Effects of Robot Body Movements on the Adoption of the Intentional Stance

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***Abstract*—We investigated the effects of robot movement qualities on the adoption of the intentional stance - 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. Results showed that people sometimes do adopt the intentional stance, even with an abstract robotic object. Expressive movement increased the ascription of intentions, but only in cases of surprising behavior. This suggests that a robot's movements can support social attunement, 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.**

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

I. Introduction

Robots are a relatively new technology that, like any other tool that we build, can change the way we look at the world and ourselves. Quoting McLuhan: 'We shape the tools and thereafter the tools shape us' [1]. Human-Computer Interaction (HCI) was shaped since the 1980s, with a growing group of non-technical users becoming familiar with the medium. In HCI, communication is commonly mediated via a screen, and conventions for (graphical) user interfaces have evolved, along with their users' skills.

For social robotics, however, the process of attunement between the technology and non-technical users is still at an early stage. Communication is primarily based on available familiarity with human nature, using human-like features that support social interaction [2]. Studies in Human-Robot Interaction (HRI) have frequently compared human-like and device-like robot designs. Results showed that anthropomorphic designs can facilitate social interaction [3,4]. Robots that look and behave like humans are found to be perceived as more usable [5]; more engaging [6]; and more accepted [7,8].

Anthropomorphism is not only defined by robot characteristics; humans have a strong disposition to look for cues of human-likeness around them [9,10]. Epley [11] 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 with other humans.

Although anthropomorphism can support HRI, it also has its drawbacks [10]. Turkle [12] argues that robots can evoke genuine human empathy, but return only a finite set of 'as if' performances mimicking 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 [13], 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 are human. Remmers [14] brings up that people do not choose to anthropomorphize, while human-like robots are designed to create an affective illusion. The distinction between real and simulated may not be relevant for AI, but it is for humans. This may lead to blurry boundaries between technology and humans, and between minds and machines. Remmers recommends to consider these ethical issues in the context of HRI.

This makes it relevant to explore how a non-anthropomorphic robot can give insight in its level of autonomy [15] by explicating intentions, thus helping to explain and predict its behavior.

Dennett [16] argues that explaining and predicting others' behavior starts with adopting a particular attitude or 'stance' toward that behavior. Treating it 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 or request that an agent is perceived as alive, nor that ascribed intentions are believed to be genuinely present [17,18]. Instead, the concept is about the social strategy to categorize objects in the environment into three groups: physical, design, or intentional. This categorization reduces uncertainty and is a strategy for effectiveness. Besides, the intentional stance reflects an awareness of attentional and emotional states. From there, a common channel of communication can emerge, enabling shared perceptual experiences and actions [19]. Similarly, people's attitude toward a robot affects the way they explore its 'nature' and influences social learning and attunement [20]. Recent studies have acknowledged the relevance of the intentional stance for social robotics and investigated whether people take the intentional stance toward robots. Can a robot be perceived as intentional and if so, what are the conditions [18,20,21]?

It has been suggested that motion plays an important role, and that simple motion cues provide a foundation for social cognition in both humans and primates [22–26]. In their influential study, Heider & Simmel [27] showed that the movements of simple geometric shapes can evoke spontaneous attributions of life and social intent. Specific temporal and spatial characteristics of motion, such as changes in speed and direction, are crucial to the attribution of intention [28,29]. In the context of HRI, several researchers investigated how robot movement is perceived as a social cue and can contribute to interaction [28–32].

We investigate the effects of a robot's body movements on the adoption of the intentional stance. Different conditions regarding the movement and behavior of the robot are compared, while the relationship between the intentional stance and perception of the robot is explored.

The remainder of this paper outlines the theoretical framework and describes related works. Thereafter the research question is introduced, followed by a description of methodology, experimental and robot design, and the measurements that were applied. Finally, the data analysis results are presented, followed by the discussion and conclusion.

II. Related works

This section introduces the theory on the intentional stance. This is followed by an overview of recent studies on the adoption of the intentional stance toward robots, and studies that address the effects of robot body movements.

A. The intentional stance

Dennett [16] proposes that humans use different strategies to understand and predict others' behavior, and distinguishes three distinct 'stances' that can be taken: the physical stance, the design stance, and 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. The physical stance represents the lowest level of abstraction. Behavior is explained based on knowledge of physical constitution and laws, e.g., the prediction of where a ball is going to land. The next level of abstraction explains behavior as 'designed' and does not require knowledge about underlying physical processes. It looks at functional mechanisms, such as the notion that when one pushes a button, some event occurs. The third and most abstract level is the intentional stance. This attitude does not require any knowledge of physical structure or design. When people adopt this strategy, they explain behavior by ascribing meaningful mental states, inferring intentions based on the mental model they apply. Dennett's theory is about efficiency: categorizing information in this way meets the criterion of 'providing maximum information with the least cognitive effort' [33].

In addition to Dennett's instrumentalist explanation of a strategic behavior, Michael [34] argues for a causal explanation. The intentional stance and cultural learning constitute a feedback loop, a mechanism in which children, as well as adults, adopt the intentional stance. This feedback loop causes children to acquire skills for understanding others' behavior, thus reinforcing their socialization.

Robots are complex systems with a certain level of autonomy [15] and, according to Dennett [16], considering a robot's behavior as 'intentional' can be efficient and strategic. From Michael's [34] point of view, 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.

B. The intentional stance towards robots

Perez-Osorio & Wykowska [20] reviewed literature on the concept of the intentional stance from a philosophical, developmental, and HRI point of view. Adoption of the intentional stance toward social robots may be pivotal in facilitating social attunement, a process that may resemble the enculturation of humans. It is proposed to transfer standard protocols from experimental psychology to HRI studies, to investigate if and how mechanisms of human social cognition —such as the adoption of the intentional stance— are evoked in HRI.

Marchesi et al. [21] investigated whether people adopt the intentional stance toward a human-like robot. A new tool is introduced, consisting of a questionnaire that probes a participant's stance by asking them to choose the likelihood of an explanation for the robot's behavior. The robot is depicted in several scenarios, presented by a sequence of three photographs. For each scenario, participants rate the explanation that they think fits best with the robot's behavior, by moving a slider on a scale. The scale has a mentalistic explanation on one end, and a mechanistic explanation on the other. Results show that subjects mostly choose mechanistic explanations for the robots' behavior. Percentages for mechanistic and mentalistic explanations were respectively 69.7 and 30.3 percent. This supports the assumption that it is possible to induce the adoption of the intentional stance toward a humanoid robot. In addition to the proposed tool, the researchers recommend further investigations into factors that influence the adoption of the intentional stance.

De Graaf & Malle [35] investigate mental state ascriptions by analyzing free-response explanations of robot behavior. In a preliminary study, robot behavior was classified as intentional, surprising, or desirable, basic properties that are known to influence explanations [36]. The subsequent study compares explanations for the equated behaviors with robot and human actors. De Graaf & Malle distinguish causal explanations and reason explanations, and further subdivide reason explanations into contextual explanations on the one hand, and belief or desire reasons on the other [36]. Results showed that explanations of robot behavior rely on similar conceptual tools used to explain human behavior. However, with robots people use more contextual explanations by referring to the robot's program or programmers. In addition, there was an increase of belief reasons and a decrease in desire reasons with explanations of robot behavior. The researchers argue that belief reasons allow for taking distance from what a robot 'thinks' or 'believes,' while people may be more reluctant to ascribe desires to the robot's behavior. The study focused on text descriptions, and it is recommended to further explore the topic in more enriched contexts.

C. Effects of movement and behavior

Terada [29] studies how reactive movement of robotic objects can cause intention attribution in humans. In two experiments, participants were invited to interact with respectively a moving chair and a moving cube. Subjects were asked directly to categorize the objects according to Dennett's three possible stances. Results showed that reactive movements - as opposed to periodic movements - yield significantly more cases of goal attribution, and more (self-reported) adoption of the intentional stance.

In another study, Terada [37] found that a robot's unexpected behavior can trigger the intentional stance. It is argued that there is no need to attribute intentions to a robot's behavior as long as it can be understood by the machine's design. Unexpectedness can also be explained by mechanistic reasons, e.g., 'the machine is not working properly.' However, if unexpected behavior cannot be explained by a mechanical cause, it may be perceived as intentional. Experimental results confirmed that a robot's unexpected behavior affects the adoption of the intentional stance. This endorses the definition of 'surprise' as an influential factors on explanations [38].

In the context of human-robot collaboration, Dragan, Lee & Srinivasa [39] gained the insight that predictability and legibility are two fundamentally different properties of motion. In their experiment, three agents that differ in complexity and anthropomorphism perform a reaching task. Subjects are presented videos of one of the agents showing different motion behaviors, and judged the movements on predictability and legibility. Results showed that legibility is fundamentally different (and at times contradictory) from predictability. It is recommended that motion behavior in human-robot collaboration is designed for intent-expressiveness.

Gemeinboeck & Saunders [32] explore how movements can give meaning and elicit affect, and challenge the idea that robots need to look like humans or animals to reach that goal. Instead, it is suggested that social capacity develops through interaction, which shifts the design focus from the robot's representation to how the agency emerges. Participants were presented three movement sequences, described by the effort descriptors from Laban Movement Analysis (LMA) [40]. All participants perceived the robot as curious or responsive, behaving in relation to their presence.

References [28] present the Greeting Machine, an abstract non-humanoid robotic object, designed to communicate positive and negative social cues in opening encounters. 'Avoid' and 'Approach' greeting gestures are designed and evaluated in a physical first-person qualitative study. Results showed that an abstract robotic object can effectively convey gestures and that a minimal brief movement may be enough to evoke positive and negative experiences. Furthermore, it is argued that abstract designs can help to distill the fundamental characteristics of movement, which can contribute to the gesture design of social robots.

D. Research question

The literature presented above suggests that human-like, as well as machine-like or abstract robot designs, can evoke the adoption of the intentional stance. Several authors, however, have recommended to investigate the factors of intention attribution further. A robot's movements and behavior have been found to play a role but how specific movement properties support human understanding of robot behavior is unknown. Consequently, it is relevant to explore the effects of movement and behavior conditions on the adoption of the intentional stance. Outcomes can inform the design of effective and transparent intent-expressive robot motion. The research question:

> *What are the effects of a robot's body movements and behavior on the adoption of the intentional stance and perception of the robot?*

III. Method

Various methodologies for empirical research have been discussed and proposed. We follow the recommendation to use protocols of experimental psychology into HRI studies [20] to investigate if and how the adoption of the intentional stance is evoked in HRI. In our experiment, we present reduced stimuli to subjects, and we use a custom made robotic prototype to maintain experimental control.

TABLE I
FACTORIAL DESIGN

	Movement	
Behavior	**Functional (F)**	**Expressive (E)**
Unsurprising (U)	Robot reacts as expected, movements with linear speed and paths	Robot reacts as expected, movements with nonlinear speed and paths
Surprising (S)	Robot reacts as unexpectedly, movements with linear speed and paths	Robot reacts as unexpectedly, movements with nonlinear speed and paths

A. Stimuli

We have modified the tool proposed in [21], by replacing the image sequences with videos presenting the robot's movement and behavior. The tool uses a slider that probes either a mechanistic or a mentalistic explanation for a presented scenario. It has been argued that the nature of the question for people's explanations should be open-ended instead of a forced-choice [35]. Our goal, however, is to determine whether people take the intentional stance or not, which is a binary question. For the mentalistic explanations, we chose only desire reasons and no belief reasons [35], so that knowledge about the robot's intelligence would not play a role. For the mechanistic explanations, we chose neutral descriptions referring to 'habits' of the robot, or contextual reasons referring to its design.

Specific properties of movements are expected to play a role: nonlinear transformations and changes in path, changes in speed and direction [24–26], and intent-expressiveness [39]. We categorized these properties into classes of 'Expressive' and 'Functional' movements. Motion design specifications are described under 'Robot Design'.

Surprisingness is found to influence the way people explain behavior [35,37]. To study the effects of movements in different contexts, we designed two types of robot behavior: 'Surprising' and 'Unsurprising.' We designed those behaviors based on how humans process visual information. People detect movement and perceive differences in a.o. color and shape at a glance [41], and (initially) expect the same ability in others [11]. For example, in one of the scenarios, we used three blue bricks and one yellow brick (Figure 2). Participants instantly detect that the yellow brick stands out and assume the robot to share that information. In the case of 'Unsurprising' behavior, the robot responds to visual stimuli as expected, while in the 'Surprising' case, it does not.

B. Experimental design

A between-subjects experiment is carried out, with a 2 (Expressive vs. Functional motion) by 2 (Surprising vs. Unsurprising behavior) factorial design (Table I). Each of the conditions is presented with videos of the robot completing three different tasks; a perception task, an action, and a responsive task. An overview of scenarios, conditions, and explanations can be found in Appendix A.

C. Robot design

Johnson [42] characterizes five primary cues for identifying intentional agents: (1) features of a face and eyes; (2) asymmetry along one axis, e.g., having a head smaller than the body; (3) non-rigid transformations or movements, contrary to linear changes; (4) self-propelled movement; and, (5) the ability to engage in reciprocal and contingent interaction.

To focus on the effects of movement and behavior, we omitted features of a face and a head. A non-anthropomorphic robotic object was created, with a minimalist, abstract design and the ability to move smoothly. For that purpose, a 4 DoF robotic arm was covered with a flexible tube and material. At rest, the robot prototype looks like a pillar or monolith without a face or head (Figure 1). The robotic arm was programmed to perform movement sequences during video recording, depending on conditions and scenarios.

For the design of distinctive motion behaviors, we aligned the functional and expressive movement types with the Effort factors from Laban's Movement Analysis (LMA). In LMA, Effort describes expressive movements related to the performer's intention or state. Effort has four factors, each of which has two opposite elements [40].

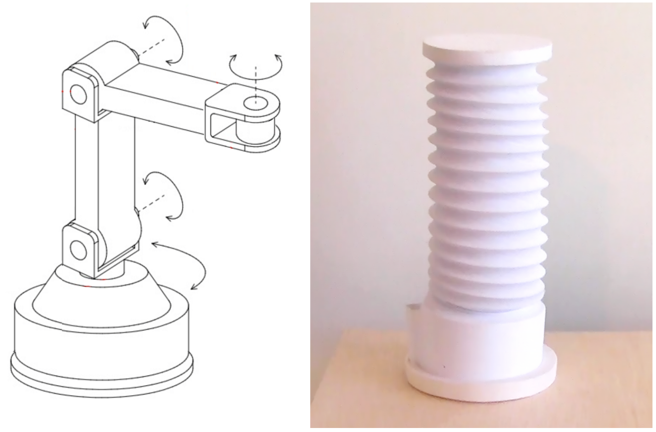

Fig. 1. A 4 DoF robotic arm, placed inside a flexible tube.

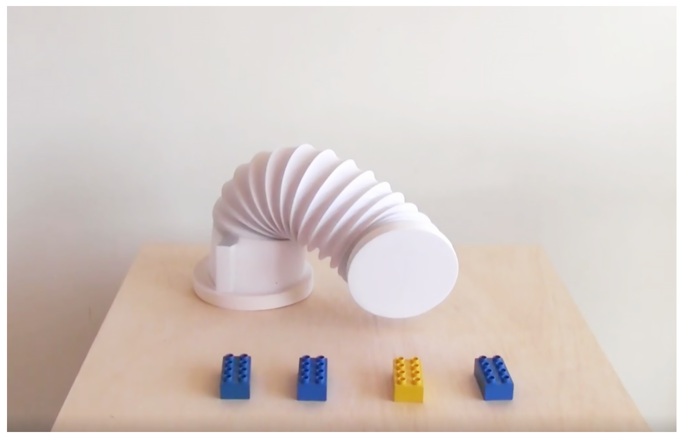

Fig. 2. Robotic prototype that allows for smooth movements.

D. Measures

The independent variables are the two factors of Expressive and Functional movements, and the two factors of Unsurprising and Surprising behavior. The dependent variables are the adoption of the intentional stance and the user's perception of the robot. We used a questionnaire to measure the dependent variables. Adoption of the intentional stance was probed with video questions, and perception of the robot was probed with the Godspeed Questionnaire Series (GQS) [43].

The questionnaire was administered and distributed via Qualtrics. Participants were asked to answer the questions in the order they were provided: general information, video questions on the adoption of the intentional stance, and the GQS. The general information questions concerned demographics and familiarity with robots and computer technology. For the video questions, participants were instructed to move a slider on a bipolar scale to the description that they believed best explained the video story. Two alternative explanations (mentalistic vs. mechanistic) were placed at opposite ends of the scale. The slider was initially placed in the center. Half of the video questions showed the mechanistic explanation on the left, and the mentalistic explanation on the right. For the other

TABLE II
LMA EFFORT FACTORS AND MOTION DESIGN

LMA effort system		Motion Design	
Effort	**Elements**	**Functional**	**Expressive**
Space	Direct-Indirect	Linear paths	Nonlinear paths
Weight	Strong-Light	Whole body moves	Body parts move
Time	Sudden-Sustained	Linear speed	Nonlinear speed
Flow	Bound-Free	Abrupt changes	Gradual changes

half, this was reversed. The order of presentation of the video questions was randomized. Each questionnaire showed videos in one of the four conditions, and conditions were randomly distributed between subjects.

The slider values from the video questions were used to calculate a score for the adoption of the intentional stance per participant. This score was computed as the average of all slider values and converted into a dichotomous variable 'Stance' with a value of 'I' (intentional) or 'D' (design). A score below 50 indicated that the participant took the design stance, otherwise that they adopted the intentional stance. Percentages of I (PI) per condition were compared. The effects of movement and behavior on robot perception were measured for the GQS scales 'Anthropomorphism', 'Animacy', 'Likeability', 'Intelligence', and 'Safety'. The following hypotheses were tested:

H1 Expressive motion significantly increases the adoption of the intentional stance, when compared to functional motion.

H2 Surprising behavior significantly increases the adoption of the intentional stance, when compared to unsurprising behavior.

H3 The effect of expressive motion is significantly stronger than the effect of surprisingness.

E. Participants

108 participants filled in the questionnaire, of which 60 female, 46 male, and 2 otherwise specified. The distributions are shown in Table III. From the 108 respondents, 71% reported that they were completely unfamiliar with robots (N=77), 25% reported to sometimes interact with robots (N=27) while the remaining 4% reported frequent interaction (N=4).

TABLE III
AGE GROUPS / FAMILIARITY WITH ROBOTS (N=108)

Age group		**Familiarity/interaction with robots**	
18-34	42	Rarely/never	77
35-54	28	Sometimes	27
55-74	37	Frequently	3
>75	1	Robot developer	1

IV. RESULTS

To test the reliability of the GQS results, Guttman's lambda was calculated. A scale of 0.76 indicates an acceptable level of reliability. 'Safety' is left out of the further analysis because of its negative effect (Table IV).

A. Effects on the intentional stance

Respondents most often chose mechanistic explanations for the robot's behavior, thus adopted the design stance (Figure 3). A two-sided binomial test shows that the observed values (N = 108, K = 77) are significant; $p < 0.001$. In some cases (n=31), the intentional stance was adopted, mostly (n=10) in the condition that combined expressive movements with surprising behavior (ES). A one-sided binomial test shows that the observed values for that condition (N = 31, K = 10) were significantly higher than for the other conditions; p = 0.05. A two-way between-subjects ANOVA test was conducted to examine the effects of the movement / behavior conditions on the selected stance (Figure 4). With regard to the hypotheses, no statistically significant interactions were found.

H1 *Expressive motion significantly increases the adoption of the intentional stance, when compared to functional motion.* This is found not to be true. Expressive movement only yields a higher IP when combined with surprising behavior (ES). In contrast, the combination of expressive movement and unsurprising behavior (EU) yields the lowest score.

H2 *Surprising behavior significantly increases the adoption of the intentional stance, when compared to unsurprising behavior.* Surprising behavior results in more cases of adoption of the intentional stance than unsurprising behavior. However, the differences are not significant.

H3 *The effect of expressive motion is significantly stronger than the effect of surprisingness.* This is found not to be true. Expressive movement only results in a higher IP when combined with surprising behavior (ES). For unsurprising behavior, functional movement yields higher scores (FU).

B. Effects on how the robot is perceived

We examined the effects of the movement/behavior conditions on the GQS results. Expressive movement had a significant positive effect on Anthropomorphism. A two-way between subjects ANOVA test demonstrated a significant effect [$F(1) = 4.07$, $p = 0.046$]. For the other GQS scales, no significant effects of movement/ behavior were found.

TABLE IV
RELIABILITY STATISTICS ON GUTTMAN'S λ SCALE

Reliability statistics - Guttman's λ scale		
	Item-rest correlation	If dropped
Anthropomorphism	0.672	0.555
Animacy	0.723	0.541
Likeability	0.422	0.760
Intelligence	0.468	0.750
Safety	0.127	**0.761**

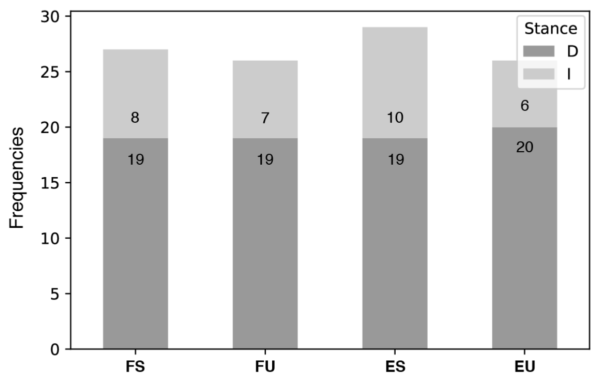

Fig. 3. Frequencies of adopted stance per condition (N = 108).

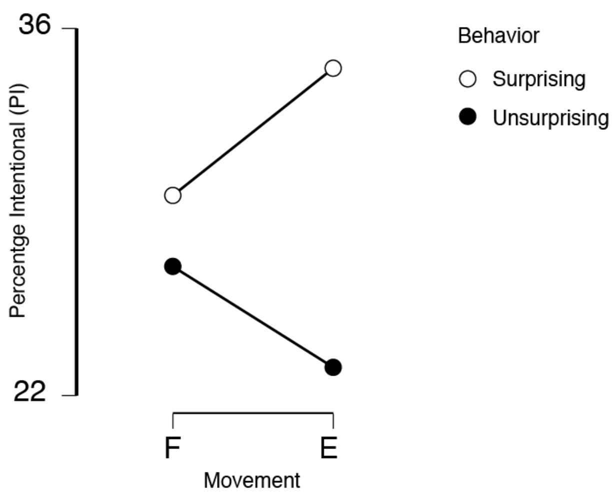

Fig. 4. Results of two-way ANOVA, showing effects of movement/behavior conditions on the intentional stance (PI).

A repeated-measures ANOVA was conducted to explore effects of stance on the GQS results. The category ‘Intentional’ demonstrated higher scores for Anthropomorphism and Animacy, while the category ‘Design’ demonstrated higher scores for Likeability and Intelligence (Figure 5). The differences were found not to be significant.

1) Familiarity with Robot Technology: To further investigate the difference in Likeability, we compared participants who reported to ‘rarely/never interact with robots’ with the rest of the participants. We refer to those groups as ’unfamiliar’ and ’familiar’ (with robot technology). A significant difference in Likeability was found. The 77 ’unfamiliar’ subjects (M = 3.24, SD = 0.82) compared to the 31 ’familiar’ subjects (M = 3.77, SD = 0.64) showed a significantly lower Likeability score t(106) = -3.22, p = 0.002.

We analysed the relation between familiarity, selected stance, and Likeability with a two-way between-subjects

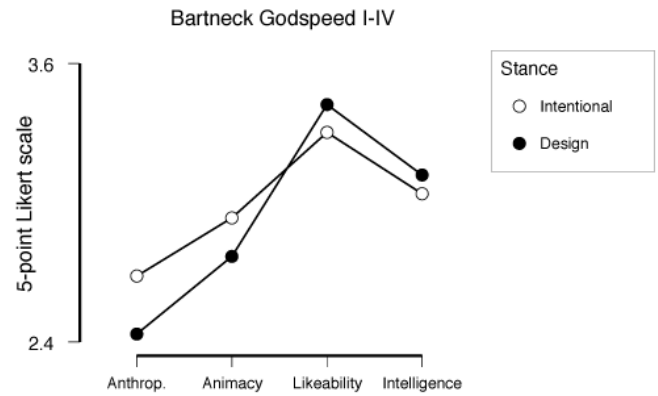

Fig. 5. Results of a repeated-measures ANOVA showing effects of the intentional stance on GQS I-IV.

ANOVA test. Significant effects were found for the familiarity condition [F(1) = 14.98, $p < 0.001$], and the stance condition [F(1) = 4.77, p = 0.031]. A Tukey post hoc analysis revealed that the difference in Likeability was most significant between the ’unfamiliar’ and ’familiar’ groups of participants who adopted the intentional stance [MD = 1.195, p = 0.005].

Taken together, from the participants who adopted the intentional stance, those who were unfamiliar with robot technology demonstrated significantly lower scores for the robot’s Likeability than those who were familiar with it (Figure 6).

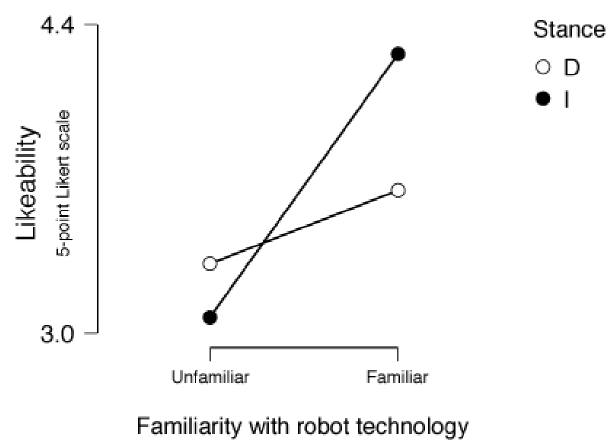

Fig. 6. Likeability ratings of participants who reported being unfamiliar/familiar with robot technology.

2) Similarities: We explored the effects of movement and behavior on the scores for the GQS results (Figure 7). The plots show a similar pattern, that seems to be related to the effect in Figure 4. The condition of expressive movement combined with surprising behavior (ES) has a higher score than the condition of expressive movement with unsurprising behavior (EU). In contrast, the condition of functional movement with unsurprising behavior (FU) has a higher score than the condition of functional movement with surprising behavior (FS). In short: EU < ES, while FS < FU. No significant differences were found between male and female participants in the adoption of the intentional stance, nor in the scores of the GQS.

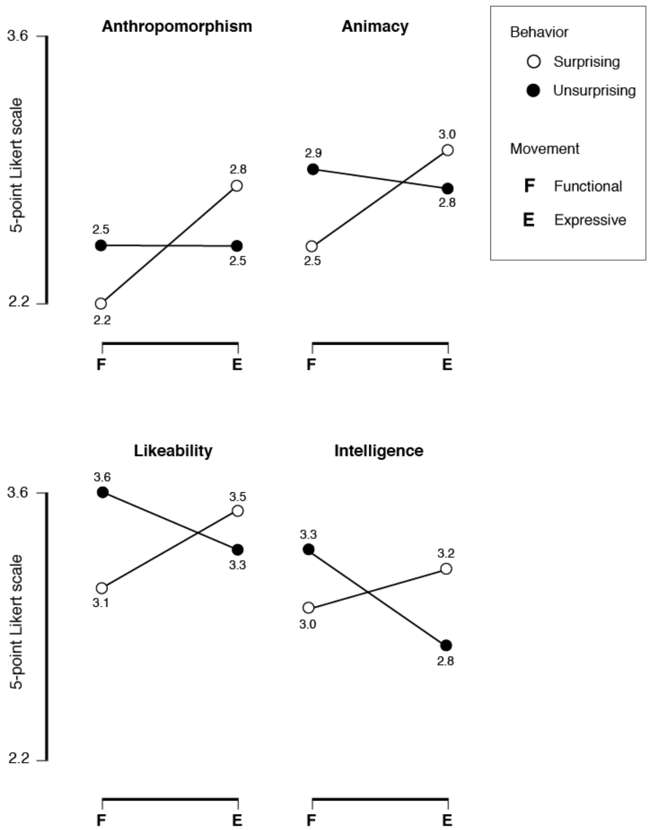

Fig. 7. Results of two-way ANOVA tests showing effects of movement/behavior conditions on GQS I-IV.

V. Discussion

Measuring the adoption of the intentional stance still presents a challenge [44]. We took the tool proposed by [21] as a starting point, which does not allow for direct interaction. To study the effects of movements and behavior on first impression, we created a controlled experimental set up with reduced stimuli. Although we expect our findings to be generalizable, further research is needed in more enriched contexts and live interactions.

Our results support previous findings that surprisingness increases intention attribution [35,37] and suggest that expressive movement reinforces this effect, as long as cues and behavior are congruent. Expressive movement alone significantly 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 is found to engage the mechanisms involved in the attribution of intentions, and gaze cues have been used to measure the adoption of the intentional stance [44]. Though without a face or head, our robot prototype mimicked gaze cues, and thereby guided attention. Studies revealed that arrow cues could trigger attention shifts similar to those triggered by gaze [45]. Especially for the design of HRI with non-humanoid robots, we recommend to further explore cues for directing attention that can also evoke the adoption of the intentional stance.

Our study is limited in many ways. With regard to the surprising / unsurprising behavior of the robot, we assumed respondents to have expectations toward the robot based on human pre-attentive processing. In follow-up research, these conditions should be validated. We used forced-choice questions to probe the adoption of the intentional stance. Whether or not people adopt the intentional stance is a binary question, but open-ended explanations would have revealed information on other reasons that people choose. The limited dichotomy fits our research question, but future directions may take more relative values into consideration. The mentalist explanations that we used in the video questions were only referring to the 'desires' of the robot, and not to its 'beliefs', so knowledge on the robot's intelligence was not required. Earlier research revealed, however, that people more often use belief reasons to explain a robot's behavior [35]. Providing only desire reasons thus limits our study. With more contextual information and the possibility to choose belief reasons, more respondents may have adopted the intentional stance.

VI. Conclusion

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

Participants generally adopted the design stance and chose mechanistic explanations for the robot's behavior. Results confirmed that surprising behavior increases the adoption of the intentional stance [35,37].

In some cases, however, people did adopt the intentional stance, even with an abstract robotic object. Expressive movement increased the ascription of intentions in cases of surprising behavior. In contrast, it decreased perceived intentionality in cases of unsurprising behavior. This suggests that expressive movement can be designed as a cue to direct attention to behavior that is not yet understood. Participants unfamiliar with robot technology significantly rated the robot as less likeable than those more familiar with it, especially within the group that adopted the intentional stance. As people become more familiar with robots, they may become more familiar with robot intentionality. However, the relationship between familiarity, intentionality, and likeability needs further investigation.

We propose investigating cues for intention attribution further, to explore the adoption of the intentional stance in live interactions and on the longer term, and are keen to contribute to futures studied on this.

VII. Acknowledgments

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APPENDIX A
CONDITIONS, SCENARIOS, EXPLANATIONS

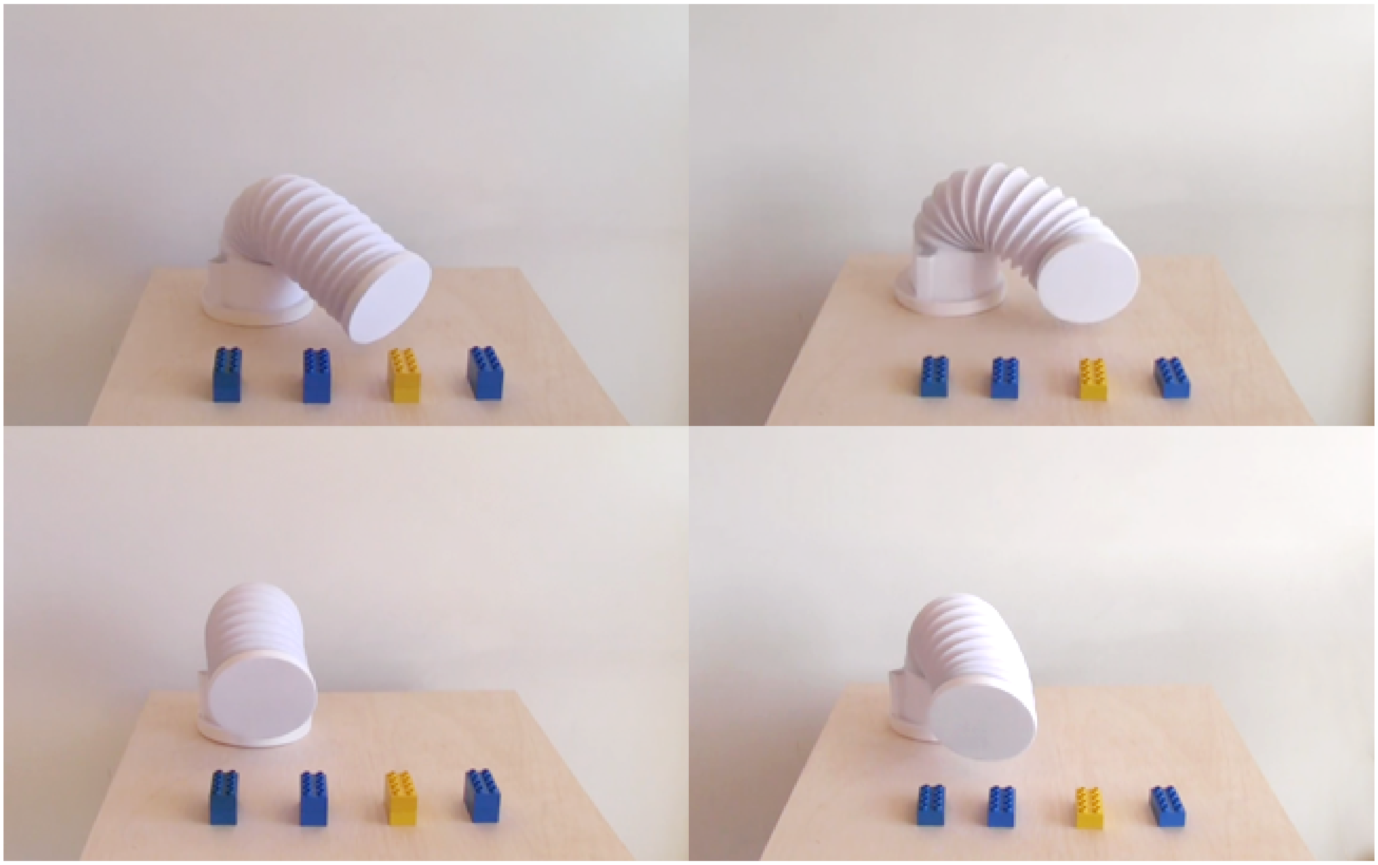

Fig. 8. Conditions for scenario 1. Clockwise: Functional/Unsurprising, Expressive/Unsurprising, Expressive/Surprising, Functional/Surprising.

Fig. 9. Video stills of the two other scenarios (here with expressive movement).

Note: The different movement conditions can best be explored in the **video recordings**.

1.21.5

TABLE V
BEHAVIORS, ACTIONS, EXPLANATIONS

Scenario 1 - Perception

Behavior	**Actions**	**Slider labels**	
		Mechanistic explanation	*Mentalistic explanation*
Unsurprising	The robot looks at the yellow brick	The robot inspects yellow objects.	The robot prefers looking at yellow.
Surprising	The robot looks at the blue bricks	The robot inspects blue objects.	The robot prefers looking at blue.

Scenario 2 - Action

Behavior	**Actions**	**Slider labels**	
		Mechanistic explanation	*Mentalistic explanation*
Unsurprising	The robot knocks over the ball	The robot knocks over balls.	The robot prefers interacting with balls.
Surprising	The robot knocks over the brick	The robot knocks over bricks.	The robot prefers interacting with bricks.

Scenario 3 - Interaction

Behavior	**Actions**	**Slider labels**	
		Mechanistic explanation	*Mentalistic explanation*
Unsurprising	The robot responds to hand movement	The robot follows moving objects.	The robot is interested in human interaction.
Surprising	The robot does not respond to hand movement	The robot inspects blue objects.	The robot ignores human interaction.