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Tom Hitron, Nevo Heimann Saadon, Guy Doron, Thomas H Weisswange, Hadas Erel

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How to Greet Humans: Designing Opening Encounters for Functional Robots with Naive Users

Tom Hitron
tom.hitron@milab.runi.ac.il
Media Innovation Lab, Reichman University
Herzliya, Israel

Nevo Heimann Saadon
The Robotics Lab, Tel Aviv University
Tel Aviv, Israel
nevoh@mail.tau.ac.il

Guy Doron
Baruch Ivcher School of Psychology, Reichman University
Herzliya, Israel
gdoron@runi.ac.il

Thomas H. Weisswange
Honda Research Institute Europe GmbH
Offenbach, Germany
Thomas.Weisswange@honda-ri.de

Hadas Erel
Media Innovation Lab, Reichman University
Herzliya, Israel
hadas.erel@milab.runi.ac.il

Abstract

Many robots are publicly deployed as predominantly functional machines, yet they are still perceived through a social lens and are expected to comply with basic social norms such as greeting. Designing recognizable greeting gestures for non-humanoid robots typically relies on movement specialists and a costly iterative process. We examined whether a participatory, kinesthetic elicitation process can be used to design a greeting gesture for a robotic arm sharing a public space. In the first study, naive participants designed greeting gestures for a robot that interrupts its primary task to welcome a newcomer entering the environment. Most designs included a nod-like movement, and a separate group of naive reviewers recognized the majority of these behaviors as greetings. In the second study, the top-ranked gesture was validated in a naturalistic encounter where a functional robot performed a task and then paused to deliver the greeting. Most participants recognized the gesture as a greeting and perceived it as a welcoming, socially normative act. Our findings suggest that non-experts can design socially normative gestures, lowering the barrier to adding a social layer to functional robots that share public spaces.

Keywords

Social Robots, Gesture Design, Human-Robot Interaction

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1 Introduction

Robots are increasingly present in public spaces, from hospital corridors to shopping malls and work environments [2, 21]. Most of these robots are not humanoid companions but rather functional machines, such as delivery systems, cleaning robots, and guidance kiosks [14, 15]. They are designed to perform tasks rather than interact socially with the people around them. However, the distinction between functional and social machines is not straightforward, primarily due to the strong human tendency to perceive the world through a social lens [6, 8], which typically results in the attribution of intentions and meaning to the objects in the environment [12]. Prior research has established that even simple non-humanoid robots are perceived as social agents, with people attributing intent and social meaning to robotic gestures regardless of the system's design or functionality [1, 7, 8]. Consequently, robots deployed in shared spaces to perform purely functional tasks almost always carry social weight, regardless of their original design intentions.

This implies that autonomous machines intended to share human spaces should be designed with social context in mind. Optimizing robotic behavior solely for functional efficiency while ignoring social presence can lead to significant negative consequences [7]. Adhering to basic social norms is a foundational requirement for seamless integration, which should be addressed before other design layers [7]. A robot that fails to fulfill such basic social expectations is nonetheless judged by human social standards, meaning that any (unintentional) violation of social norms may cause its actions to be perceived as inappropriate, intrusive, or aggressive [9]. For example, a robot that fails to greet people in its environment is not perceived as a neutral machine carrying out its task, but rather



Figure 1: The two setups of Study 1. Left: a participant creating a greeting gesture for the robotic arm. Right: another participant encountering the robot performing the gesture designed by the other participant.

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as ignoring those around it, leading to a negative experience and an unfavorable perception of the robot. In contrast, a robot that acknowledges people with a simple greeting is perceived more positively, which leads to higher levels of cooperative behavior [7].

Norm-compatible behavior for non-humanoid functional robots, particularly positive opening encounters, is therefore a basic requirement for human-robot interaction (HRI) design [27]. Prior work shows that even abstract, simple robotic objects can use basic movements to signal greetings [1]. This implies that functional robots should not be redesigned as dedicated social agents. Rather, it suggests that brief, non-verbal social signals could be layered onto an ongoing functional task, allowing a robot to acknowledge the people around it without interrupting or replacing its primary function. While prior work demonstrates the feasibility of designing norm-compatible behaviors, creating consistently recognizable greeting gestures remains a challenge due to the lack of direct mapping to human behavior [5, 17]. An effective gesture-design process typically requires collaboration with movement experts across iterative cycles in which candidate gestures are designed, implemented, evaluated, and refined, demanding considerable technical resources and expertise [1, 17, 18].

Learning-by-demonstration, a method frequently used for functional robot training, has recently been adapted to social behaviors [19], in which a gesture is first demonstrated by the person's own body and then applied to the robot. While this approach significantly lowers the barrier to gesture design, it has focused on general expressive capabilities, such as appearing curious or attentive. It remains to be tested whether such a participatory approach can be leveraged to design gestures that are consistently interpreted as socially normative and that support the assimilation of the robot into the social environment.

The present work extends this approach to normative behavior in a shared space, evaluating whether a participatory, kinesthetic elicitation approach can be used to design a greeting gesture for a non-humanoid robotic arm. To this end, a two-phase study was conducted. First, naive non-expert participants elicited greeting gestures through kinesthetic demonstration for a scenario where a working robot paused its task to greet a newcomer. These gestures were then evaluated by a separate group of participants. To further test whether the process resulted in normative social behavior, we identified the top-ranked gesture and conducted an additional validation study in which new participants encountered a working robot that paused its task to perform the selected gesture as they entered a shared space. We evaluated their perception of the gesture and the robot within the social environment.

2 Related Work

Relevant previous work includes studies on greeting in HRI and methods for eliciting socially meaningful robot behavior.

2.1 Greeting in Human-Robot Interaction

Greeting is a fundamental social norm that signals willingness to interact, establishing the foundation for the encounter that follows, and whose absence constitutes a violation with lasting negative effects on the interaction [10, 16]. Greeting behaviors have been studied and designed for a range of robotic morphologies, including very simple non-humanoid ones [11, 25]. For example, in a study by Anderson-Bashan et al. [1], participants faced a robot designed as a small ball moving on a dome. Despite its abstract appearance, they consistently interpreted its gestures as social cues. When the ball moved toward the participant, it was perceived as an indication of willingness to engage in interaction. When it moved away, it was perceived as reluctance to interact.

Interestingly, violating greeting conventions also carries negative consequences in human-robot interactions. In a study by Erel et al. [7], participants encountered a robotic dog that performed one of three opening behaviors: a positive gesture indicating willingness to interact, a negative gesture indicating unwillingness to interact, or no opening gesture at all. The robot's opening behavior was followed by a request for help. Participants who received a positive opening encounter were significantly more likely to comply with the robot's request, while those who experienced a negative or absent opening encounter were largely unwilling to help.

Together, these studies establish that greeting is both important and consequential in HRI, and that it is achievable even for non-humanoid robots, yet they do not provide a systematic and accessible process for designing such gestures.

2.2 Methods for Eliciting Socially Meaningful Robot Behavior

Several methods have been proposed for designing expressive robot behavior, with technology-driven approaches relying on advanced technologies and inspiration from experts in different fields such as choreographers, movement analysts, and animators [17, 18, 20, 26]. For example, Chew et al. [4] fine-tuned a large language model on multiparty interaction data, including pose, transcript, and audio, to generate body pose, hand gestures, and speech for a target individual in a group. The model outperformed a diffusion-based baseline, demonstrating that socially appropriate behavior may be generated without specialist design.

A different approach relies on experts as a source of inspiration during an iterative design process, rather than as direct programmers of the resulting behavior. Zuckerman et al. [28] designed social gestures for a non-humanoid robotic object using a collaborative process involving professional dancers and an animator. The dancers first improvised social behaviors such as welcoming and following, after which the animator mapped the selected movements onto the robot's constrained morphology. Gestures were evaluated in a lab study with 39 healthy older adults, in which almost all participants described the robot's movements using terms such as attending, caring, and seeing, associating the non-humanoid robot with a social experience (see similar approach in [23]).

A more accessible direction without relying on advanced technology or expert involvement was explored by Leusmann et al. [19]. They proposed a kinesthetic teaching approach in which non-expert participants first acted out expressions with their own bodies and then physically manipulated a robotic arm to record corresponding expressions, iterating until satisfied. Participants created expressions for different target scenarios. In an online study, videos showing a condensed subset of the gestures were then presented to a second group. Seven of the 13 expressions were correctly understood by a majority of participants. This study demonstrated that



Figure 2: The robotic platform, on which participants designed and recorded greeting gestures.

non-expert elicitation can produce understandable robot expressions without specialist involvement.

Across these approaches, the resulting behaviors were often validated only through benchmark datasets or video-based studies. Furthermore, most methods did not account for socially normative gestures, such as greetings. The present work extends the kinesthetic elicitation method introduced by Leusmann et al. [19] to test its compatibility with the design of socially normative robotic behavior, evaluating whether it can be used to design a greeting gesture that is recognizable and socially appropriate during a physical encounter in a shared space.

3 General Method

To evaluate whether a participatory, kinesthetic elicitation approach can be used to design a greeting gesture, we conducted two studies that were approved by the institutional ethics committee. All participants received course credits for their participation and provided informed consent.

3.1 Robotic Platform

Both studies used a robotic arm mounted on a mobile base at human shoulder height. The platform was designed to reflect that the robot has a functional role in the lab environment, allowing it to navigate, perform tasks, and display non-verbal gestures during human encounters (see Figure 2). The robotic arm was driven by four Dynamixel XM430-W350-T servo motors that provided position control. System coordination was handled by an OpenCR 1.0 microcontroller for real-time servo communication, paired with a Raspberry Pi for behavior orchestration and network connectivity.

3.2 Gesture Elicitation System

To learn how naive users naturally express greeting behavior and translate it directly onto the robotic arm, we employed the Jazzy Puppet system [13], a web-based no-code kinesthetic teaching system that enabled participants to design and record gestures directly on the robot. Using the Jazzy Puppet system, participants could physically move the robotic arm by hand, record the resulting motion, immediately play it back on the robot, and iterate until satisfied. This approach preserved the original gesture's timing and velocity profile, and required no programming knowledge, making it accessible to participants without a technical background.

4 Study 1: Gesture Elicitation

In the first study, we explored designing greeting gestures for the non-humanoid robotic arm through a participatory design process. The study involved two types of participants: naive non-expert designers who created greeting gestures using the kinesthetic learning-by-demonstration methodology, and naive non-expert reviewers who evaluated the gestures and provided their interpretations. The study was conducted in an open corridor within a laboratory, providing an environment in which a robot shared a public space while maintaining experimental control.

4.1 Participants

Thirty-eight students took part in Study 1 (27 female, 11 male): 19 participants designed a greeting gesture and 19 additional participants reviewed a gesture and provided an interpretation. Each designer was matched with one reviewer. Sessions were conducted separately so designers and reviewers never shared the space. Participants had no prior experience with robots or gesture design.

4.2 Procedure

Gesture Design Session. Participants were first asked to demonstrate a greeting naturally, without the robot. A researcher entered the corridor, and the participant was asked to greet the researcher using non-verbal gestures. The participant was then introduced to the robotic arm and asked to design a greeting gesture for the robot, to be performed as a transition from an ongoing functional task of sorting objects, to a greeting directed at the researcher upon entry (see Figure 1, Left). After recording, the gesture was played back on the robot, and the participant was explicitly prompted to evaluate the result and indicate whether they wished to make changes. Participants were free to iterate until they were satisfied with the recorded gesture.

Gesture Review Session. Each reviewer experienced a gesture previously designed by another participant. Reviewers entered the space and encountered the robot performing the gesture (see Figure 1, Right). Following the encounter, reviewers provided a verbal description of the gesture and rated their confidence level (1 = not confident, 5 = very confident). They also completed the Robotic Social Attributes Scale (RoSAS) [3], which measured the perception of a robot's warmth, competence, and discomfort.

4.3 Results

4.3.1 Gesture Types. Analysis of the 19 gestures produced by designers revealed three distinct movement categories. The majority of gestures (12/19) involved up-and-down movements of the robotic arm, resembling a nod. Fewer gestures (4/19) involved horizontal movement of the robotic arm, resembling a waving motion. The remaining gestures (3/19) could not be mapped to any recognizable human greeting behavior.

4.3.2 Reviewers' Interpretation. Verbal descriptions were independently coded by three researchers to determine whether each reviewer had recognized the gesture as a greeting ($\kappa = 0.95$). Of the 19 reviewers, 12 correctly identified the gesture as a greeting. Among the correctly identified gestures, 7 were nod-like, 3 were wave-like, and 2 were not linked to a recognizable human greeting

behavior. The confidence rating for identifying a gesture ranged between 2 and 5 (1 = not confident, 5 = very confident; M = 3.8, SD = 0.85). Several reviewers explicitly described a sense of being acknowledged by the robot: *"It really felt like he noticed me. Did he say hello to me?"* (P8, Reviewer). They also described the gesture as an invitation to interact: *"it felt like he wanted to come say hi"* (P2, Reviewer); *"it felt like he came to shake my hand or something"* (P5, Reviewer). The remaining 7 reviewers did not interpret the gesture as a greeting. Some described the robot's movement as a scanning behavior: *"The robot scanned me, examined me. It wanted to see who entered the room"* (P15, Reviewer). Others felt it merely identified their presence: *"it registered that I came in, noticed that a foreign object entered, but it didn't make a gesture"* (P16, Reviewer).

4.3.3 Robot Perception. The reviewers' ratings also indicated mixed perceptions of the robot. In the warmth sub-scale, reviewers' responses covered almost the full range: 1.5 to 7. Similarly, the range of the competence scale was 2.2 to 7.8 and the discomfort was 1.3 to 4.8.

4.3.4 Summary. These findings indicated that the participatory design process produced a promising outcome, with most reviewers recognizing the gesture as a greeting while a minority did not. The uneven recognition, together with the mixed warmth and confidence ratings, implied that this method may require designing several alternatives and selecting the most understandable gesture among them.

5 Study 2: In-Situ Gesture Validation

To test whether the top-ranked gesture from Study 1 would be perceived as a normative greeting in a shared space, we conducted a follow-up study with a new sample of participants who encountered the robotic arm performing the gesture in a slightly adapted setting.

5.1 Participants

Fifteen students took part in Study 2 (12 female, 3 male).

5.2 Selected Gesture

The gesture for Study 2 was selected based on three criteria: correct identification as a greeting, the highest confidence rating, and the best combined RoSAS score, defined as the highest warmth paired with the lowest discomfort. The selected gesture was a nod-like movement that performed best across all three criteria.

5.3 Procedure

Participants were informed that they would be entering an area that included technologies but were not provided with any further information about the nature of the interaction. They were asked to walk to a room at the end of the lab and wait there for the experiment to begin. The robot was positioned at the room's entrance, sorting objects placed on a table in front of it. It performed the selected greeting gesture as the participant approached the room entrance. The robot was operated using a Wizard of Oz approach [22], with the wizard triggering the gesture as the participant approached, ensuring consistent timing. Following the encounter, participants were asked to provide a verbal description of the experience and of the robot, which was recorded and transcribed. Descriptions were analyzed using thematic coding.

5.4 Results

Of the 15 participants, 11 correctly identified the gesture as a greeting. Participants who recognized the gesture described it as a welcoming or greeting behavior directed toward them. They compared the movement to a culturally familiar greeting: *"It was welcoming me. It reminds me of a kind of bowing up and down, like they do in Japan"* (P5, Participant). They described it as a socially normative behavior: *"It recognized that I've entered the room, so it nodded to make me feel it was welcoming me in"* (P4, Participant); *"It kind of said hello, it was moving its head up and down, like a person nodding saying hello when you walk into a room"* (P14, Participant).

6 Discussion & Conclusion

The present work demonstrates that norm-compatible robotic gestures can be designed for a non-humanoid robot without movement specialists or technical experts. Using a participatory, kinesthetic elicitation approach, naive non-expert participants generated a greeting gesture that observers interpreted as a normative social cue in a shared space. These findings indicate that non-experts can effectively leverage the physical affordance of an abstract robotic platform to encode recognizable social intent. This extends prior work on non-expert elicitation [19] from general expressive states toward socially normative behaviors that support the assimilation of the robot into its environment.

However, our findings also suggest that gestures designed by non-experts are not uniformly clear or aligned with intent, so a more rigorous process is required. Rather than relying on a single designer, a multi-stage approach should elicit multiple gestures, identify recurring patterns, and select the gesture that yields maximum clarity and observer confidence.

Another finding from our experiments revealed that the designed gesture successfully established a perception of normative social behavior, even though it was performed while the robot was executing a functional, non-social task. This indicates that a social layer may be overlaid onto standard robotic routines without disrupting the primary task, supporting the design of socially normative behavior for functional robots that share human spaces.

Taken together, our findings indicate that a social layer can be integrated into functional robots without complex resources or expert involvement. Drawing on humans' inherent sociality [24] and tendency to anthropomorphize their surroundings [6], non-expert designers can intuitively generate behaviors others read as social cues, lowering the barrier to integrating functional robots into shared human environments by accounting for the social context.

7 Limitations

This work has several limitations. The gesture design used a specific shared space and robotic morphology. Additionally, the participant sample size reflects the preliminary stage of the work. Our findings also cannot account for cross-cultural variations, which shape social expectations and normative boundaries. Finally, how the gestures shape participants' perception of the surrounding space, beyond the robot interaction itself, also remains to be evaluated.

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