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# Robot body movements and the intentional stance

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**Abstract —** We investigated the effects of movement qualities on the adoption of the intentional stance, i.e., whether observers of an abstract robotic object ascribe intentions based on its movements. Seeing a robot as intentional can help to explain and predict its behavior. Our results provide evidence that the ascription of intentions for expressive movements increases when a robot's behavior is surprising but decreases when it is unsurprising. This suggests a subtle relationship between expressive movement and surprising behavior, and that robot movements should be expertly designed for expressing intentions. Significantly, participants unfamiliar with robot technology rated the robot less likeable than those familiar with robot technology, particularly the group that adopted the intentional stance. This suggests that people familiar with robot technology are more likely to take a positive attitude towards ascribing intentions to an abstract robot, based on its movements. However, the relationship between familiarity, intentionality, and likeability needs further investigation. We discuss the implications of our findings for the design of robots and human-robot interaction.

**Keywords —** Human-Robot Interaction, Social Robots, Motion Design, Theory of Mind, The Intentional Stance.

## 1. INTRODUCTION

Human-Computer Interaction (HCI) is a well-established field, which grew significantly in the 1980s and 1990s alongside the rapid growth of non-technical users of computing devices. As a result of the work in HCI, conventions for (graphical) user interfaces evolved along with users' familiarity with computers. For social robotics, however, the process of attunement between the technology and non-technical users is still at an early stage. Human-Robot Interaction (HRI) is often based on familiarity with human-human interactions [1]. Humans have a strong disposition to look for cues of human-likeness around them [8,9], and studies in HRI suggest anthropomorphic designs facilitate social interaction [2-7]. Epley [10] defines three psychological factors that affect anthropomorphism: lack of an adequate mental model of the other; the motivation to explain or understand others' behavior; and a need for social connection.

But anthropomorphism in HRI can also have significant drawbacks [9]. Turkle [11] argues that robots can evoke genuine human empathy but return only a finite set of 'as if' performances that mimic feelings. Because humans are vulnerable to the seductions of subjective technology, they can become too dependent and be shaped in a degenerative way. According to Bryson [12], robots have an instrumental role toward us. They serve as tools, and should not be designed to have an ambiguous moral status, as if they were human. Remmers [13] argues that people do not choose to anthropomorphize, while human-like robots are designed to create an affective illusion, and this may lead to the blurring of boundaries between technology and humans, and between minds and machines. Remmers recommends consideration of ethical issues inherent in HRI with human-like robots. Within this context, the design of robots can help humans become familiar with their 'robot nature.' For example, robots can have different levels of autonomy [14], and their designs should help explain and predict behavior.

Dennett [15] argues that explaining and predicting others' behavior starts with adopting a particular attitude or 'stance'. Three distinct stances can be taken: the physical, the design, or the intentional stance. Each of these stances applies a higher level of abstraction and is chosen depending on the complexity of the entity encountered, as a strategy for efficient social interaction. Treating an entity as intentional is called 'adopting the intentional stance.' This is a narrower concept than anthropomorphism and does not require the explicit ascription of mental states. Neither does it implicate that an agent is perceived as alive, nor that ascribed intentions are genuinely present [16,17]. Instead, the concept is about categorizing objects in the environment to reduce uncertainty and as a strategy for effectiveness.

The intentional stance also reflects an awareness of attentional and emotional states. From there, a common channel of communication can emerge, enabling shared perceptual experiences and actions [18]. The attitude toward a robot affects interaction and influences social attunement and learning [19]. As a result, adoption of the intentional stance toward robots could trigger a positive feedback loop for human-robot learning that is beneficial for the success of social robots [19]. Recent studies have acknowledged the relevance of the intentional stance for social robotics and investigated whether people take the intentional stance. These studies examined the conditions that promote the perception of robots as intentional [17,19-21,28].

Investigations of the contribution of robot movements to the attribution of mental states in HRI have found that temporal and spatial characteristics can play a crucial role [21-24]. This is supported by studies showing that motion cues provide a foundation for social cognition in humans and primates [25-27].

## 2. EXPERIMENT

In this study we have attempted to answer the question: *What are the effects of robot body movements on the adoption of the intentional stance and perception of the robot?*

Marchesi et al. [20] propose a tool for investigating the adoption of the intentional stance toward a human-like robot. We took this tool as a starting point. We used an abstract robotic object to reduce the potential effect of visual cues associated with the attribution of intentions, e.g., human-like features. While Marchesi et al. [20] used image sequences, we have used videos showing robot movement in different scenarios. Like Marchesi et al. [20], our tool uses a slider that probes either a mechanistic or a mentalistic explanation for a presented behavior. For the mentalistic explanations, we used only desire- and no belief reasons, so that knowledge about the robot's intelligence was not required. For the mechanistic explanations, we chose neutral descriptions that refer to 'habits' of the robot, or contextual reasons for its design [28].

### 2.1. Robot and motion design

A minimalist, abstract robotic object was created and optimized for smooth movements. To focus on the effects of movement, we omitted features of face and head. A 4 DoF robotic arm was covered with a flexible tube and material and programmed to playback movement sequences during video recording (Figure 1, Appendix A).

Specific motion properties are expected to play a role: nonlinear transformations; changes in path, speed, and direction [21,22,25-27]; and intent-expressiveness [30]. We categorized these properties into classes of 'Expressive' and 'Functional' movements. Surprisingness has been found to influence the way people explain behavior [29,30]. To study its effect on the adoption of the intentional stance in HRI, we designed two types of robot behavior: 'Surprising' and 'Unsurprising.'

### 2.2. Experimental design

A between-subjects experiment was carried out, with a 2 (Expressive vs. Functional motion) by 2 (Surprising vs. Unsurprising behavior) factorial design (Table 1). Each of the conditions was presented with videos of the robot performing three different tasks (Figures 2a and b, Appendix A).

| | ***Movement*** | |
|---|---|---|
| ***Behavior*** | ***Functional*** | ***Expressive*** |
| ***Unsurprising*** | *Robot acts as expected, movement with linear speed and paths* | *Robot acts as expected, movement with nonlinear speed and paths* |
| ***Surprising*** | *Robot acts unexpectedly, movement with linear speed and paths* | *Robot acts unexpectedly, movement with nonlinear speed and paths* |

**Table 1. Factorial design**

The independent variables are the factors of movement and behavior. The dependent variables are the adoption of the intentional stance and the user's perception of the robot. We used a questionnaire to assess the dependent variables. After questions on demographics and familiarity with robot technology, we probed the adoption of the intentional stance with video questions and evaluated robot perception with the Godspeed Questionnaire Series (GQS) [31].

108 participants were recruited, of which 60 females, 46 males and 2 otherwise specified. From the 108 respondents, 71% reported being unfamiliar with robots (N=77), 25% reported to

sometimes interact with robots (N=27) while the remaining 4% reported frequent interaction (N=4).

### 2.3. Results

Participants generally adopted the design stance and chose mechanistic explanations for the robot's behavior. In some cases, however, they did take the intentional stance, and most often in the condition of expressive body movement combined with surprising behavior.

We explored the effects of the movement-behavior conditions on the adopted stance with a two-way ANOVA test. Although not significant, some results were remarkable. For example, expressive movement increased the adoption of the intentional stance in cases of surprising behavior. In contrast, expressive movement with unsurprising behavior decreased the adoption of the intentional stance (Figure 3, Appendix A).

The GQS scores reveal a similar pattern. Data visualizations show cross-shaped graphs (Figure 4, Appendix A) in which surprising behavior draws an upward slope, while unsurprising behavior draws a downward slope between functional and expressive movement. This may be caused by a perceived (in)congruence between expressiveness and surprisingness and suggests that the two should be aligned.

A two-way ANOVA test showed a significantly positive effect of expressive movement on Anthropomorphism [F(1) = 4.07, p = 0.046].

People unfamiliar with robot technology rated the robot as less likeable than those more familiar with robot technology (see Figure 5, Appendix A). A two-way ANOVA test showed a significant difference between the groups that reported being unfamiliar and familiar with robot technology [F(1) = 14.98, $p < 0.001$]. A Tukey post hoc test revealed that this was most significant in the group of participants who adopted the intentional stance [MD = 1.195, p = 0.005]. The relationship between familiarity, intentionality, and likeability needs further investigation.

## 3. DISCUSSION

Adoption of the intentional stance can support HRI, help to explain and predict, and become familiar with robot behavior. Measuring the adoption of the intentional stance, however, presents a challenge [32]. We have adapted the tool proposed by Marchesi et al. [20] as a starting point and studied the effects of movement and behavior on the adoption of the intentional stance based on observing the movement of a robot. Although we expect our findings to be generalizable, a limitation of our approach is the lack of interaction, and further research will be needed in live contexts.

Our results support previous findings that surprisingness increases intention attribution [28,29] and suggest that expressive movement reinforces this effect, as long as cues and behavior are congruent. Expressive movement alone increased anthropomorphism, but not the adoption of the intentional stance. This suggests that when expressive movement was not pointing at surprising behavior, it was perceived as the result of (human-like) design, rather than intrinsic to the robot. When designing motion for intentionality, expressiveness can be used as a cue to direct attention. How to adapt a robot's motion design over time should be further investigated: people may become familiar with the robot's behavior and its movements, which may affect the effectiveness of expressive movements as a cue.

Gaze has been found to engage mechanisms involved in the attribution of intentions and goals, and gaze cues have been used to measure the adoption of the intentional stance [33]. Though without a face or head, our robot prototype mimicked gaze cues and thereby guided attention. Studies have revealed that arrow cues can trigger attention shifts similar to those triggered by gaze [32]. For the design of HRI with non-humanoid robots, the investigation of other cues for directing attention that evoke the adoption of the intentional stance will be especially worthwhile.

Research on intention attribution toward robots is at an early stage. Schellen & Wykowska [32] argue that we first need to establish well-validated methods for measuring the adoption of the intentional stance before we can investigate the conditions under which it is adopted. Measures of intention attribution are recommended, such as paradigms that analyze reaction time, gaze cues, and neuropsychological markers [32].

## 4. CONCLUSION

We found that people sometimes adopt the intentional stance, even with an abstract robotic object. Expressive movement increased the adoption of the intentional stance in cases of surprising behavior. In contrast, it decreased intention attribution in cases of unsurprising behavior. When used effectively, we suggest that a robot's movements can guide attention to behavior that still needs to be understood and generate familiarity through the adoption of the intentional stance. We propose further investigating motion design as a cue for robot intentionality, considering measurements that can be made during social interaction, and exploring the effects of familiarity with robot movements.

**Acknowledgment —** We would like to thank MSc. Media Technology staff and students for the great support and inspiration.

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## APPENDIX A – Figures and Tables

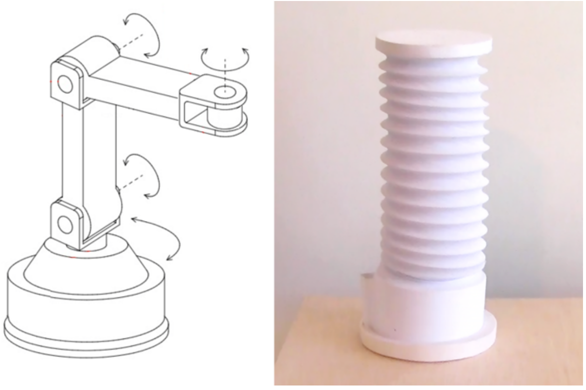

Figure 1. A 4 DoF robotic arm, placed inside a flexible tube.

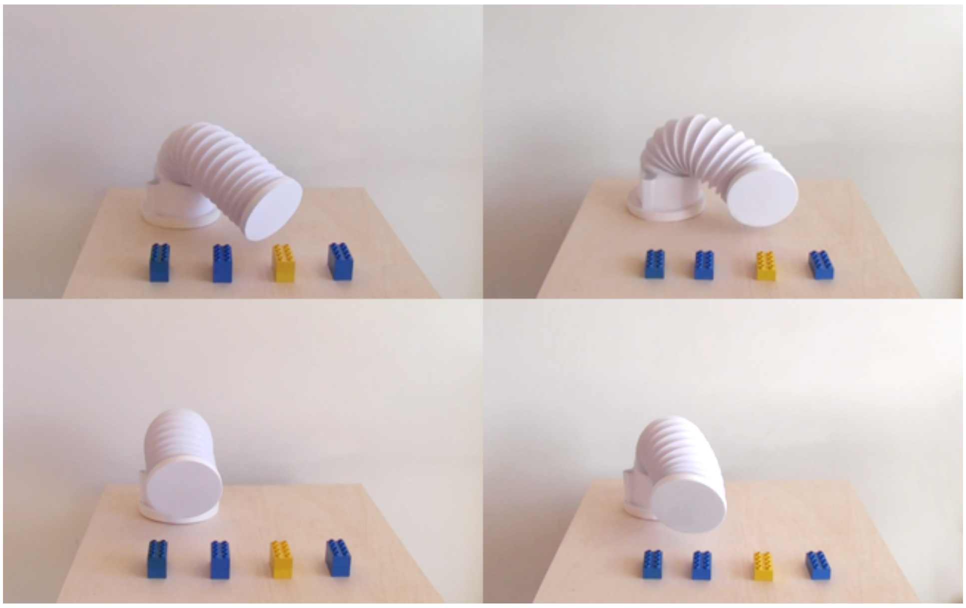

Figure 2a. The four conditions in the ‘Perception’ scenario. Top: Functional/Unsurprising, Expressive/Unsurprising. Bottom: Functional/Surprising, Expressive/Surprising.

Figure 2b. The ‘Action’ and ‘Interaction’ scenarios. Both video stills showing expressive movement.

The movement conditions can best be explored in the video recordings:
https://www.youtube.com/playlist?list=PLFx9hNADMJxzIbNmVo4nXNUh_-I2g8Sbx

An overview of behavior, actions and explanations per scenario can be found here:
https://drive.google.com/file/d/1QbJLvNqnIQyq0jcxiEDiBZ5KKnHIKV3i/view?usp=sharing

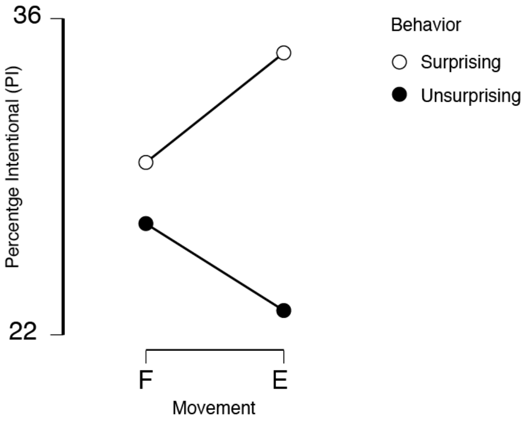

**Figure 3. Results of a two-way ANOVA. Effects of movement/behavior conditions on the intentional stance.**

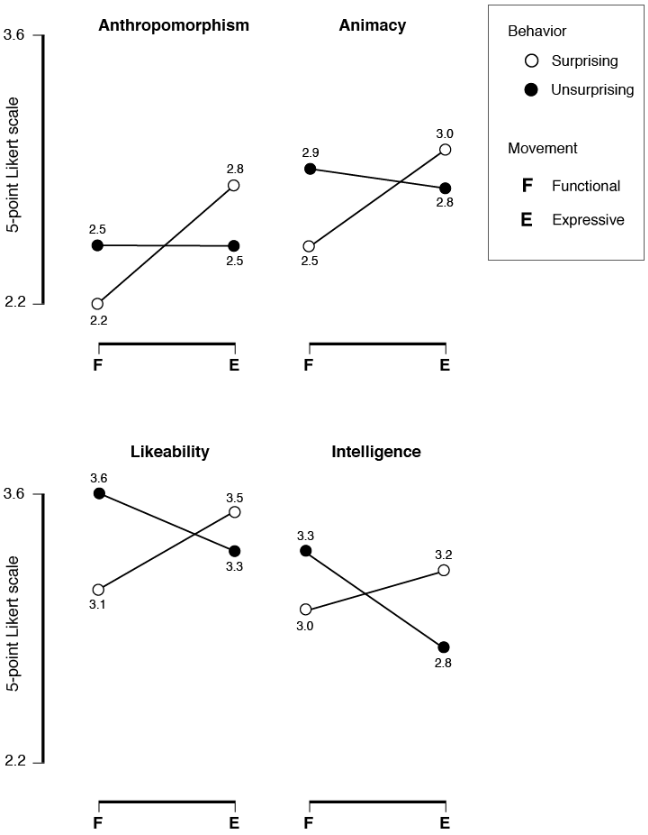

**Figure 4. Results of a two-way ANOVA test. Effects of movement/behavior conditions on the GQS I-IV.**

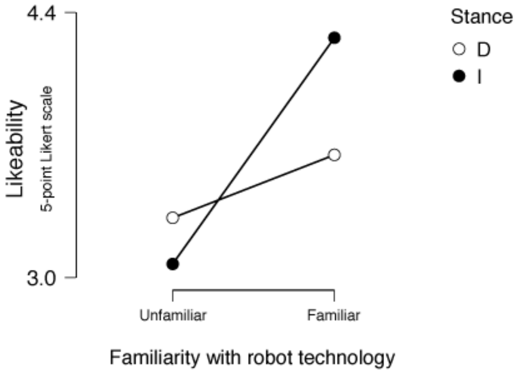

**Figure 5. Results of a two-way ANOVA test. Effects of the adopted stance on likeability of the robot, between subjects who reported being familiar/unfamiliar with robot technology.**