Interpreting Non-Anthropomorphic Robots’ Social Gestures

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ABSTRACT
In this paper we report on two studies analyzing the factors that determine whether and how the behavior of non-anthropomorphic robots is interpreted in a social context. Non-anthropomorphic robots have several advantages: they have no human features and therefore are less likely to raise unrealistic expectations by people. In addition their simple design and low number of parts allows them to be smaller, cheaper, and a better fit for home or office adoption. At the same time, they present a challenge for social interaction due to their inability to mimic human social communication with restricted movement and a limited gesture space. We present the systematic exploration of two different non-anthropomorphic robots designed for social interaction. The first was designed to perform gestures during opening encounters (greetings). The second was designed to perform gestures that convey the robot’s emotional state, toward affecting behavior change. Using both quantitative and qualitative methods, we demonstrate that the gestures of these non-anthropomorphic robots were consistently perceived by the participants and were interpreted as conveying social intent and emotions. We further find that specific movement components—specifically the vertical component and the approach vs. avoid component—were the most salient factors in participants’ perception of their interaction with the robots, leading to design implications for robot gesture designers.

ACM Reference Format:

1 INTRODUCTION
Robots designed for social interaction are developing rapidly [16] and are predicted to take part in a wide range of application domains, including home [6], education [15] and work setting [11]. Implementing readable robot behaviors and understanding people’s interpretations of these behaviors is thus one of the main challenges the Human-Robot Interaction (HRI) community is currently facing.

Humanoid and anthropomorphic robots have been extensively studied in the context of social interaction. These robots are able to imitate human-like behavior to some extent through verbal cues and gestures, including facial expressions, nodding, hand waving, and eye gaze [1, 2, 4]. Studies with anthropomorphic robots indeed indicate the possibility to create meaningful social interactions [1, 5, 13]. That said, anthropomorphic robots are complex from a mechanical perspective, and some studies point to the unrealistic expectations they raise, leading to frustration that sometimes results in a decline in the willingness to use the robot [7].

Non-anthropomorphic robots are one possible way to overcome these issues [3, 14]. Non-anthropomorphic robots, or robotic objects, are typically designed as abstract objects with no human-like characteristics. These robots are mechanically simpler than anthropomorphic robots and have very few Degrees of Freedom (DoF). Robotic objects are easier to design and control, cheaper to manufacture, more reliable, have fewer parts, and may better fit home or office use due to their smaller size [10]. At the same time, robotic objects have limited movement capabilities, and are therefore more restricted in their communication modalities, as human gestures cannot be directly mapped to movement of robotic objects. This raises questions as to the possibility of using robotic objects as social agents, and specifically if and how they can be interpreted in social interaction. We do know, on the other hand, that people tend to view even inanimate objects through an intentional and social lens [9]. This suggests that, if designed properly, gestures of non-anthropomorphic robots can be interpreted as social behaviors.

2 INTERPRETING SIMPLE ROBOT GESTURES
Our goal is to better understand the factors that determine people’s ability to consistently interpret gestures of non-anthropomorphic robots, and whether these can lead to a meaningful social experience. To that end, we present highlights from the results of two studies with two different non-anthropomorphic robotic objects. The first, the “Greeting Machine” (Figure 1A), was designed to participate in opening encounters (greetings). The second, “Kip” (Figure 1B), was designed to perform gestures that convey the robot’s emotional state, toward affecting human behavior change.

To date, there are only a small number of experimental studies evaluating social gestures of non-anthropomorphic robots [3, 14]. Specific, empirically-based design guidelines for interpretable social gesture features are even more scarce. In this paper, we report two studies evaluating how people perceive and interpret the non-anthropomorphic robots’ gestures. We show one study in which gestures were designed performance artists and movement experts, and one where the gestures were purely mechanistic. Both suggest specific loci of focus for gesture design.

2.1 STUDY I - THE GREETING MACHINE
In the first study we set out to explore whether a non-anthropomorphic robot with no human-like visual features, can evoke an experience of an opening encounter (greeting), and how people perceive the robot’s nonverbal behavior. Opening encounters play a significant role in the initiation of social interactions, and shape the nature of the interaction that follows [12]. They involve emotional cues, which signal in what way one is willing to be involved in the encounter as well as the nature of the involvement [8].
In this study we evaluated the gestures of a robotic object in the form of a dome, with a ball rolling on its surface. The gesture design was based on a brainstorming session with four movement experts (an animator, a puppeteer, a choreographer, and a comic book artist), who demonstrated gestures on a low-fidelity prototype. Based on the discussions in the brainstorming session we defined two main gesture classes: Approach (back-to-front) and Avoid (front-to-back). These gestures were evaluated in a user study with 26 participants who experienced eight gestures of the Greeting Machine. A qualitative analysis revealed that participants perceived the interaction as socially and emotionally rich in the context of an opening encounter. The Approach gestures were perceived as positive social cues, and were described as “greeting” and “welcoming”. The Avoid gestures were interpreted as negative social cues and were described as “avoiding” and “rejecting”. From this study we learned that even an abstract design with minimal gestures can help users interpret their social interaction with robotic objects in a more predictable way.

2.2 STUDY II - KIP

In the second study we used a non-anthropomorphic 2-DoF robot. 61 Participants watched simple point-to-point gestures by the robot, and were asked to associate the gestures with perceived emotions. The gestures were not hand-crafted by a designer or animator, but were purely mechanistic: single-velocity movements across a matrix of nine end positions, including all possible combinations of bottom, middle, and up on the vertical axis, and left, center, and right on the horizontal axis.

Analyzing the relationship between gesture vectors and perceived emotions, we found that the most salient component of the gesture (i.e., the one most linked to higher association with specific emotions) was the vertical movement, and the second most salient component was whether the horizontal movement was toward the participant or away from the participant. We further found that upward as well as toward-participant movements were related to positively valanced emotions, and downward movements as well as away movements were related to negatively valanced emotions.

From this study we learn that people classify even mechanistic gestures of a 2-DoF non-anthropomorphic robot in a consistent and predictable way when mapping them to different emotions.

3 CONCLUSION

Our systematic evaluation of two robotic objects reveals that limited gestures of non-anthropomorphic robots can be consistently interpreted as social interaction cues. Using both quantitative and qualitative methods we demonstrated that these robots’ gestures were easily and consistently perceived as conveying social intent and emotions relevant for human interaction. This was true both for gestures designed by movement experts, and for purely mechanistic point-to-point trajectories. The salience of Approach vs. Avoid movements was common to the findings of both studies, with Approach being clearly connected to positive affect, and Avoid to negative affect. The second study additionally emphasized that specific movement components, for example the vertical axis, have more profound effects of the emotion perceived from the robot than others. We can thus extract implications for designers to focus on approach and avoid gestures for affect, and to emphasize the vertical axis in gesture design. Taking these implications into account can help users interpret their social interaction with robotic objects in a more predictable way.

REFERENCES