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Physical Touch from a Robot Caregiver: Examining Factors that Shape Patient Experience

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***Abstract*— Robot-initiated touch is a promising mode of expression that would allow robot caregivers to perform physical tasks (*instrumental touch*) and provide comfort (*affective touch*) in healthcare settings. To understand the factors that shape how people respond to touch from a robotic caregiver, we conducted a crowdsourced study (N=163) examining how robot-initiated touch (present or absent), the robot's intent (instrumental or affective), robot appearance (Nao or Stretch), and robot tone (empathetic or serious) impact the perceived quality of care. Results show that participants prefer instrumental to affective touch, view the robot as having greater social attributes (higher warmth, higher competence, and lower discomfort) after robot-initiated touch, are more comfortable interacting with the human-like Nao than the more machine-like Stretch, and favor consistent robot tone and appearance. From these results, we derived three design guidelines for caregiving robots in healthcare settings.**

I. Introduction

Physical touch is fundamental in human caregiving, notably to provide physical assistance (instrumental touch) and to communicate emotion (affective touch) [1]. A caregiver may clean a patient's arm with an instrumental touch or comfort a patient with an affective pat on the shoulder. Given the importance of touch to facilitate physical aid and emotional support between human caregivers and patients, it is crucial to understand how patients respond to robot-initiated instrumental *and* affective touch as social robots begin to enter medical settings as caregivers.

Human-robot interaction (HRI) research has begun to investigate human-robot touch for its potential to expand communication capabilities of social robots, such as conveying emotions [2], [3], relieving stress [4], [5], and offering assistance [6]. Robot-initiated touches (e.g., handshakes [7], [8], pats on the back [9], and hugs [10], [11]) have been shown to increase trust [12], [13], motivation to finish a task [14], [15], and perception of a robot's warmth, animacy, and likeability in human-robot interactions [8].

Although human-robot touch is a growing area of research, it has not been studied as thoroughly in medical settings. Preliminary work suggests robot-initiated touch can be useful in performing instrumental procedures like bed baths [6] and affective tasks like comforting during radiotherapy treatment [16]. Although both kinds of robot-initiated touch have been evaluated favorably, human patients consistently prefer instrumental to affective touch from caregiving robots [17], [18]. Since the context of a touch (e.g., physical setting [17], verbal communication before the touch [17], [18], and an existing bond between the robot and human [15]) significantly impacts how the touch is perceived [9], further work is necessary to understand 1) how to make necessary instrumental touches most comfortable and 2) when an optional affective touch can enhance the patient experience.

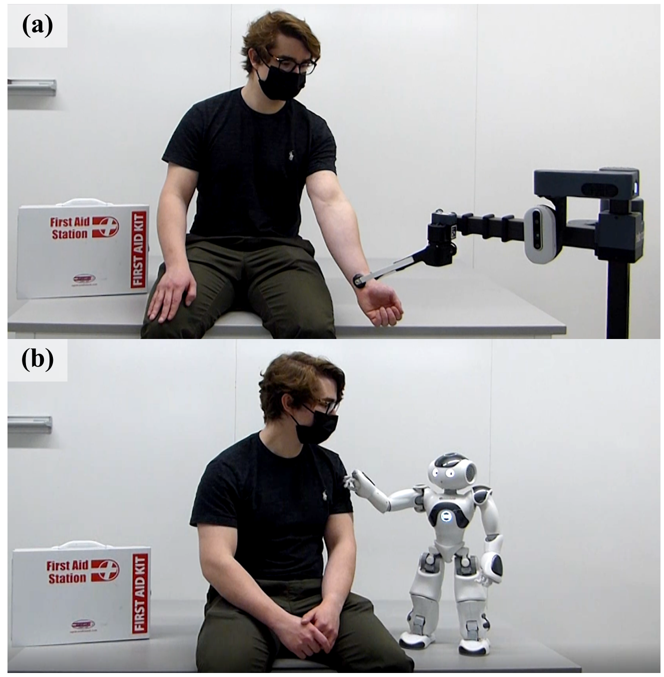

Fig. 1. Participants watched videos of a robot providing physical care, including (a) a Stretch robot taking a patient's temperature (instrumental touch) and (b) a Nao robot comforting an ill patient (affective touch).

We address the gap by exploring how a robot caregiver's appearance and tone, qualities that have demonstrated significant influence on trust and compliance with a robot [19], affect the quality of a medical screening involving instrumental and affective touch in an observational crowdsourced study. In summary, we found touch from the robot resulted in greater perceived warmth and competence, and lower discomfort. Moreover, we found interaction effects between the robot's appearance and the presence of touch, as well between the robot's appearance and tone. From our results, we propose several design guidelines for robotic caregivers capable of social touch to improve patient comfort and perceived quality of medical care.

II. Related Work

We frame our research within literature exploring human-robot social touch and robot-initiated touch in medicine.

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A. Human-Robot Touch

Recent work in HRI indicates promising affective outcomes from haptic interactions with robots [20], [21]. Breathing robots resembling animals decrease users' anxiety [22] and pain [5] when stroked, and robots that recognize the meaning of human-initiated touch may elicit affection [21], [23]–[26]. Human-robot hugs can produce feelings of comfort and support [10], [11], and haptic devices that, for instance, transmit squeezes, pats, and strokes, may facilitate affective touch between geographically separated users [27], [28]. Studies emphasizing the mechanics of human-robot touch recommend parameters for force, velocity, duration, and position to make touches feel natural and convey particular emotions [3], [29].

Robot-initiated touch, such as handshakes [7], [8], pats on the back [9], or hugs [10], [11], may likewise supplement human-robot interactions, but success relies upon appropriate contextual and mechanical implementation. Users struggle to identify the intent of touch in ambiguous scenarios [30], and facial displays dominate perception of robot affect when affective touch is accompanied by other cues [4]. Robot-initiated touch has been found to reduce stress and strengthen perceived human–robot social bonds, regardless of whether a bond had previously been established [31]. Furthermore, robot-initiated touch may improve perception of a robot's trustworthiness even when the touch itself is seen as inappropriate [13]. After users failed to complete a computer task, a robot-initiated affective touch improved their view of the robot's social performance regardless of whether they received positive or negative feedback [9], implying that touch has some independent force beyond supporting visual or verbal modalities. van Erp and Toet's guidelines for robot-initiated social touch emphasize that perception of a robot's social attributes is highly situation-dependent [32].

B. Robot-Initiated Touch in Healthcare

Within healthcare, human-robot touch is essential for robots that perform physical tasks, such as giving bed baths [6] and physically transferring bedridden patients [33]). Moreover, physical touch is necessary for robots that provide companionship and emotional support to patients with tactile interactions like being pet and held [34]–[36]. In the most comprehensive study examining robot-initiated touch in a medical setting to-date, Chen et al. evaluated how perceived intent and verbal warnings influence subjective response to robot-initiated touch [17], [18]. A Cody robotic nurse wiped each participant's arm either before or after informing the participant it intended to clean their arm or comfort them. Participants responded more favorably to the instrumental touch than to the affective touch despite experiencing the same physical sensation, which suggests that perceived intent influences the experience of touch. Participants responded less favorably to the verbal warning, which may have resulted from the startling nature of the announcement. Although Chen et al. began to illuminate how robot intent and verbal warnings affect the experience of touch, other potentially influential factors remain unexplored, including robot appearance and tone.

III. Methods

To examine how people perceive a robot caring for a patient in a medical setting, we conducted an online human subjects study where participants watched videos of a robotic caregiver interacting with a human patient. We varied four factors: the presence of physical touch, robot intent, robot appearance, and robot tone (Figure 1). After viewing the interaction, participants completed a questionnaire assessing their perceptions of the robot and the overall quality of care. The online format allowed us to study the interplay of many independent variables with a diverse range of participants.

A. Study Design

We conducted a 2 (touch: present or absent) x 2 (robot intent: instrumental or affective) x 2 (robot appearance: Nao or Stretch) x 2 (robot tone: empathetic or serious) mixed methods human-subjects study with the presence of touch, robot appearance, and robot tone as between-subjects variables and robot intent as a within-subjects variable. This study was approved by the University of Chicago's Institutional Review Board (IRB20-1867).

Each of the video recordings involved a robotic caregiver conducting a brief medical screening with a 24-year-old male patient (see Figure 1 and the supplemental video). We filmed a separate video for each of the 32 combinations of our independent variables:

- **Presence of Touch**: The robot either touched (**Touch**) or did not touch (**No Touch**) the patient.
- **Robot Intent**: The robot either took the patient's temperature (**Instrumental**) or comforted the patient (**Affective**).
- **Robot Appearance**: Either a Softbank Robotics Nao robot (**Nao**) or a Hello Robot Stretch robot (**Stretch**) interacted with the patient.
- **Robot Tone**: The robot either spoke with a serious tone (**Serious**), e.g., "I will make a note in your chart," or an empathetic tone (**Empathy**), e.g., "I'm sorry that you haven't been feeling well lately."

Instrumental Intent Video Scenario. In the videos involving instrumental robot intent (e.g., Figure 1a), the robot informed the patient that it would measure his temperature using sensors in its fingers and asked the patient to extend his arm. For 10 seconds, the robot either 1) gently held the patient's wrist in the touch condition or 2) hovered just above the patient's forearm in the no touch condition. Then, the robot thanked the patient and stated his temperature was 37°C.

Affective Intent Video Scenario. In the videos involving affective robot intent (e.g., Figure 1b), the patient told the robot that he was concerned about his frequent migraines. The robot either 1) turned toward the patient and gently patted his arm in the touch condition or 2) turned toward the patient without reaching out in the no-touch condition.

Finally, the robot informed the patient that the doctor would see him shortly, and the video ended. The tone of the robot's comments in the video scenarios was either 1) empathetic, e.g., "Please don't worry; headaches are normal and we definitely have something to help you" or 2) serious, e.g., "After the doctor evaluates your condition, she will discuss treatment options with you." The length of dialogue was similar for both tone conditions.

The Nao robot was programmed with Choreographe, while the Stretch robot was teleoperated during filming. The Nao robot's text-to-speech was used as the voice for both robots to prevent any variation in robot voice or intonation.

B. Hypotheses

We anticipate that perception of a robotic caregiver and the quality of care it provides a human patient will be shaped by the presence of physical touch, robot intent, robot appearance, and robot tone. Since robot-initiated touch increases human trust [12], [13], motivation [14], and perception of a robot's warmth, animacy, and likeability [8], we predict:

H1 When the robot caregiver **touches** the human patient, participants will (a) rate the patient's **quality of care** more highly and (b) perceive the robot to be **warmer, more competent, and less discomforting**.

Prior work suggests that human patients are more comfortable with instrumental robot-initiated touch [17], [18], but affective robot-initiated touch can enhance robot social appraisals [9].

H2 Participants will view a robot that uses **instrumental intent** as opposed to **affective intent** (a) as giving the patient higher **quality of care**, however, (b) less **warm**.

Finally, research demonstrating the benefits of 1) robot anthropomorphism on people's intention to use service robots [37] and 2) robot expressions of empathy on perceptions of robot friendliness [38] informs our hypotheses about robot appearance and tone.

H3 Participants will perceive the human-like **Nao robot**, compared to the machine-like **Stretch robot**, as (a) providing a higher **quality of care** and (b) **warmer**.

H4 Participants will view the robot using an **empathetic tone** as opposed to a **serious tone** as (a) providing a higher **quality of care** and (b) **warmer**.

C. Procedure

After providing informed consent, participants watched the two video scenarios of a robot caregiver performing a medical screening. After each video, participants completed a survey to capture their perceptions of the interaction.

All participants watched one instrumental and one affective interaction in a randomized and counterbalanced order. The presence of touch (present or absent), robot appearance (Nao or Stretch), and robot tone (empathetic or serious) were consistent between the two videos for each participant so that the scenario made sense as a single medical screening. For the between-subjects variables, participants were assigned to conditions randomly.

D. Measures

Each video was immediately followed by a questionnaire. Questionnaire items that were not open-ended assessed participant agreement on a 9-point Likert scale ranging from 1 (*Strongly Disagree*) to 9 (*Strongly Agree*).

1) Robot Performance: We assessed participants' perceptions of the robot's performance by asking them to rate the robot's quality of care, human-likeness, job performance, empathy, and mindfulness of the patients' best interests.

2) Robot Social Attributes: We evaluated participants' perceptions of the robot's warmth, competence, and discomfort using the Robotic Social Attribute Scale (RoSAS) [39].

3) Robot Touch: We asked participants in the touch condition to rate the appropriateness, naturalness, and comfort of the touch.

4) General Impressions: The questionnaire concluded with open-ended questions to gauge participants' general impressions of the medical screening, the robot as a caregiver, and the robot-initiated touch.

E. Participants

We recruited 193 subjects living in the United States on the Prolific crowdsourcing platform. 28 were eliminated because they failed to complete the survey, and 2 produced invalid results due to a technical video issue, leaving 163 subjects (81 female, 77 male, 5 nonbinary or self-identified) with an average age of 30.5 years ($SD = 10.7$). Participants were randomly distributed across groups, resulting in a near-uniform distribution of gender and experience with robots. Of the 163 participants, 43 had some degree of familiarity with robots, e.g., as toys or tools, while 9 had direct experience working with or programming robots. Each experimental condition contained between 17 and 23 participants ($M = 20.4, SD = 1.7$). We determined a target sample size of 152 subjects by conducting an *a priori* power analysis given α = 0.05, power = 0.95, and $\eta_p^2 = 0.0415$ for an analysis of covariance (ANCOVA). The effect size of $\eta_p^2 = 0.0415$ was calculated from the effect sizes found for the touch ($\eta_p^2 = 0.049$) and attitude ($\eta_p^2 = 0.034$) main effects on robot moral attitudes from Arnold and Scheutz [9].

IV. Results

We used an analysis of variance (ANOVA) to investigate the influence of four independent variables (presence of touch, touch intent, robot appearance, and robot tone) and their two-way interactions on perception of a robotic caregiver and the patient experience. For pairwise comparisons, we employed Tukey's honest significant differences test. The effect size is reported as partial eta squared (η_p^2).

A. Manipulation Check

To confirm that participants perceived the robot in our empathetic tone condition as truly empathetic, we examined participant responses to the questionnaire item "The robot was empathetic." We found that our empathetic condition was perceived as significantly more empathetic ($M = 4.99, SD = 2.39$) than our serious condition ($M =$

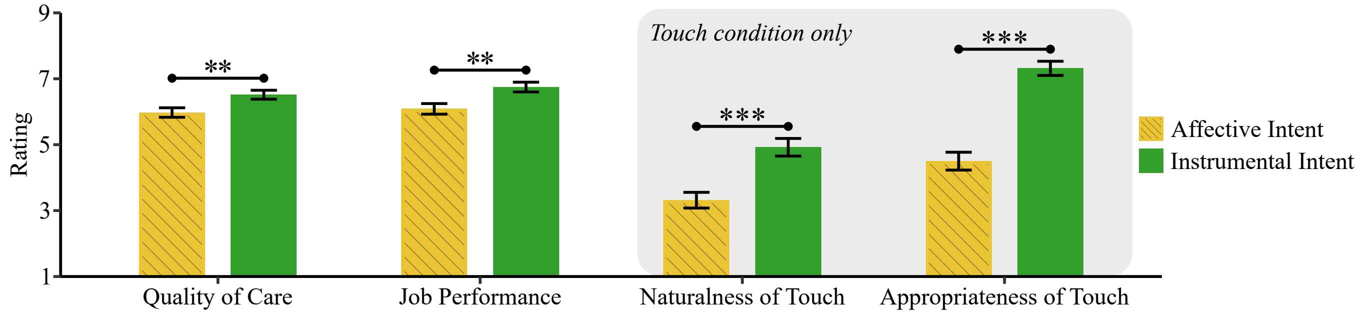

Fig. 2. Instrumental as opposed to affective robot intent produced higher quality of care and robot job performance ratings. When the robot touched the patient (examining only participant responses in the Touch condition), instrumental intent was perceived as more appropriate and natural than affective intent. (Standard error bars shown; **: $p < 0.01$, ***: $p < 0.001$).

$3.54, SD = 2.10, F = 33.80$, $p < 0.001$, $\eta_p^2 = 0.100$), validating our experimental design of the robot's tone.

B. Quality of Care

We analyzed participant perceptions of the quality of care by examining responses to the questionnaire item "Please rate the quality of care between 1 and 9." As shown in Figure 2, we found a significant main effect for the robot intent ($F = 7.34$, $p = 0.007$, $\eta_p^2 = 0.020$), where participants felt instrumental touch ($M = 6.52$, $SD = 1.74$) contributed more to quality of care than affective touch ($M = 5.98$, $SD = 1.74$). **The higher quality of care rating for instrumental touch over affective touch shows support for H2(a)** and confirms prior work demonstrating a similar preference for instrumental touch [17], [18], [40]. Neither the presence of touch, robot appearance, nor robot tone had a significant main effect on quality of care, so **H1(a), H3(a), and H4(a) were not supported**.

C. Care Experience

We also examined participant impressions of the overall care experience and found a main effect of robot intent on the appropriateness and naturalness of a touch as well as a contribution to job performance (Figure 2). Across each measure, instrumental touch was rated more positively than affective touch. We assessed appropriateness of touch with participant responses to "The robot touch was appropriate." As shown in Figure 2, we found a significant main effect for robot intent ($F = 64.10$, $p < 0.001$, $\eta_p^2 = 0.310$). Similar to the quality of care result, this indicates that participants felt instrumental touch ($M = 7.32$, $SD = 1.88$) was more appropriate than affective touch ($M = 4.50$, $SD = 2.36$). Moreover, we found a significant main effect for robot intent ($F = 19.37$, $p < 0.001$, $\eta_p^2 = 0.120$) with participants' ratings in response to "The robot touch was natural." Thus, participants also felt instrumental touch ($M = 4.92$, $SD = 2.34$) was more natural than affective touch ($M = 3.32$, $SD = 2.08$). Finally, our analysis of participant responses to "The robot performed its job well" revealed a significant main effect for the robot intent ($F = 9.11$, $p = 0.003$, $\eta_p^2 = 0.030$), indicating that participants felt instrumental touch ($M = 6.75$, $SD = 1.89$) contributed more to job performance than affective touch ($M = 6.09$, $SD = 2.06$). Altogether, these results provide further evidence that **instrumental touch was preferred to affective touch in support of H2(a)**. No other significant main effects or interactions were observed for the touch's appropriateness, naturalness, or contribution to job performance.

D. Perceptions of the Robot

To measure participants' perceptions of the robot's warmth, competence, and discomfort, we examined their responses to the RoSAS questionnaire [39]. Our analysis revealed significant interaction effects of touch and tone with robot appearance (Figure 3).

1) Effect of Touch: We found a significant main effect for the presence of touch on participant ratings of the robot's warmth ($F = 13.04$, $p < 0.001$, $\eta_p^2 = 0.007$), competence ($F = 8.15$, $p = 0.004$, $\eta_p^2 = 0.004$), and discomfort ($F = 5.94$, $p = 0.015$, $\eta_p^2 = 0.002$). The presence of touch, compared with the absence of touch, was associated with higher ratings of warmth (Touch: $M = 4.52$, $SD = 2.34$, No Touch: $M = 4.15$, $SD = 2.29$), higher ratings of competence (Touch: $M = 6.36$, $SD = 1.97$, No Touch: $M = 6.10$, $SD = 2.13$), and lower ratings of discomfort (Touch: $M = 3.26$, $SD = 2.57$, No Touch: $M = 3.49$, $SD = 2.61$). **Improved perception of the robot's social attributes following robot-initiated touch demonstrates support for H1(b)**. The type of touch did not have a significant main effect on warmth, so **H2(b) was not supported**.

Additionally, we found a significant interaction effect between the presence of touch and robot appearance on both warmth ($F = 5.80$, $p < 0.01$, $\eta_p^2 = 0.003$) and competence ($F = 3.85$, $p = 0.050$, $\eta_p^2 = 0.002$), as well as a marginally significant interaction effect for discomfort ($F = 3.588, p = 0.058, \eta_p^2 = 0.001$). As shown in Figure 3(a), the Nao robot touching the patient resulted in significantly greater warmth ($M = 4.86, SD = 2.39$) than the other robot appearance and touch pairs: Stretch-No Touch ($M = 4.09, SD = 2.40, p < 0.001$), Nao-No Touch ($M = 4.23, SD = 2.18, p < 0.001$), Stretch-Touch ($M = 4.23, SD = 2.26, p < 0.001$). Similarly, as shown in Figure 3(b), the Nao robot touching the patient resulted in significantly higher perceptions of the robot's competence ($M = 6.59$, $SD = 1.91$) than the other robot

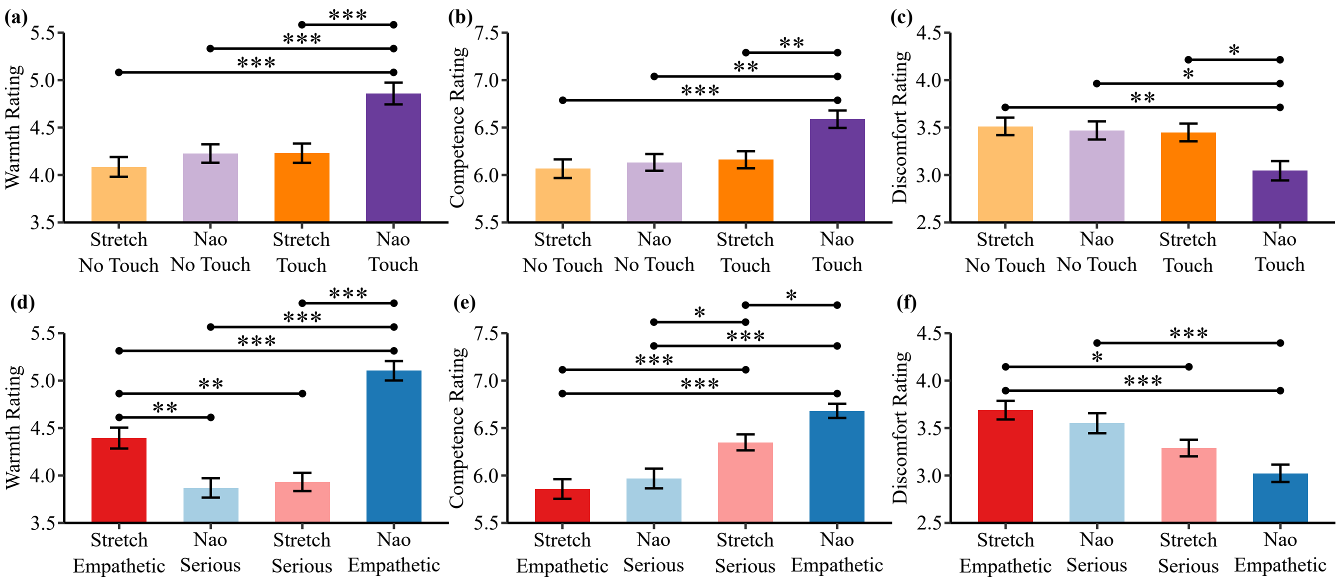

Fig. 3. Interaction effects were found between the robot's appearance and touch as well as between the robot's appearance and tone. (a-c) The pairing of the Nao robot and a touch resulted in significantly greater perceived warmth and competence and lower perceived discomfort. (d) The empathetic tone significantly improved perceptions of the robots' warmth, with the Nao-Empathetic pair resulting in the greatest perceived warmth. (e-f) The pairing of the Nao and an empathetic tone and the Stretch and a serious tone resulted in greater perceived competence and less perceived discomfort. (Standard error bars shown; *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$; full scale range: [1, 9])

appearance and touch pairs: Stretch-No Touch: ($M = 6.07$, $SD = 2.25$, $p < 0.001$); Nao-No Touch: ($M = 6.13$, $SD = 1.98$, $p = 0.003$); Stretch-Touch: ($M = 6.16$, $SD = 2.00$, $p = 0.007$). Moreover, as shown in Figure 3(c), the Nao robot touching the patient resulted in significantly lower perceptions of the robot's discomfort ($M = 3.04$, $SD = 2.59$) than the other robot appearance and touch pairs: Stretch-No Touch: ($M = 3.51$, $SD = 2.59$, $p = 0.003$); Nao-No Touch: ($M = 3.47$, $SD = 2.63$, $p = 0.011$); Stretch-Touch: ($M = 3.45$, $SD = 2.54$, $p = 0.019$). All other pairwise comparisons were not statistically significant. **Together, these interaction effects indicate that when the more human-like Nao robot touched the patient, it was viewed significantly more favorably (more warm, more competent, less discomfort) than when it did not touch the patient. However, when the Stretch robot touched the patient, participants did not view it any differently than when it did not touch the patient, highlighting differences in how people perceive touch from these two distinct robots.**

2) Effect of Tone: We found a significant main effect for the robot's tone ($F = 65.59$, $p < 0.001$, $\eta_p^2 = 0.030$) on warmth, where participants rated the empathetic tone ($M = 4.75$, $SD = 2.38$) as warmer than a the serious tone ($M = 3.90$, $SD = 2.18$). **A higher perception of the robot's warmth when the robot displayed an empathetic tone shows support for H4(b)**. No significant main effects were observed for the effect of tone on competence or discomfort.

We found significant interaction effects between the robot's tone and appearance on warmth (Figure 3(d)), competence (Figure 3(e)), and discomfort (Figure 3(f)). The interaction effect between the tone and robot appearance on warmth ($F = 14.36$, $p < 0.001$, $\eta_p^2 = 0.007$) is shown in Figure 3(d). An empathetic Nao ($M = 5.10, SD = 2.27$) was observed to be warmer than all other combinations: Stretch-Empathetic: ($M = 4.39, SD = 2.44, p < 0.001$); Nao-Serious: ($M = 3.87, SD = 2.15, p < 0.001$); Stretch-Serious: ($M = 3.93, SD = 2.20, p < 0.001$). The second warmest combination was the Stretch robot and an empathetic tone, which had greater warmth ratings than both Nao-Serious ($p = 0.003$) and Stretch-Serious ($p = 0.007$) conditions. Tone dominated robot appearance in perceived warmth, with both robots using an empathetic tone appearing warmer than either robot using a serious tone.

We also found a significant interaction between the robot's tone and appearance on competence ($F = 43.18$, $p < 0.001$, $\eta_p^2 = 0.020$), as shown in Figure 3(e). Pairing the Nao robot with an empathetic tone ($M = 6.68$, $SD = 1.66$) resulted in greater perceived competence than all other combinations: Stretch-Serious: ($M = 6.35$, $SD = 1.94$, $p = 0.040$); Nao-Serious: ($M = 5.97$, $SD = 2.19$, $p < 0.001$); Stretch-Empathetic: ($M = 5.86$, $SD = 2.30$, $p < 0.001$). The second highest combination was the Stretch robot and a serious tone, which had higher competence ratings than both Nao-Serious ($p = 0.020$) and Stretch-Empathetic ($p < 0.001$) conditions.

Finally, we found a significant interaction between tone and robot appearance on discomfort ($F = 22.96$, $p < 0.001$, $\eta_p^2 = 0.008$) , as shown in Figure 3(f). The Nao-Empathetic condition ($M = 3.02$, $SD = 2.49$) resulted in significantly less discomfort than the Stretch-Empathetic ($M = 3.69, SD = 2.66, p < 0.001$) and Nao-Serious conditions ($M = 3.55, SD = 2.73, p < 0.001$). The Stretch-Serious pair ($M = 3.29, SD = 2.46$) resulted in significantly less discomfort than the Stretch-Empathetic pair ($p = 0.015$).

In summary, **participants perceived robots using an empathetic tone as warmer than robots using a serious tone, independent of appearance**. However, when it came to participants' ratings of the robots' competence and discomfort, we observed interesting interaction effects. **Participants viewed the Nao robot as more competent and causing less discomfort when it had an *empathetic* tone. However, the opposite was true for the Stretch robot: participants viewed it as more competent and causing less discomfort when it had a *serious* tone.**

3) Effect of Appearance: We found significant main effects of robot appearance on the perception of the robot's warmth ($F = 13.15$, $p < 0.001$, $\eta_p^2 = 0.007$), competence ($F = 6.64$, $p = 0.010$, $\eta_p^2 = 0.003$), and discomfort ($F = 5.02$, $p = 0.025$, $\eta_p^2 = 0.002$). The more humanoid Nao robot, compared with the more mechanical Stretch robot, was associated with higher ratings of warmth (Nao: $M = 4.52$, $SD = 2.30$, Stretch: $M = 4.15$, $SD = 2.33$), higher ratings of competence (Nao: $M = 6.34$, $SD = 1.96$, Stretch: $M = 6.11$, $SD = 2.13$), and lower ratings of discomfort (Nao: $M = 3.27, SD = 2.62$, Stretch: $M = 3.48, SD = 2.57$). **For all three social attributes, the Nao's appearance was warmer, was more competent, and elicited less discomfort, supporting H3(b)**.

E. Other Findings

We also found a significant main effect for the robot's tone ($F = 9.64$, $p = 0.002$, $\eta_p^2 = 0.030$) on agreement with the statement "The robot had the patient's best interests in mind." Participants felt the empathetic tone ($M = 5.80$, $SD = 2.40$) better conveyed mindfulness of the patient's best interests in mind than the serious tone ($M = 4.98$, $SD = 2.35$).

V. Discussion

This work revealed that the presence of touch and robot intent, appearance, and tone shaped an observer's appraisal of a robotic caregiver, perception of the quality of care, and comfort when observing the robot interact with a patient.

Consistent with previous findings in nurse-patient [41]–[43] and human-robot interactions [17], [18], participants preferred instrumental to affective touch and saw it as more appropriate, natural, and important for performance. Multiple participants found the affective touch "*creepy*," and one elaborated, "*I don't think it would be warranted or appropriate for the robot to touch you in an effort to comfort you*." Familiarity with medical robots performing exclusively technical tasks could be responsible for the disparity between instrumental and affective touch. The robot's intent to provide emotional support in our affective scenario likely defied participants' expectations and left them unsure of how to interpret the robot's behavior. However, the average quality of care across all conditions (6.24 out of 9) suggests that the robot's performance was generally satisfactory. Furthermore, prior work suggests that occupational competence [44] and expressions of vulnerability [45] may increase trust in robots and thus the appropriateness of robot-initiated affective touch in a medical setting.

Ratings of the robot's warmth, competence, and discomfort provide insight into appropriate design for caregiving robots. The presence of touch, a human-like appearance, and an empathetic tone produced the best care experience and had a greater collective positive effect on perception of the robot than when employed separately. For example, pairing the humanoid Nao robot with touch had a synergistic effect on perceived warmth and competence. An empathetic, human-like robot resulted in the least discomfort, whereas an empathetic, non-social robot produced the most discomfort.

Notably, participants rated the robot as more competent and less discomforting when the robot's appearance and tone were consistent: an empathetic Nao was viewed more positively than a serious Nao, while a serious Stretch was viewed more positively than an empathetic Stretch. Complementary appearance and tone likely resulted in a more positive interaction because the robot's empathy agreed with participant expectations of its human-likeness.

VI. Design Guidelines

We explored four factors critical for realizing positive experiences within a medical screening conducted by a robot. Via responses to a crowdsourced survey, we characterized the influence of robot-initiated touch, robot intent, robot appearance, and robot tone on an observer's perception of quality of care. Our results inform the following design guidelines for robotic caregivers in medical contexts.

DG1: Robot-initiated touch can improve perception of a caregiving robot's social attributes. Medical examinations make patients feel vulnerable by nature, and research on interactions between human caregivers and patients has shown that intentional affective touch puts patients at ease [26], makes interactions feel genuine [30], and is crucial for immediate patient satisfaction and long-term physiological outcomes [46]. Our results indicate that the presence of robot-initiated touch produced significantly higher ratings of the robot's warmth and competence and significantly lower ratings of the robot's discomfort. In the context of care, robot-initiated touch may improve the patient experience by presenting robotic caregivers as compassionate, social agents rather than strictly machines.

DG2: A human-like robot appearance improves patient experience. Our human subjects study confirmed that the Nao's humanoid appearance was warmer, more competent, and caused less discomfort than the mechanical Stretch robot. The Nao's face may allow comfortable eye contact during conversation, and its human-like arms and hands may be more familiar to participants, enabling them to anticipate the robot's capabilities and intentions. Caregiving robots should be designed to have physical features that meet human expectations of function to maximize patient trust and comfort.

DG3: Patients are most comfortable when robot tone matches robot appearance. The humanoid Nao received the most positive warmth, competence, and discomfort ratings with an empathetic tone, while the mechanical Stretch received the most positive competence and discomfort ratings with a serious tone as shown in Figure 3(d-f). It is likely that the empathetic tone was uncanny when paired with the machine-like Stretch robot because like an affective touch, it defied participants' expectations of the robot's emotional capacity. Thus, we recommend mechanical caregiving robots use a serious tone and human-like caregiving robots use an empathetic tone to ensure the most positive patient experience. The robot itself should be chosen such that its appearance matches its intended function and expected use of empathy.

VII. Conclusion

As robots and other assistive devices become increasingly prevalent in medicine to aid state-of-the-art procedures, care risks losing the emotional, human element that is equally important for maintaining a high standard of care. Instrumental touch is an expected interaction modality from robot caregivers providing medical assistance and improves perceptions of the robot caregiver. Affective touch is not an interaction modality that is strictly necessary, however, it can surpass verbal communication in its ability to comfort patients and improve their bond with a caregiver. When affective touch is initiated by a robot, it does improve robot caregiver perceptions; however, it may defy patients' expectations of the robot's emotional capabilities and is sensitive to contextual factors. For example, we found that a humanlike appearance was seen as favorable to improving the overall patient experience. Yet, there were also interaction effects between the robot appearance and tone, where patients were most comfortable when the tone and appearance were in agreement with their expectations. Thus, future work may shed greater light on the influence of specific factors on how affective touch from robot caregivers is perceived, especially from a first-person perspective. In the present work, we contributed the first look at the interaction of robot touch, intent, appearance, and tone and their effect on patient experience during a robot-led medical exam in a crowdsourced observational study. We believe that the guidelines for caregiving robots derived from our results can assist both researchers and practitioners in designing medical interactions involving robot-initiated touch.

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