a more robust context allows the interpretation of touch to incorporate the appearance and attitude from the robot, with more detail visible in terms of the robot's function and performance. How does touch affect one's attributions toward a robot if the robot is giving instructions while reacting critically or encouragingly? To capture further some of the real-life spontaneity with which robot-initiated touch may occur, the study seeks to represent a touch that is not announced or prepared for by the robot. Because of how gender roles can affect how robots are interpreted [30], including the gender-typicality of those with whom they interact, the study also sought to represent the robot touching a male and female subject in respective conditions [10, 22]. One of the questions being investigated is how gender might affect how touch is interpreted by an observer, especially given different "social meanings" for touch between genders in settings where status is asserted [7, 15]. Accordingly, we are interested in paying close attention to how male and female participants respectively ascribe social qualities to the robot after observing its overall interaction.

An in-lab setting for such a design would, again, yield direct experience for a participant of the robot's touch. Facing difficulties of consent, previous in-lab worked has often prepared participants for being touched by having it announced beforehand, or by having the participant touch the robot first. Such measures, however, not only make it harder to know how the touch itself is interpreted (as opposed to the bonding of touching the robot first), as admitted in [25], but also lose some of spontaneity that would more closely resemble interpersonal touch.

Given the "social meaning" point mentioned above, then, a legitimate research step forward can be taken by having an observer interpret a simulated scenario that shows a real touch in social context. To give more detail than a verbal description or photograph, this study created a video for participants to observe before taking a survey about the robot, described below.

From the previous HRI research our primary hypothesis is that robot touch, whether with negative and positive attitudes, will improve ratings of the robot's social qualities and performance. Though our review of the literature on touch, gender expectations, and interpersonal attraction cues us to look for gender effects from participant rating, neither past HRI work nor studies of interpersonal touch provide a conclusive suggestion about what the significant effects would be [34, 36, 41]; accordingly we did not hypothesize significant gender effects in terms of attributions, whether between male and female participants or between the gender of the person observed being touched.

3 METHODS

In order to test how people appraise a social robot whose interaction might include touch, we set up a survey that would be based on a videorecording (with audio) of a human-robot-interaction. To extend the usual metrics for assessing robots' sociality, this survey sought to elicit judgments about the robot as a worker, teammate, and overall agent, not just as a touching instrument. We decided on an Amazon Mechanical Turk (AMT) in part because we would have a chance at reach a broader demographic than the college students typically signing up in a university setting. Nor, when it came to robot touch in an ordinary (simulated) task environment, did we think the college demographic would be as usefully varied in terms of the office environment presented. We find that AMT studies have been suitably defended as an appropriate method [14], though we also recognize recent cautions about ways in which AMT's might have unanticipated limits to the subjects recruited that end up participating [33]. By way of avoiding one of the pitfalls mentioned by Stewart et al., we recruited participants at both day and evening times.

3.1 Materials

Scenario. The scenario (used as video template) was that of a person entering a room and being greeted by a PR2 robot standing next to a desk, on which sits a computer keyboard and monitor. The robot first asks the person to put their cellphone in a bin next to the computer, and it then invites the person to sit down at the computer and enter the information requested on the screen. It gestures with one arm toward the computer screen and with the other arm points to the chair. In each condition, the computer goes black after the person inputs a few items of information. At that point the robot looks toward the participant then the screen and back and either 1) offers the verbal feedback, "That's OK, I know how to fix this" while gently touching the person on the back (above the chair back), 2) offers negative feedback of "What did you do?" while touching the person in the same fashion, 3) offers the positive feedback without touching, 4) offers the negative feedback without touching. After this is done, the robot tells the person to "Hit the Enter key twice" at which point the screen returns to normal and the person finishes their input of information. The robot then says, "Thank you" to the participant and the video ends.

Video recordings. We made a separate video for each of the four response scenarios above. Because we were interested in the effect of gender on how touch is regarded, these four were recorded for a male actor and female actor both, making a total of eight different videos from which the AMT would choose (randomly) for a participant to observe before taking the survey. Fig. 1 shows the four snapshots from the moment in the video where the male or female actor were either touched or not touched by the robot. The PR2 robot used for the recording was fully remotely controlled.

Survey. The post-experiment survey consisted of 12 questions, plus a validating question at the end to make sure the participant had seen correctly whether or not the robot had touched the person in the video. For each question participants were asked to rate their agreement on the following scale: 1 = strongly disagree 2 = disagree 3 = neither disagree nor agree 4 = agree 5 = strongly agree. The questions were as follows:

I felt that the robot was very capable of performing its job
I had confidence in the skills of the robot
I believe that the robot was well qualified
The robot has specialized capabilities that can increase our performance
I believe the robot really looked out for what was important to the person
The person's needs and desires were very important to the robot
I think the robot went out of its way to help the person
I believe that the robot tried to be fair in dealings with the person
The robot has a strong sense of justice
I liked the values of the robot
Sound principles seem to guide the robot's behavior
To what extent would you want this the robot as your teammate?

Participants. We recruited 400 US subjects from AMT: 68 were eliminated either because they did not finish the experiment or because they did not pass the "probe"(which tested whether they saw the robot touch the person), leaving 332 subjects for the study (135 female/197 male) with an average age of 44.43 years (see Fig. 2 for a breakdown according to each experimental condition).

G	T	A	F	M
f	+	+	21	22
f	+	-	20	28
f	-	+	12	28
f	-	-	21	24
m	+	+	16	25
m	+	-	12	25
m	-	+	12	25
m	-	-	21	20

Figure 2: Number of female (F) and male (M) subject in each condition (G=actor gender, T=touch/no-touch, A=positive/negative).

Procedure. Participants were informed that the purpose of the study was to collect data on how humans perceive human-robot interactions in daily life scenarios. They were told that, upon giving informed consent and completing a brief demographic questionnaire, they would be presented with a brief video showing the scenario and then be asked to answer questions about the scenario.

4 RESULTS

We performed an analysis to determine the optimal number of factors to retain in an exploratory factor analysis using different methods (such as the Kaiser rule or optimal coordinates) and obtained that two factors (for three out of four methods) and one factor (for one out of three methods) were optimal. From a Maximum Likelihood Factor Analysis with varimax rotation we obtained loadings for all twelve questions, with questions 1 through 4 loading on one factor, which was roughly about robot skills and capabilities, and questions 5 through 12 loading on the other factor, which was about roughly about the robot's moral attitude (together both factors explained about 70% of the variance). We then performed 2x2x2x2 ANOVAs with *subject gender* (male/female), *agent gender* (male/female), *attitude* (positive/negative) and *touching* (touch/no touch) as independent variables and each of the two factors as dependent variable, respectively. For the first factor on robot skills and capabilities we found significant main effects for subject gender ($F(1, 316) = 8.67$, $p = .003$, $\eta_p^2 = .027$)

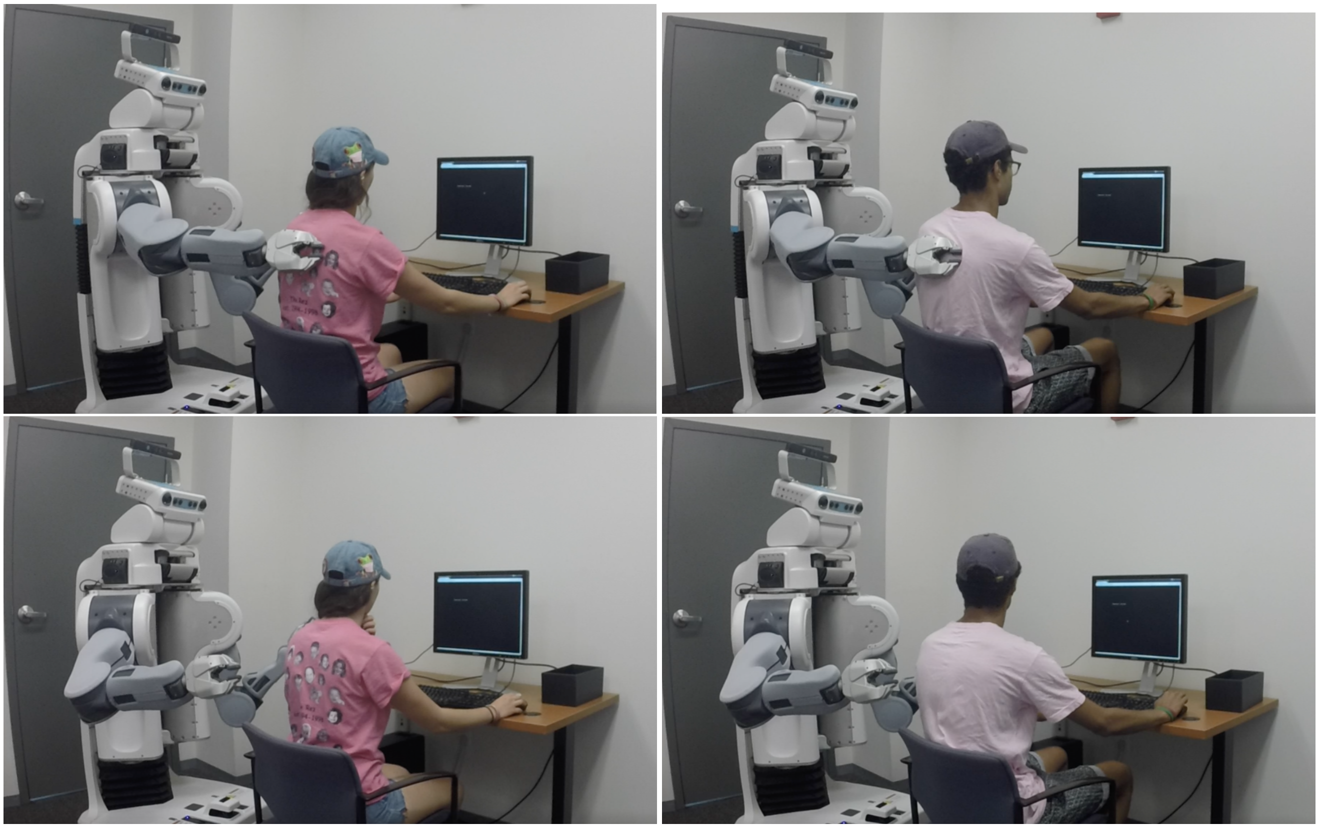

Figure 1: Snapshot from the video conditions. Top row: the female and male subjects as they are touched by the robot. Bottom row: the female and the male subjects without being touch by the robot.

and attitude ($F(1, 316) = 13.30$, $p < .001$, $\eta_p^2 = .040$), as well as significant two-way interactions between touch and actor gender ($F(1, 316) = 10.75$, $p = .001$, $\eta_p^2 = .033$) and subject gender and attitude ($F(1, 316) = 8.45$, $p = .004$, $\eta_p^2 = .026$), and a significant three-way interaction between touch, subject gender and actor gender ($F(1, 316) = 5.26$, $p = .022$, $\eta_p^2 = .016$). For the second factor on robot moral attitudes we found significant main effects for touch ($F(1, 316) = 16.17$, $p < .001$, $\eta_p^2 = .049$), actor gender ($F(1, 316) = 4.77$, $p = .030$, $\eta_p^2 = .015$), and attitude ($F(1, 316) = 11.13$, $p < .001$, $\eta_p^2 = .034$), but no significant interactions. Based on these results, we performed more detailed analyses on the individual questions to examine the significant differences found for both factors.

Answers to "Capable of performing its job"

We performed a 2x2x2x2 ANOVA with *subject gender* (male/female), *agent gender* (male/female), *attititue* (positive/negative) and *touching* (touch/no touch) as independent variables and the answer to the "I felt that the robot was very capable of performing its job." as dependent variable. We found significant main effects for subject gender ($F(1, 316) = 8.45$, $p = .004$, $\eta_p^2 = .026$) and attitude ($F(1, 316) = 24.99$, $p < .001$, $\eta_p^2 = .073$) which were eclipsed by a significant two-way interactions for subject gender and attitude ($F(1, 316) = 8.45$, $p = 0.004$, $\eta_p^2 = .033$) showing that males agreed significantly less that the robot was performing its job when its attitude was negative than when its attitude was positive while for females the agreement the negative attitude made no real difference. We also found a significant two-way interactions between agent gender and touch $F(1, 316) = 6.80$, $p = 0.009$, $\eta_p^2 = .021$) which was eclipsed by a significant three-way interactions between subject gender, agent gender, and touch $F(1, 316) = 5.11$, $p = 0.024$, $\eta_p^2 = .016$) showing that male subjects only gave the male no-touch condition a lower rating ($M = 3.47$, $SD = 1.06$), the other conditions were about equal around 3.8, while female subjects rated the male touching highest ($M = 4.35$, $SD = .78$), followed by female no-touch ($M = 4.21$, $SD = .78$), female touch ($M = 3.98$, $SD = 1.11$) and male no touch ($M = 3.64$, $SD = .90$).

Answers to "Confidence in the skills of the robot"

We performed a 2x2x2x2 ANOVA with *subject gender* (male/female), *agent gender* (male/female), *attitude* (positive/negative) and *touching* (touch/no touch) as independent variables and the answer to the "I had confidence in the skills of the robot." as dependent variable. We found significant main effects for subject gender ($F(1, 316) = 4.2$, $p = .041$, $\eta_p^2 = .013$), attitude ($F(1, 316) = 11.31$, $p < .001$, $\eta_p^2 =$

.035), and touch ($F(1, 316) = 4.1$, $p = .044$, $\eta_p^2 = .013$) with female subjects having higher confidence in the robot's skills ($M = 3.81$, $SD = 1.09$ vs $M = 3.58$, $SD = 1.08$ for males), subjects preferring the positive attitude ($M = 3.86$, $SD = .98$ vs. $M = 3.49$, $SD = 1.16$ for the negative attitude) and touching ($M = 3.79$, $SD = 1.06$ vs. $M = 3.55$, $SD = 1.11$ for no touch). Moreover, we found a strong two-way interaction between agent gender and touching ($F(1, 316) = 12.26$, $p < .001$, $\eta_p^2 = .034$) showing that subjects rated the robot touching the male subject significantly higher in confidence in skills ($M3.92$, $SD = .93$)) than in the no touching condition ($M = 3.28$, $SD = 1.13$), while the confidence in the robot's skills was rated numerically lower ($M = 3.69$, $SD = 1.15$) for touching the female than no touch ($M = 3.79$, $SD = 1.04$).

Answers to "Well-qualified"

We performed a 2x2x2x2 ANOVA with *subject gender* (male/female), *agent gender* (male/female), *attitude* (positive/negative) and *touching* (touch/no touch) as independent variables and the answer to the "I believe that the robot was well qualified." as dependent variable. We found a significant main effects for subject gender ($F(1, 316) = 10.72$, $p = .001$, $\eta_p^2 = .033$) and for attitude ($F(1, 316) = 20.50$, $p < .001$, $\eta_p^2 = .059$) which was eclipsed by a significant two-way interaction between subject gender and attitude ($F(1, 316) = 5.92$, $p - .021$, $\eta_p^2 = .016$) showing that the robot's positive vs. negative attitude did not make as much of a difference for female subjects ($M = 3.98$, $SD = .97$ vs. $M = 3.78$, $SD = 1.15$) as for male subjects regarding its qualification ($M = 3.83$, $SD = .95$ vs. $M = 3.13$, $SD = 1.13$).

Answers to "Tried to be fair"

We performed a 2x2x2x2 ANOVA with *subject gender* (male/female), *agent gender* (male/female), *attitude* (positive/negative) and *touching* (touch/no touch) as independent variables and the answer to the " believe that the robot tried to be fair in dealing with the person." as dependent variable. We found significant main effect for attitude ($F(1, 316) = 10.96$, $p = .001$, $\eta_p^2 = .035$) and touching ($F(1, 316) = 9.2$, $p = .003$, $\eta_p^2 = .028$) which were eclipsed by a significant three-way interactions between subject gender, attitude, and touching ($F(1, 316) = 6.08$, $p = .014$, $\eta_p^2 = .019$) showing that for male subjects a negative attitude without touching yields the lowest fairness rating ($M = 2.86$, $SD = 1.21$) compared to negative with touching ($M = 3.26$, $SD = 1.21$), or positive without ($M = 3.36$, $SD = 1.27$) and with touch ($M = 3.53$, $SD = 1.21$). For female subjects the ratings, the overall range is wider: as with male subjects case, negative with no touching has the lowest rating ($M = 2.67$, $SD = 1.20$), then come equally positive without touch ($M = 3.54$, $SD = 1.38$) or negative with touch ($M = 3.56$, $SD = 1.41$), then positive with touch as the highest ($M = 3.76$, $SD = 1.3$).

Answers to the other questions

The questions "I believe the robot looked out for what was important to the person.", "I think the robot went out of its way to help the person.", "Sound principles seem to guide robots behavior.", "To what extent would you want this robot as your teammate?" and "I liked the values of the robot." had highly significant main effects for attitude and touch: positive attitude leads to higher ratings, and touching leads to higher ratings. "I liked the values of the robot" and "The robot has a strong sense of justice." led to higher ratings only with touch, while "The person's needs and desires were very important to the robot." only led to higher ratings with positive attitude.

5 DISCUSSION

The general results across all twelve questions showed that conditions in which the robot touched the person in the video produced higher agreement that the robot possessed the positive qualities posed by the survey. The study's results therefore support previous findings in HRI, and our hypothesis, that touch improves people's evaluation of a robot's social performance. Survey respondents rated the robot who touched the person higher on being skilled, looking out for what was important, being attentive to needs and desires of person, and being a desirable teammate. Touch also bolstered respondents' ratings of the robot being fair, having their values, and going "out of its way" for people. While the survey's attributions did not increase uniformly with touch (the effect on the attribute of being "capable of performing its job" being marginal, not significant for "well-qualified"), they certainly confirm that the observed gesture of touch enhanced the overall social appraisal of the robot.

The positive attitude of the robot via verbal response, as one would expect, yielded more positive ratings for the robot overall (it had only a marginal effect for the robot possessing a "sense of justice," which may show that such a notion may be too weighty to involve positive attitude for the video's simulated task performance). More notably, negative attitude did not render the robot's touch counter-productive or anti-social – touch was generally preferred as an accompaniment to the negative feedback as well. This suggests that the character of the observed touch (gentleness, motion, part of the body, timing) has some independent force relative to visual or verbal channels of interaction, rather than just being aligned with other modalities of behavior shown to the observer.

So far as those general points go, the empirical results square well with what previous research would have led us to expect. As we zoom in on some of the gender effects and interactions from the survey, however, there are some very interesting, distinctive patterns to consider for tactile HRI investigations. There are significant differences both in whether a male or female actor is observed being touched in the video and in how male and female respondents evaluated the robot's touch.

To begin with, attribution to the robot of being "capable" show an interesting discrepancy in the effect of touch. Male and female participants collectively found the robot more "capable" when the robot was observed touching the male actor rather than not touching him ($M = 4$, $SD = .94$ vs.$M = 3.53$, $SD = 0.99$), but female participants found the robot more capable when not touching the female actor than when touching her ($M = 4.21$, $SD = .78$ vs. $M = 3.9$, $SD = 1.11$). Male participants, for their part, found the robot slightly more capable in touching the female actor than not ($M = 3.82$, $SD = 1.02$ vs.$M = 3.71$, $SD = 1$), but showed a wider gap between touching and not touching the male actor ($M = 3.8$,

SD = .97 vs. M = 3.47, SD = 1.06). In other words, male participants seemed to take a male not being touched as more negative for robot appraisal than do female participants, and female participants are more positive than male ones toward a robot that does not touch a female actor.

The same asymmetry holds for "confidence in the robot's skills" and the robot being "well-qualified" – both male and female participants agreed most about the robot's having skills when observing the touching of the male actor (with female confidence at M = 4.25, SD = .80 and male at M = 3.74, SD = .96), but female respondents were comparatively more confident in the robot's skills when it did not touch the female actor than when it did (M = 4.03, SD = .92 vs. M = 3.75, SD = 1.18). As for the robot observed not touching the male actor, both males and female participants rated the robot lower in skills than any other conditions (M = 3.27, SD = 1.12 and M = 3.3, SD = 1.19). For whether the robot was "well-qualified," female participants rated the robot highest when the male actor was touched (M = 4.14, SD = 1.01) and when the female actor was not (M = 4.06, SD = .93), with the female being touched slightly lower (M = 3.85, SD = 1.2) and not touching the male actor rated lowest (M = 3.48, SD = 1.03). Male participants rated the robot touching the male actor and female actor equally well-qualified (M = 3.58, SD = 1.01 and M = 3.58, SD = 1.18), while rating not touching a female actor higher (M = 3.44, SD = 1.07) than not touching the male actor (M = 3.33, SD = 1.15).

In terms of interaction between the gender of the person touched and the robot's appraisal, then, we have 1) a higher appreciation on the part of female participants for a female subject not being touched, and 2) a shared sense that the male not being touched results in the lowest rating for robot's capability, skills, qualifications, etc. We will return to these points below.

Why is there a lower rating of a robot not touching a male among these conditions? When we examine the role of positive vs. negative attitude via the verbal response ("It's OK" vs. "What did you do?!"), we see a related discrepancy when it comes, again, to capability and confidence in the robot's skills. In conditions where the robot had a negative attitude, male participants showed much lower ratings than than they gave for the robot with a positive attitude – both for capability (M = 4.08, SD = .85 vs. M = 3.32, SD = 1.03) and skills (M = 3.84, SD = .07 vs. M = 3.3, SD = 1.13). Female participants' ratings, on the other hand, do not seem as affected by negative vs. positive attitude, whether for capability (M = 4.08, SD = .86 vs. M = 3.95, SD = 1.02) or skills (M = 3.90, SD = 1.01 vs. M = 3.74, SD = 1.16). This striking result could be couched as women being more accepting, or at least more accustomed to facing negative attitudes (especially, perhaps, in a technological context); alternatively, one could surmise male participants are more sensitive and reactive to a negative attitude from the robot. At the same time, one could ask if participants, especially female participants, observed the interaction as a setting of cross-gender touch (due to the male voice and particular form of the PR2) that was less appropriate in a workplace than same-gender touch [7].

When one considers the general lower ratings for the robot that does not touch the male actor, one could well view touch as helping to mitigate or soften a perceived insult or reprimand. One might also theorize about female interactants' comparative strength in filtering out negative attitude in their appraisal of skill, capability, etc. It adds an interesting question to the higher rating female participants gave to the robot not touching the female actor – does touch lack the mitigating function that it might play generally for male interactants? Or, again, is this a case where cross-gender touch is considered less appropriate?

The results for the robots having "sound principles" tend to support the idea that some kind of cultural norm or phenomenon concerning male vs. female treatment is feeding into robot appraisal (albeit a norm held to different degrees in terms of male vs. female participants). The robot was seen to be most principled when giving positive feedback and touching both the male and female actor, but much less principled when giving negative feedback and not touching the male actor than when giving negative feedback and not touching the female actor. This perhaps suggests that touch directed toward a man is thought of more positively and straightforwardly pro-social, with not touching a man carrying more negative cost to the rating.

As one further wrinkle to how gendered dimensions to robotic touch, attitude, and role might play into larger societal judgments and values, we can look more closely at the question of whether the robot was seen as trying to be "fair." Looking at the interactions between attitude and the gender of the person touched (or not touched), the positive attitude combined with touch was rated higher for both a female and male actor being touched (M = 3.7, SD = 1.15 and M = 3.56, SD = 1.36). And, not unexpectedly, a positive attitude combined with not touching the female actor was equally high as a negative attitude with touch (M = 3.17, SD = 1.43 and M = 3.17, SD = 1.34). A negative attitude with no touch for her was lowest ranked for fairness (M = 2.87, SD = 1.14). With the male actor, on the other hand, the condition of negative attitude and not being touched received decidedly lower rank (M = 2.66, SD = 1.28) than the other three combination (positive attitude with touch, M = 3.56, SD = 1.36; positive with no touch, M = 3.67, SD = 1.11; and negative with touch M = 3.65, SD = 1.18). Again, there seems to be a drop-off that comes with a negative attitude and no mitigating touch when it comes to a male interactant in this robotic work context.

When it comes to the interpretation of touch in a social environment, our results bear out a general point that understanding the signaling and function of touch cannot be isolated from other modes of sociality in HRI analyses. Those observing them being touched will be robust interpreters of, and thus possibly dynamic interactants with, the robot's performance, not excluding expectations of gender and workplace roles. Given the gender effects we have found, there is more fine-grained work to be done to test the presuppositions behind less approval for robot-initiated touch of women than men. One direction in which to build is to connect tactile HRI with work on technology and gender, for example the idea of "male self-assurance and female hesitation" [8]. In parallel, the results point to further examination of different workplace expectations, to see more clearly how cross-gender touch is seen and how perceived robot gender instantiates them. In what ways is not being touched related to one's attitude toward the observed or perceived technology? For now, this study at least establishes evidence that male observers approve of robot touch on different terms than female observers. The results around capability and skills invite further reflection about how gender stereotypes, roles, and expectations may play into how touch works with a robot's presumed competence, authority, and power in a given context. It will be crucial in future efforts to discern more precisely how cultural and societal norms are finding their way into appraisals of robot touch and intensify debates around robot uses [31]. Certainly HRI research will benefit from staying connected to interpersonal research and gender research in psychology [19, 27], to better discern where human-robot interaction poses distinctive challenges and offers distinctive details to how interactions operate in context [10, 21]. This will require paying attention to context-based expectations of touch, for example the appropriateness of cross-gender touch within subordinate-superior workplace relationships, as well as how female interactants may respond to forms of politeness more positively than male interactants [29, 35]. From these particular results there seems to be an important set of HRI discussions to develop around gender dynamics amid personal conflict, settings of instruction and/or correction, and emotional regulation.

Given the size of the PR2, and that in the video its voice sounds more typically male, another clear direction for further work will be looking at variation in form, voice (and perhaps even cues like a given name, to see if that frames expectations). It will also be important to probe expectations and assumptions about how gender-typical certain roles might be, to see how much those inform how capable, skilled, value-oriented, etc. a social robot is deemed. In-lab research may adjust the configuration of shared space, including different interfaces (e.g. text vs. voice), to see on what terms tactile experience enhances a robot's perceive competence and trust. That said, the lab environment itself may not be the best indication of how participants would react in real-world settings [18].

Again, taken all together, these results confirm touch's potential for relationship improvement between human and robot, but they carry important cautionary markers for how context and societal expectations may contour that overall positive effect for different people. Certainly the study underscores that designing human-robot interactions needs to account for how expected roles, representation of authority, and ascriptions of ability help condition notions of "teamwork," "rapport," and "compliance" [6], as well as HRI ethics writ large [3]. This will be even more important for the mapping and study of robotic application domains, to which any general theoretical commitment about robot touch should be put to the test. Anticipating how the staff and residents of a nursing home, say, will present robotic technology's skill and authority, versus how children will interact in a domicile, may lead to better tactile accompaniment and more humane safeguards for social interactions.

Limitations. While this study uses video to provide a standardized stimulus for observing participants, one must bear in mind that ultimately the study relies on an observation of touch, not a full participation in touching or being touched. To the degree that a controlled setting will be able to provide a consistent and direct tactile stimulus, future study could yield richer detail into how a robot's touch operates socially and physically. Even within the frame of observing (e.g., a confederate being touched), actual physical presence near the observed touch (rather than video) may change the terms by which the touch is judged. Whether as observed or directly experienced, it is clear this study's recorded interaction could have included additional, important variations, especially given the gender effects it gathered. As mentioned above, it is notable that the robot's voice had a typical male register; for that reason, having a more female-identified robot voice might shed crucial light on how much a male identification might have informed the various ratings of the robot. Likewise, the norms of cross-gender touching and workplace expectations will a great deal of further experimental attention.

Another limitation of the study concerns the type of survey administered. Because we sought attributions to the robot itself, the questions were directed to personal qualities, not the nature of the touch and behavior itself. Going forward with research into HRI touch will require ways to track attributions without cuing participants that touch is the behavior being examined, while building on previous interpersonal measures of social and task attraction [24].

6 CONCLUSION

Through this study we have confirmed the general trajectory of results from previous HRI work around robot-initiated touch, namely that it can lead to more positive evaluations of the touching robot. We have expanded upon those findings to show that this positive effect extends to an array of agent-like qualities attributed to the robot, both work-oriented and relationship-oriented. In addition, we have found that a touch gesture situated in a simulated work context elicits gender effects from the survey responses, both in terms of female respondents generally giving more positive rating to a lack of robotic touch (toward female interactants) and in terms of different reactions to a male not being touched with negative attitude. We can conclude that robot-initiated touch may well channel and reflect broader gender-oriented evaluations about when and for what touch is appropriate in a work context. Further work will need to keep testing the rough ground of socially embedded robot-human touch, with more fine-tuned variance among tasks, relationships, observers, and interactants. The way that touch may mitigate or dampen conflict with a male user, for instance, should be considered in light of the wider context where that interaction takes place and the expectations of those observing touch. More progress in testing promises to come from settings of emerging implementations, where the line between "functional" and simply "affective" will often blur (care, therapy, companionship, guidance in public space). Given the qualities and attributions investigated in this study, these more subtle tests may hold particular import for work on multi-agent systems and human-robot teams. Though sometimes neglected in analyses of social interaction, touch promises to keep revealing itself as inextricable from humanity's most fundamental social practices and deepest ideals for how to live with one another.

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