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More than you expect: priors influence the adoption of intentional stance toward humanoid robots

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Abstract. Expectations about other's behavior based on mental states modulate the way we interact with people. On the brink of the introduction of robots in our social environment, the question of whether humans would use the same strategy when interacting with artificial agents gain relevance. Recent research shows that people can adopt the mentalistic statement to explain the behavior of humanoid robots [1]. Adopting such a strategy might be mediated by the expectations that people have about robots and technology, among others. The present study aims to create a questionnaire to evaluate such expectations and to test whether these priors in fact modulate the adoption of the intentional stance. We found that people's expectations directed to a particular robot platform have an influence on the adoption of mental state based explanations regarding an artificial agent. Lower expectations were associated with anxiety during interaction with robots and neuroticism. Meanwhile, high expectations are linked to feeling less discomfort when interacting with robots and a higher degree of openness. Our findings suggest that platform-directed expectations might also play a crucial role in HRI and in the adoption of intentional stance toward artificial agents.

Keywords: Expectations, adoption of the intentional stance, iCub, priors.

1. Introduction

Social interaction strongly depends on predictions. To negotiate the complex social environment, our brain is constantly anticipating the next step. We root these predictions on interpretations about others' mental states [2, 3, 4], i.e. the old man goes fishing because he hopes to catch fish this time. This predictive and explanatory strategy has been denominated the intentional stance. The intentional stance is a powerful and easy to implement. For instance, drivers interactions with fellow drivers and pedestrians anchor on inferring the co-specifics intentions. Furthermore, people not only use this strategy to interact with humans but also to explain the behavior of other complex systems like other animals, computers and groups of people. However, nowadays, the type of agents with whom humans interact has diversified. From the hated chatbots, to humanoid robots, passing through virtual agents, we face now a wide variety of counterparts in social interaction. In this context, it is plausible to think that humans would also use the same strategy to interact with social robots and human like agents [5]. But, how do humans interact with artificial agents, would people adopt the intentional stance to predict robots behavior, and if that case, which factors would modulate the adoption of the intentional stance.

Research in human-robot interaction has turned toward the understanding of how adopting intentional attitudes toward robots might be a determinant component that modulates social dynamics with artificial agents. Research has shown mixed evidence. For instance Krach et al. [6] and Chaminade et al. [7] suggested that robots do not naturally evoke the adoption of intentional stance. Both studies found that the neural correlates of adopting the intentional stance were not observed in interactions with artificial agents. However, other studies support the idea that artificial agents evoke the intentional stance. A couple of studies suggest that observing a robot performing goal directed actions activate similar mirror neuron system activity compared to observing other humans ([8, 9]). In the same line, Wykowska et al. [10] found that observing a robotic agent performing grasping and pointing actions can bias perceptual processing in a similar that observing a human agent does. In other words, people interpreted robots and other humans as goal-driven agents.

More recently, particular interest has been driven towards how and when humanoid robots evoke mentalistic explanations of behavior [11-14]. Research with this type of robots is crucial as those share the most physical features and behavior with human agents and also because these robots would be the first ones that will interact with people in social contexts. In particular, [15] evaluated whether people would rate the behavior of the robot in terms of lay causal explanation of human behaviour. They found that people tended to adopt the intentional stance toward the robot to a similar degree as in the case of observing other humans. Furthermore, Marchesi et al. [1] observed that, in specific context that, people have the tendency to adopt the intentional stance towards humanoid robots. This authors have developed a questionnaire that systematically explores the spontaneous adoption of intentional stance toward a humanoid robot iCub ([16, 17]). This tool was created aiming at evaluating whether people explain the behaviour of iCub using mentalistic or mechanistic terms. After observing the behavior of the robot in a sequence of three photographs, participants were asked to rate if the behavior of the robot was motivated by a mechanical cause or by a mentalistic reason. Results showed that participants had a preference for mechanistic explanations, as has been presented previously in the literature ([6], [18], [13]). Interestingly, in some scenarios people tended to explain the behavior of iCub in mentalistic terms. The results showed also that some participants were more likely to choose mentalistic explanations meanwhile others preferred mechanistic explanations. Authors concluded that human-like appearance of the robot, the kind of action context and the goal-oriented behavior are crucial for attribution of mentalistic explanations. Additionally, another important factor identified by this study was the individual differences in attitudes that might be a results of priors and expectations regarding the behavior of the robot. Authors suggest that expectations could be a crucial factor that might affect the likelihood of adoption of the intentional stance towards artificial agents. However, their study did not allowed to determine how those expectations influenced the score of the Instance questionnaire.

1.1. Expectations about robot behavior

In the current society, people have become increasingly accustomed to technology. However, despite finding ourselves increasingly surrounded by gadgets, devices and artificial agents, we ignore how social cognitive processes are engaged in interaction with machines and, specifically, with social agents. Furthermore, robots are all over the news. We constantly exposed to news and post in social media that mention how robots are more and more capable to do human task. Although, we are far from achieving all what the media promises, such exposure to technology has created in the future users high expectations regarding what are the robots capable of. Researchers have focused on developing tools that measure general preferences and expectations toward robots and assessed how those might have an impact on actual human robot interaction as presented by [19]. People would prefer robots that look like machines, with human-like speech and that are predictable, smart but controllable, and polite (for review see [20, 21]). On the contrary, people expect robots to look and behave coherent and adaptively to the (social) context [22]. The expectations seem to be adjusted depending on the purpose and task of the robot. In general, people expect robots to be reliable [23], simple, predictable, precise (no errors), autonomous but not independent, not having a human-like personality [20], and in general to be taking care of repetitive tasks rather to be involved in social tasks [21]. These general expectations have been measured either by open questions and interviews or using standardised questionnaires. For example, the Negative Attitudes towards Robots Scale (NARS) [24] that evaluates reactions and expectations about the behaviour of robots and the Frankenstein Syndrome Questionnaire (FSQ) ([25] that measures people's acceptance of humanoid robots.

In sum, findings using diverse methods reveal that people use the same social categories to understand and predict the behavior of a robot based on their preferences and expectations. Using the available information, people create individual impressions of robots in general. Such stereotypes and ideas might cascade down and adjust to concrete robots (i.e., iCub, Pepper, Cozmo) deployed in schools, counters or homes. Ultimately, priors might play a crucial role on the social dynamics with robots, and might modulate adoption of the intentional stance towards artificial agents.

1.2. Aim of the study

Previous studies have shown that people tend to attribute mentalistic explanations to robot behavior depending on diverse factors. One of these factors might be expectations that participants have regarding a determined robot and its role/task/purpose. The present study aims at identifying whether participants' expectations have an impact on the attribution of mentalistic/mechanistic scores of the Instance questionnaire. For this purpose, we first designed and tested a questionnaire that evaluates the expectations of participants. In a subsequent step, we devised an experiment to measure the whether expectations influenced the scoring of Instance questionnaire after observing a robot performing a task. We expected to design a questionnaire sensitive to the inter-individual variations in expectations regarding the robot (iCub) and hypothesize that such variations might become a determinant factor on the attribution on mentalistic/mechanistic explanations to the robot.

2. RobEx questionnaire design

We designed a questionnaire to understand how expectations toward a robot could potentially have an impact on HRI. Therefore, the main objective of the questions was to identify what are the expectations that participants have regarding iCub. Access to this information might be crucial to interpret the qualitative/implicit data collected in our experiments. With this objective in mind, we created a series of questions that evaluate what people think about the robot capabilities, its usefulness, behavioural repertoire, and predictions regarding pleasantness during the interaction and safety concerns. We were inspired by previous questionnaires and the comments we obtained from our participants in several experiments. The questionnaire was developed and tested using the humanoid robot iCub as referent, but was designed to be applied to any robot platform. The questionnaire includes 18 items with positive and reverse formulated items. For the administration of the questionnaire, items were divided into two sections in different pages, each one containing either the positive or the reverse item. The order of the items was randomised before data collection and each participant solved the questions in the same order. Participants were asked to observe a picture of iCub (Figure 1, panel A) before answering the questions. The picture depicted iCub on a neutral position to avoid creating any positive or negative bias. Table 1 shows the items of the questionnaire in the first column. The items were designed in English and then translated to Italian. Participants responded to each question of the sub-scales using a 6-point Likert scale (6 - "Completely agree" to 1 - "Completely disagree").

2.1. Participants

The questionnaire was administered online to 101 Italian people using the platform SoSci (https://www.soscisurvey.de). Eighty-two participants were aged between 18-35, nine between ages of 35-49 and nine between the ages of 50-65. Responders were recruited via email or through social media. Before responding the questionnaire, participants signed an informed consent digital form, followed by a demographic survey including age, gender, marital status, education level, and work field.

Table 1. Items from the RobEx questionnaire, component identified and saturation.

Item (I think this robot…)	**Component and Saturation**
can protect personal privacy	Component_1 (.494)
would not be a good home assistant	Component_1 (.724)
is capable of easing daily tasks for people.	Component_1 (.775)
would do a great job as a home assistant	Component_1 (.819)
is unable to help people on daily task	Component_1 (.821)
would be a boring interaction partner	Component_2 (.600)
is capable of being an enjoyable interaction partner	Component_2 (.765)
is not able to hold a conversation	Component_2 (.783)
can hold a conversation with people	Component_2 (.834)
would not be able to hurt anyone	Component_3 (.700)
can violate personal privacy	Component_3 (.814)
could harm people	Component_3 (.825)
has limited mechanistic movements	Component_4 (.461)
has human-like movements	Component_4 (.660)
can do only a few tasks	Component_4 (.720)
is constantly controlled by someone	Component_5 (.884)
can adapt to the environment.	Component_6 (.626)
can operate itself without human intervention.	Component_6 (.767)

2.2. Analysis

Descriptives of each item and inter-item correlations with reliability were examined. Additional analysis of the principal component analysis (PCA) were performed to identify the effect of the different component on the total variance. Further analyses included calculation Cronbach's alpha for each. Additionally, to investigate the effects of the education level, and field of work within two groups as "Humanities-related" and "Non-humanities related" occupations. All the analysis were performed using SPSS.

2.3. Results

Reliability. The Principal Component Analysis (PCA) showed 6 main components. Scree plot of each analysis is shown below. Initial eigen values indicated that the first two factors explained 35% and 14% of the variance respectively. The third, fourth, and fifth factors had eigen values just over one, and each explained 6%, 5% and 5%

of the variance, respectively. Reliability test revealed that Cronbach's alpha for the questionnaire was .837. We also checked for the checked the similarities between the items based on their factor loadings (Table 1).

Regarding the expectations, participants seemed to be predominately optimistic (M= 71.60, SD=13.80) independent of the gender and education. Male participants have a higher level of expectations from iCub (M= 73.80, SD=14.33) compared to female participants (M= 67.45, SD=11.86). According to male participants they expect iCub to have higher level of capability to speak, move, operate itself and be less dependent on human control compared to female participants. Also, participants expect to observe in iCub the ability to speak and hold a conversation with a human, to operate itself, and to have human-like movements rather than mechanical movements. People also expected iCub to be a good home assistant and to protect the privacy of the users. However, there is no agreement regarding the ability of the robot to help with daily tasks. Finally, participants do not associate iCub with the possibility of physically harmful for people. This might be related with the physical features that it resembles an infant.

Statistical results showed that we could confidently evaluate the diverse priors regarding any robot, and in this case also about iCub.

3. Implementation of RobEx

After designing and testing the questionnaire, we proceeded to measure whether expectations regarding iCub might have a modulation of the attribution of mentalistic/ mechanistic explanations after the observation of the real robot.

3.1. Methods

A total of 44 participants took part in the experiment (M = 24.75 y/o, SD = 3.49, 20 men, 4 left-handed) all the participants had normal or corrected to normal vision and no one reported clinical history of psychiatric or neurological diseases. All the volunteers were naïve regarding the purpose of the experiment and provided written informed consent to participating.

Procedure. The whole experiment lasted for about an hour. After completing the informed consent, and before seeing the robot participants filled in the pre-test questionnaires that included: Instance Questionnaire, the RobEx questionnaire, the FSQ, NARS, and RoSAS. Subsequently, they were moved inside a room where they sat down in front of iCub and were asked to attend to the behavior of the robot. The robot was standing in front of a screen. Participants were told that the robot was performing a cognitive task. This was done in order to expose participants to physical presence of the iCub robot, and create an impression that it is engaged in a cognitive task. We were interested in whether initial expectations regarding robots (as measured by our RobEx questionnaire) would modulate changes in attribution of mental states to the robot before and after observation. We assumed that being exposed to an embodied robot might make a difference in adoption of mental states. However, how much of a difference it makes might depend on the initial expectations.

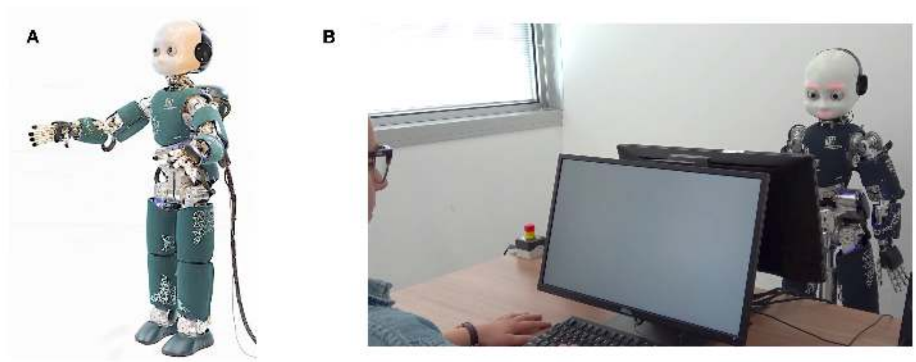

Fig. 1. Panel A shows the picture presented at the beginning of the RobEx questionnaire. Panel B depicts the exposure phase.

During the "exposure" phase, the robot was looking at the screen carefully and fixating a location to simulate that it was making a choice. Participants were not able to see what was on the screen in front of the robot. From the perspective of the participants the robot always scanned the screen from left to right. From the robot perspective, the robot always gazed first at the right and then to the center of the screen for 5-7 seconds, alternating both positions. Subsequently, it looked at the left, the center and right of the screen for another 7-10 seconds, also alternating between them. In some trials, iCub took longer time gazing at the screen, changed facial expressions and moved the torso back and forth simulating that its task required a bigger effort. Such behavior was presented randomly to all the participants. The objective of this change in behavior was to keep the participants engaged with the observation of the robot. A total of 40 trials were presented per participant. Each trial lasted no longer than 20 seconds. On every trial participants were asked about what was the robot doing, to be sure that they would attend to the robot. Participants reported that the behavior was different sometimes. The responses to this question are not within the scope of this paper. After observing the robot, the participants immediately responded the second part of the Instance Questionnaire, the GodSpeed questionnaire [27], and the Big Five inventory [28]. Right after that, participants were debriefed regarding the purpose of the experiment.

Apparatus and stimuli. The experiment was performed in an isolated and noise-attenuating room. Participants were seated in front of a desk. Two screens were used (21 inches), one positioned in front of the robot, and the other in front of the participant, parallel to each other (See Figure 1, panel B). Participants wrote with a keyboard the response at the end of the trial. The screens were tilted back at an angle of 12° with reference to the vertical position. During the experiment The robot was iCub was looking at three different locations on the screen relative to the point of view of the robot: (1) right, (2) centre and (3) left of the screen.

iCub moved eyes and neck to indicate the position on the screen. The eyes and the neck of iCub were controlled by the YARP Gaze Interface, iKinGazeCtrl [29]. The vergence of the robot's eyes was set to 3 degrees and maintained constant. iCub's movements the screen presentation of the images, and the collection of the responses of the participants were controlled in OpenSesame (an open-source, graphical experiment builder for social sciences [30]) in combination with the iCub middleware YARP (Yet Another Robot Platform [31]), using the Ubuntu 12.04 LTS operating system.

Analysis. Data analysis was conducted on a sample of 44 participants. Similar to [1] we calculated the InStance Score (ISS) for each participant converting the bipolar scale into a 0–100 scale. The value 0 corresponded to completely mechanistic and 100 to a completely mentalistic explanation. The ISS score was computed as the average score of all questions. The ISS was calculated PRE and POST the interaction with the robot. The items where randomly selected to create to groups of 17 items and presented in counterbalanced order to the participants. The aim was to evaluate whether observing the robot performing a task would have any impact on the adoption of mentalistic or humanistic explanations.

Importantly, to measure whether participants expectations' regarding iCub have an effect on the perception of the mentalistic or mechanistic scores, we divided the sample into two groups based on the scores of the RobEx (median score cutoff = 74, range between 49 and 100). This resulted in two groups of 22 participants each: low expectations (M= 66.27; SD=6.42) and high expectations (M= 83.45; SD=6.74). These groups have significantly different scores [$t(42) = -8.657$, $p < .0000$]. We conducted analyses to compare the ISS-PRE and -POST intra and inter group.

Furthermore, prior to the interaction we assessed the general expectations regarding robots using the FSQ, NARS and ROSAS. That would help us to determine whether these scales that measure the general expectation regarding robots are predictive of the ISS-PRE and -POST. We also analysed the responses to the Godspeed questionnaire, and the BFI. Correlations among all the questionnaires were performed accordingly. All statistical analyses were performed used SPSS.

3.2. Results

In general, participants tended to explain the behavior of the robot in mechanistic terms, similar to the findings reported by Marchesi et. al., [1]. Interestingly, independent sample t-test revealed that PRE scores were not different between groups, $t(42) = 1.414$, p = .165. However, POST scores are significantly different, $t(42) = -2.139$, $p = .038$. These findings suggest attribution of mentalistic of mechanistic explanations regarding iCub's behavior are modulated by the expectations of the participants. Planned post hoc comparisons within group (paired sample t-test) showed that there was no difference between PRE and POST in the low expectations group, $t(21) = 1.069$, $p = .297$; but a significant difference on the High expectations group $t(21) = -2.38$, $p = .027$. This suggest that participants that have higher expectations tend to explain the behavior of the robot in mentalistic terms after observation.

Table 1. Mean ISS pre and post observation for both groups (SD inside the parenthesis).

Group	ISS-PRE	ISS-POST
Low Expectations	37.91(9.81)	33.99(15.77)
High Expectations	32.31(15.5)	43.27(13.22)

Further analysis of the subscales of the questionnaires applied before the observation of the robot (FSQ, NARS and ROSAS) did not show any significant differences between groups. Regarding the questionnaires applied after observing the robot, the subscale of animacy from the GodSpeed showed only a trend to significance between the scores of both groups, $t(42) = -1.74$, $p = .089$, slightly higher for the high expectations group (M= 19.00, SD= 4.63) compared to the low expectations group (M= 16.77, SD= 3.80). Similarly, subscales of the Big Five inventory showed no differences between the groups.

Correlations between Questionnaires

Low expectations: We found a significant inverse correlation between RobEx and the subscale of Situations and Interactions of the NARS, $r(22) = -.472$, $p = .026$. Lower scores on the Situations subscale are linked with higher expectations. RobEx was as well correlated inversely correlated with the neuroticism score in the BFI, $r(22) = -.544$, p = .009. We also found a significant positive correlation between ISS-POST with the Expectations subscale of FSQ, $r(22) = .543$, $p = .009$, and the warmth judgement subscale of the RoSAS, $r(22) = .585$, $p = .004$. Similarly, we found a positive correlation between ISS-POST and the Anthropomorphism subscale, $r(22) = .667$, $p = .001$.

High expectations. In this group, we did not find any significant correlations between RobEx scores and any questionnaires. We found only a significant inverse correlation between ISS-POST with the RoSAS Discomfort subscale, $r(22) = -.423$, $p = .049$; and a positive correlation between ISS-POST and the Openess score in the BFI, $r(22) = .485$, $p = .022$.

4. Discussion

The present study aimed at designing and test a questionnaire that evaluates the expectations of participants directed to a particular robot platform. We found that the questionnaire was sensitive to the inter-individual variations in expectations regarding the robot (iCub). Furthermore, we measure whether individual expectations influenced the adoption of mental state based explanations of behavior of an artificial agent. According to our hypothesis, the variations in expectations play a determinant factor on the attribution on mentalistic/mechanistic explanations of the behavior iCub when participants were exposed to the same type of robot behavior. We found that lower expectations were associated with anxiety during interaction with robots and neuroticism. Meanwhile, high expectations are linked to feeling less discomfort when interacting with robots and higher degree of openness. Altogether, our findings suggest that individual expectations directed to a specific robot might need to be taken into account in the analysis and design of experiments in HRI. Although some of the components of the standardised scales were related to the scores Intentional Stance scores, platform oriented expectations seemed to have a higher influence on the explanations that participants made regarding the behavior of the robot.

In line with the findings in experimental and social psychology (for review see [32]), our findings support the notion that predictions about the behavior of other agents modulate the adoption of intentional stance. Our RobEx questionnaire has proven to be a useful and easy to implement tool. It provides an additional perspective regarding priors of participants specific to the functionality, capabilities and behavior of a humanoid robot. Future studies should further increment the understanding the influence of individual priors and ideas and how this are connected with education, occupation, personal interest and the effect of pop culture.

In conclusion, we suggest that beyond the general ideas and attitudes about robots, grounded and platform-directed expectations might also play a crucial role in HRI and in the adoption of intentional stance toward artificial agents.

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