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Attributing intentionality to artificial agents: exposure versus interactive scenarios

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Abstract. Recent studies suggest that people can interact with robots as social agents. However, it is still unclear what mental processes people rely on when interacting with robots. One core process in social cognition is the adoption of intentional stance, a strategy that humans use to interpret the behavior of others with reference to mental states. In this work, we sought to examine how the adoption of intentional stance may be modulated by the type of behaviors exhibited by a virtual robot and the context in which people are exposed to it. We developed an interactive virtual task and used the InStance Test to measure the attribution of intentionality to the robot. Our results show that participants attributed more intentionality to the virtual robot after interacting with it, independently of the type of behavior. Leveraging data from a previous study, we also show this increase is stronger than in a non-interactive, purely observational scenario. This study thus improves our understanding of how different contexts can affect the attribution of intentional stance and anthropomorphism in Human-Robot Interaction.

Keywords: Intentional Stance, Human-likeness, Human-Robot Interaction

1 Introduction

One of the key process of human social cognition that entails perceiving other agents as social entities is the attribution of intentionality to their behaviors [1]. This process is thoroughly explained by Daniel Dennett [2], [3], who defines the concept of "stances" (or strategies) that humans adopt to explain and predict others' behaviors. Dennett presents two stances that we can adopt: (i) the intentional stance, that is adopted when we interpret the agents' behavior with reference to mental states; and (ii) the design stance, which is adopted when we interpret the behavior of observed agents with reference to how they were designed to behave. When it comes to human agents, adopting the intentional stance is a default strategy enabling an efficient way to navigate the social environment (for a review see [4]). It remains to be answered, however, if and how humans adopt the intentional stance towards artificial agents.

To operationalize and empirically address the philosophical concept of intentional stance, Marchesi and colleagues [5] developed the InStance Test (IST). For example, using IST, it was shown that individuals' tendency to adopt the intentional stance toward robots is characterized by differences in their neural activity at rest [6]. In addition, studies found that the adoption of the intentional stance can be modulated by numerous factors: (i) related to the robot, such as appearance and repetitive behavior[7];

(ii) related to the human, like prior exposure to robots[8]; and related to the task, like collaborative framing [9] Moreover, multiple exposures to robots over time could result in negative subjective perceptions of robotic agents [10] and can decrease the likelihood to attribute mental states to them [7], [11].

In this paper, we sought to investigate whether the quality of the robot's movements would influence the adoption of the intentional stance toward it. Indeed, motion plays a crucial role in social cognition in humans [12]. For example, it has been shown that the movements of simple shapes can evoke attributions of intentions [13]. In HRI, the type of movements performed by robots were found to affect the adoption of the intentional stance [14]. The human-likeness of the machine's movements and the extent to which it resembles biological motion could potentially provide the basis for mentalistic explanations [15], [16]. However, in a previous study using robotic virtual agents [17], we showed that IST scores increased after observing the robot with mechanistic behaviors but not to the robot with human-like behaviors. In other words, machine-like behaviors of the robotic virtual agent had a positive effect on participants' adoption of intentional stance. Overall, how the human-likeness of robots' motion may affect the adoption of intentional stance toward them remains unclear.

Another important factor, which may influence intentionality attribution, is the context of the interaction. Following the second-person neuroscience framework presented by Schilbach and colleagues [18], we focused on the domain of second-person robotics proposed by Dominey [19]. This framework suggests that the mental processes engaged during an interaction differ from those engaged by the observation of another agent. Thus, since our previous study mentioned above [15] was merely observational, results may be different in case participants fully interacted with the robot. For example, previous studies found that interactive scenarios are also beneficial for general attitudes toward the robot (e.g. likeability and perceived intelligence) [20], [21]. By integrating the behaviors to which participants were exposed in the previous study in an interactive task, we seek to investigate whether intentionality attribution depends on the type of encounter, i.e. observational or interactive.

1.1 Aim of the study

This study aimed to examine behavioral and contextual factors that may affect the adoption of intentional stance toward robots. Specifically, we investigated the effects of quality of the robot behavior (human-like vs robot-like motion) and of the nature of the task (interactive vs observational). Based on the literature described above, we hypothesized that the adoption of the intentional stance **(i)** would be modulated by the human-likeness of the robot behavior, even though, based on the literature, it remains difficult to clearly predict the direction of such modulation; **(ii)** would positively correlate with perceived intelligence and likability; and **(iii)** would be stronger in an interactive scenario compared to a mere exposure to the same agent exhibiting the same behaviors. To test these hypotheses, we designed an experiment involving an interactive task occurring in a virtual environment, and used IST and the Godspeed questionnaire (GSQ). The virtual environment incorporated a 3D avatar modeled after the humanoid robot iCub, which allowed us to overcome the mechanical constraints of the embodied robot, manipulate the human-likeness of the agent's motion and compare behaviors that follow the properties of biological motion with jerky, mechanistic movements that are more typical of robots.

2 Methods and Materials

2.1 Participants

Forty-one participants (M/F: 16/25; age: 26.7±7) took part in the study. All participants had normal or corrected-to-normal vision and were not informed about the purpose of the experiment. All participants gave their informed written consent. The experiment was conducted under the ethical standards (Declaration of Helsinki, 1964) and approved by the local Ethical Committee (Comitato Etico Regione Liguria). The data of one participant (male, age 24) have been excluded because they did not complete the experiment. Therefore, data of forty participants were included in the final analysis.

2.2 Apparatus

Participants were seated facing two 22'' LCD monitors. The first screen displayed the virtual environment for the decision task running on a computer with an AMD Ryzen Threadripper 2950X 16-core 3.5 GHz CPU, 128 GB of RAM and a NVIDIA GeForce GTX 1060 3GB video card. The 3D-animated virtual environment including avatars with the appearance of the iCub robot [22] was developed using Unreal Engine (Epic Games: www.unrealengine.com). An ad-hoc Python program (version 3.9.5) handled stimulus presentation and data collection. Participants responded on a QWERTY keyboard. The second monitor was used to display the InStance Test and Godspeed Questionnaire (GSQ), which were administered through SoSci (https://www.soscisurvey.de).

2.3 Procedure

After providing consent, participants were instructed about the structure of the experiment. Participants completed the first part of the IST (IST Pre). After that, they performed an interactive task with a virtual agent presented on a screen (see Section 2.4). At the end of the task, participants were asked to complete the second part of IST (IST Post) and 2 GSQ subscales. Participants were randomly assigned to one of the two experimental groups. In one group, the behavior of the iCub avatar in the interactive task was characterized by biological motion resulting in human-like movements (human-like iCub). In the other group, the iCub avatar was exhibiting the same types of behaviors but moving mechanically, in a typical robotic fashion (robot-like iCub). In summary, the task included one between-subjects manipulation related to the human-likeness of the avatar behavior (human-like vs robot-like movements). Task and subjective measures are described in details in the next sections. Participants did not have a specified time limit to complete the experiment and could take break between the task and IST. Average time required to complete the experiment and read instructions was around 1 hour and 30 minutes.

2.4 Task

The interactive task was loosely inspired by the Shell Game [23]. In our version, the game required the presence of a game partner (here the robot) and a player (here the participant) to guess the position of a ball hidden under one of the cups. The game and the instructions were not explicitly framing the task as collaborative or competitive. In the virtual environment displayed on the monitor, the robot was facing the participant on the other side of a table on which two identical red cups and one ball were placed. As in typical cups and ball games, the cups were shuffled to hide the ball position then the player had to guess under which of the two cups the ball was hidden.

Each trial began with iCub looking at the participants and then at the movement of the cups on the table game. After the cups stopped moving, participants were asked to press ‘a’ to choose the cup on their left and ‘d’ to choose the cup on their right. After this decision step, cups were lifted to show the ball position and thus the outcome of the trial (i.e., hit or miss). In order to create an interactive scenario, iCub then provided social feedback in the form a non-verbal behavior. Feedback from iCub were always congruent with participant performance, meaning positive feedback after a hit and negative feedback after a miss. Positive feedbacks were iCub clapping hands or nodding, in both feedback types, iCub was also showing a happy face expression. Negative feedback were iCub punching the table and shaking its head and iCub was showing a sad expression during both negative behaviors (see Figure 1). Behavioral data were collected (e.g. response times and accuracy) but their analysis is out of the scope of this paper.

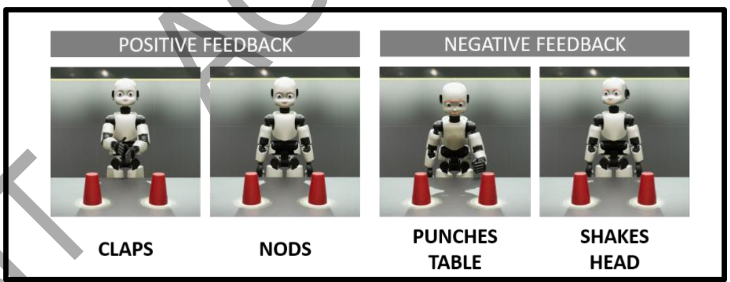

Figure 1. Feedback from iCub presented to the participants at the end of the trial. Positive feedback were always including a happy face expression and negative feedback were always presented with a sad face expression.

2.5 Subjective measures

To measure whether interacting with the virtual robot modulated participants’ tendency to adopt intentional stance toward the robot, the IST [5] was administered before and after exposure to the robot (pre- and post-). In order to avoid participants to rate twice the same items, we split the IST in two halves, based on a prior work [24].

IST pre- and post- consisted of 17 items each. Each IST item consists of a scenario made of three different pictures of iCub involved in an action alone or with a human partner (see Figure 2). Two sentences describing the situation are presented below the scenario. One description is written with mentalistic words and the other with mechanistic terms. Participants were asked to indicate whether the mentalistic or mechanistic description was fitting the scenario better by moving a slider placed on a line between the two sentences. IST scoring was calculated by assigning 0 to the extreme of the slider line on the mechanistic side (adopting the mechanistic stance) and 100 to the extreme side of the line on the mentalistic side (adopting the intentional stance). IST pre- and post- averaged scores were calculated for each participant. IST delta scores were calculated for each participant subtracting IST pre- score from IST post- score, to have a unique measure for modulation of IST related to the interaction.

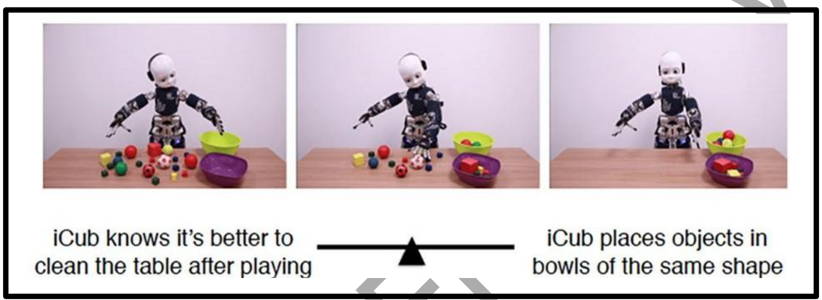

Figure 2. Example of the IST items. Each item presents a scenario made of 3 pictures. Two sentences are presented below the scenario: one giving a mentalistic explanation and one a more mechanistic description.

In addition, we used the Godspeed questionnaire (GSQ) to assess participants' attitude toward the robot. In GSQ, Bartneck and colleagues identified five subscales (anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety) which are useful to investigate people's perception of robots [25]. To limit the duration of the experiment, we selected the two most relevant GSQ subscales: likeability and perceived intelligence. Both subscales are composed by 5 items on 5-points scale with opposite poles (e.g. dislike-like, incompetent-competent). These two subscales were shown to be associated with the quality of the interaction scenario [21].

3 Results

First, we examined if the two groups were different based on demographical information. The t-test showed no differences between the two groups based on age ($t(38) = 0.63$, $p = 0.533$, Cohen's $d = 0.199$, $M_{human\text{-}like} = 27 \pm 7.7$; $M_{robot\text{-}like} = 25.7 \pm 6.2$). The Chi-Squared analysis showed a significant difference based on sex ($X^2 = 3.956$, $p = 0.047$, $M/F_{human\text{-}like} = 4/16$; $M/F_{robot\text{-}like} = 10/10$). Given that sex was unbalanced, we performed an independent samples t-test to test whether this could affect IST and GSQ measures. No effect of sex was found (all p-values > 0.063).

3.1 InStance Test

We submitted IST scores averaged individually to a two-way ANOVA with groups as a between-subject factor and IST pre/post as a within-subject factor. The results showed a within-subjects effect of IST score ($F(1,38) = 68.535$, $p < 0.001$, $\eta^2 = 0.461$) and no effect of the group ($p = 0.38$) or interaction ($p = 0.11$) (see Figure 3).

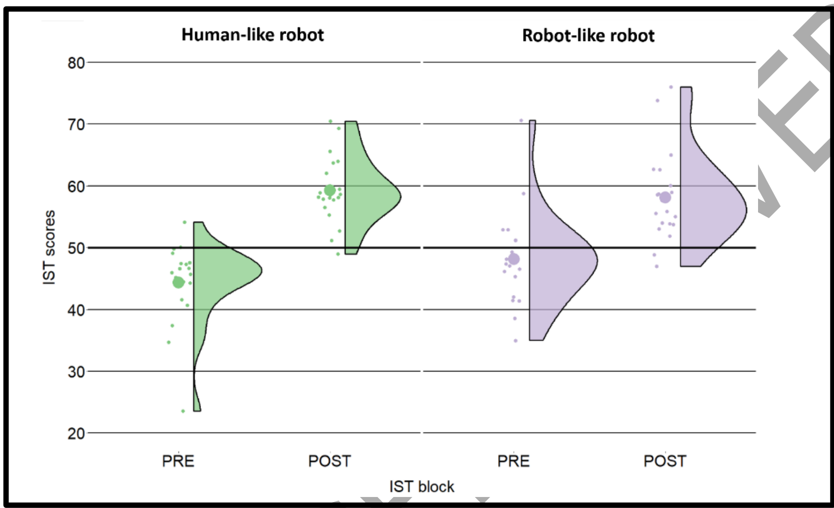

Figure 3. The graph presents IST Pre and Post scores for each of the two groups (human-like or robot-like behavior of iCub). Bigger dots represent the mean score, smaller dots are single participant IST score and on the side the distribution of the sample. The score of 50 represents a neutral response between "completely mechanistic explanation" (0) and "completely intentional explanation" (100).

To check whether IST PRE and POST scores were significantly different from 50 we performed two separate one-sample t-test. Results showed that IST PRE scores are significantly lower than 50 ($t(39) = -3.284$, $p = 0.002$, Cohen's $D = 6.368$) and IST POST scores are significantly higher than 50 ($t(39) = 8.643$, $p < 0.001$, Cohen's $D = 9.212$), meaning that participants had a bias towards one or the other stance, rather than being ambivalent.

3.2 Godspeed Questionnaire

We first looked for between-subjects difference using an independent t-test and found no difference between the human-like and the robot-like group, neither on the Likability subscale ($p = 0.955$) nor on the Perceived Intelligence subscale ($p = 0.999$). Mean score of the Likeability subscale was 3.79±0.624 for the human-like agent and 3.78±0.476 for the robot-like agent. Mean score of the Perceived Intelligence subscale was 4.11±0.685 for the human-like agent and 4.11±0.61 for the robot-like agent. Then, we performed a correlation analysis to examine possible association between IST and GSQ scores. The analysis did not show any significant correlation (all p-values > 0.123).

3.3 Differences with previous exposure study

To examine differences in intentional attribution based on different type of interaction with the virtual agents, we proceeded to compare IST scores with those reported in our previous study [15], in which participants watched the same behaviors exhibited by the virtual robots here but without any interactive context (i.e. non-interactive task). The non-interactive task consisted in watching short video clips of the robot behaviors and rating them in terms of how human-like the movements were. Previous study sample counted 97 participants (M/F: 49/48; age: 26±6.5). Forty-nine participants watched and rated the virtual human-like robot (M/F: 24/25; age: 25.7±6.5) and 48 did the same with the robot-like robot (M/F: 25/23; age: 26.2±6.6). We submitted Delta IST scores to an ANCOVA with type of interaction as a between-subject factor and IST PRE scores as a covariate in the model. The Deltas IST calculation helps to investigate the magnitude of the changes in the IST scores. Results showed a significant effect of the type of interaction on Delta IST ($F(1,134) = 28.12$, $p < 0.001$, eta sq = 0.163) where the interactive scenario increased IST scores significantly more than the exposure (M exposure = 2.609 vs M interaction = 12.478) (see Figure 4). No other main effect or interaction was found to be significant.

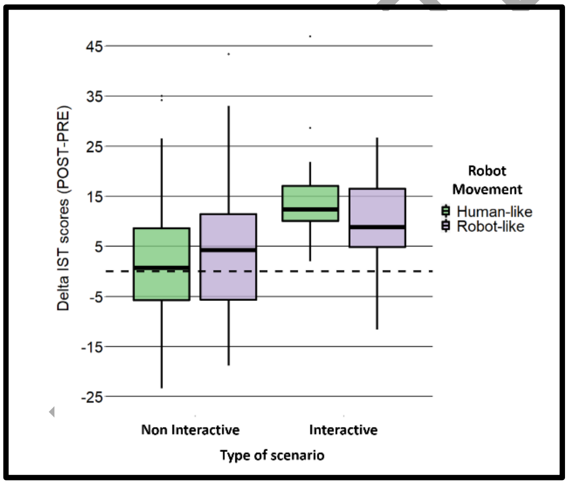

Figure 4. The graph shows the delta of IST scores (IST Post – IST Pre scores) comparing the exposure with the interactive task, divided by the type of behavior the avatar was showing (human-like vs robot-like). Each boxplot shows a thicker black line as median value, colored part representing interquartile range and vertical lines as upper and lower whiskers. The dashed line represents the delta value of 0, meaning no difference between pre and post-IST score. Delta above "0" represent an increase in IST scores from Pre to Post.

4 Discussion

The aim of this study was to investigate whether adoption of the intentional stance toward robots their perception as likeable or intelligent is influenced by the human-likeness of their movements (human-like vs robot-like motion) and by the context of the task (interactive vs observational). To this aim, we asked participants to interact with a virtual robot and administered IST and GSQ to measure intentionality attribution, likeability, and perceived intelligence. Because mechanical constraints make it difficult to implement biological motion on real, embodied robots, we designed this study in a virtual environment as a first step. This allowed us to implement jerky, robot-like movements and compare them to more human-like movements.

Consistently with previous IST studies [5], [17], participants showed a general bias toward a mechanistic explanation of robot actions in the IST Pre phase. As stated in our first hypothesis, we were expecting the human-likeness of the robot's behavior during the task to modulate attribution of intentionality after the interaction. Contrary to our hypothesis, we found an increase in IST scores independently of the type of behavior; meaning that after interacting with robot in our setting, participants tended to adopt the intentional stance more, independent of the type of movement it was exhibiting. One possible explanation for this is that the robot with which participants interacted was virtual rather than physically embodied. As such, the behavior might not have modulated the IST as much as in physical presence settings [10].

Our second hypothesis was also not confirmed. Indeed, unlike previous studies [26], we found no correlation between intentionality attribution and the levels of likeability and perceived intelligence in the GSQ; which were overall high with relatively low variability. Other studies had found an increase in likeability and perceived intelligence in interactive scenarios [20], [21]. One explanation could be that these subjective measures were generally high due to the positive effect of the interaction, thus blurring the possible relation with attribution of intentionality. Future studies should investigate the factors that might influence the correlation between these measures in HRI.

Our last hypothesis was confirmed by the observed difference in the increase of IST scores between interactive and non-interactive settings. The interactive setting was characterized by a dynamic decision task and the robot was giving feedback to participants after the decision. The non-interactive setting consisted in watching short videos of the robot and rating the human-likeness of its behaviors. Indeed, participants who merely observed the robot's behavior without any social context (non-interactive setting) attributed less intentionality to it compared to those who interacted with it. This result was also independent of the level of human-likeness of the robot's behavior. This finding is in line with the perspective of second-person approach originally presented by Schilbach and colleagues [18] for human-human interactions and extended to human-robot interactions by Dominey [19]. Indeed, it suggests that even in virtual environments, the possibility to interact with the virtual agent can affect the strategy we use to predict and interpret their behaviors.

Interestingly, our previous results with merely observational exposure to the same behaviors that we used in this study showed that IST scores only increased in case of robot-like motion. This suggested that intentionality attribution was dependent on prior expectations about the agent [17]. In other words, given that humans expect robots to move in a jerky, mechanistic fashion, violating such expectation might hinder the adoption of the intentional stance toward them. The results of the present study indicate that such an effect could be attenuated in interactive scenarios. While further studies are needed to confirm these results, we believe this is an important finding, as it suggests that the quality of the robot's motion might matter less than the interactive nature of the task. The attribution of mental states to robots can increase the acceptance and positive attitudes towards them [26]. Therefore, the ability to create scenarios (i.e. interactive) that favor the adoption of the intentional stance may be key to successful human-robot interaction and more broadly to human-agent interaction. Moreover, we believe that implementing communicative gestures on the robotic agent (i.e. feedback in this study) could make the experimental scenario more interactive and engaging for participants and so future users.

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