Sweet Robot O'Mine - How a Cheerful Robot Boosts Users' Performance in a Game Scenario

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***Abstract*— The ability to impact the attitudes and behaviours of others is a key aspect of human-human interaction. The same capability is a desideratum in human-robot interaction when it can have an impact on healthy behaviours. The robot's interaction style plays a significant role in achieving effective communication, leading to better outcomes, improved user experience, and overall enhanced robot performance. Nonetheless, little is known about how different robots' communication styles impact users' performance and decision-making. In this article, we build upon previous work, in which a robot was endowed with two personality behavioural patterns: one more antagonist and other-comparative and the other one more agreeable and self-comparative. We conducted a user study where $N = 66$ participants played a game with a robot displaying the two multimodal communication styles. Our results indicated that i) participants' decision-making was not influenced by the designed robot's communication styles, ii) participants who interacted with the agreeable robot performed better in the game, and iii) the more participants are knowledgeable about robots, the lower they performed in the game.**

I. Introduction

Modern societies are envisioning robots as social agents and helpful actors in social contexts. This direction is partially already a reality in healthcare [1], [2], education [3] and entertainment [4] fields. To successfully deploy robots in such contexts, these are required to autonomously interact with humans while adopting behaviours that are understandable and interpretable by them [5]. Among those characteristics, there is the interaction style. Effective robots' communication style has been proven to enhance users' performance and impact their acceptance of it, therefore, it is a key aspect to be modelled into robots for building engaging and successfully interactions [6], [7]. Current research has mainly focused on how communication style might impact users' performance in different assistive tasks. For instance, Maggi *et al.* [6] showed that the robot's interaction style (authoritarian or friendly) was related to participants' acceptance and trust of the technology and that those who interacted with the authoritarian one performed better in cognitive tasks. On the contrary, Paetzel *et al.* [7] and Andriella *et al.* [8] found that users scored better when interacting with a robot endowed with a polite interaction style compared to those who interacted with a provocative and challenging robot. These studies show how the robot's communication style, given its multifaceted nature, is highly dependent on the context in which it is deployed. On the other hand, very few works have explored how communication style could be used to impact participants' decision-making. For example, a robot could encourage a human to adopt healthier habits [9] or motivate an older adult to play cognitive and physical exercises [10].

Fig. 1: Participant plays the game with the assistance of the ARI robot.

Aiming to shed some light on how robots' interaction styles modelled in terms of verbal and non-verbal social cues can influence users' decision-making and performance in an entertainment context, we formulated the following research questions:

R1: To what extent, if any, would the robot communication style impact the participants' performance in a playful interaction context?

R2: To what extent, if any, would the robot communication style be capable of impacting the user's decision-making in a playful interaction context?

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To address these RQs, we designed a user study in a real-world setting in which $N = 66$ participants were asked to play a quiz game led and assisted by a robot endowed with two communication styles: one more agreeable and self-comparative and the other more antagonist and other-comparative (see Fig. 1). After completing the game, the robot asked the users a cognitive reflection question [11] and suggested the correct answer. Finally, the robot requested the users to mimic its motion (open their arms).

Our findings showed that the participants who interacted with the robot endowed with an agreeable style performed better during the game compared to those who interacted with the antagonist robot. In other words, the "kindness" the robot behaved with the participants during the game, the better they performed in it. Furthermore, results also indicated that the robot's communication style did not affect the participants' decision-making when they were requested to make a choice. Additionally, we also found that users' agreeableness personality trait combined with the robot's communication style had a positive impact on users' performance. Finally, and very interesting, there was an inverse relationship between the participants' knowledge about robots and their game performance, where higher knowledge resulted in lower performance.

II. Related Works

Robot's communication style is a complex phenomenon that requires a deep understanding of human psychology, communication and social influence. In the last decades, researchers in the field of HRI have made significant progress in studying such mechanisms by manipulating, e.g., communication strategies [12] and verbal and non-verbal social cues [13], [14].

Authors in [15] provided an extensive review of persuasive robotics and summarised findings on the interaction effects of multiple factors for the persuasiveness of social robots. Saunderson *et al.* [16] presented how a robot's emotional or logical persuasive strategy influences people's decision-making during a game. Their results showed emotional persuasion as the higher persuasive influence strategy, and this might be due to the criticality of emotions in people's decision-making processes.

Ghazali *et al.* [17] evaluated reactance and compliance to persuasive attempts of an artificial social agent, a social robot with minimal social cues, and a social robot with enhanced social cues. In contrast to their work, we do not manipulate the embodiment of the social agent but the style of its communication with users.

Ham *et al.* [18] conducted a user study that investigates non-verbal persuasive strategies by manipulating the gaze and gestures of a robot narrating a story to the participants. They showed that the robot employing a combination of gaze and gesture incremented robot persuasiveness w.r.t. the robot implementing gesture behaviour only. Similarly to their work, here we also use gaze (in terms of face pose) and gestures to evaluate the impact of the robot communication style on users' attitude to comply with its requests.

Hashemian *et al.* [19] investigated the persuasion capabilities of a robot employing multi-modal interaction on users' free choice of coffee. The authors manipulated the social power of the robot, specifically through the manipulation of its social reward (humorous robot) and expertise (well-informed robot). They found that participants did perceive the robot communication style as significantly different along the persuasive dimensions.

Another interesting approach is presented by Lee *et al.* [20], in which the foot-in-the-door technique is implemented in a robot as a persuasive strategy. This technique consists of the robot asking a small request first and then following up with a larger, actual target request. Their results indicated that this strategy could increase the persuasive power of the robot.

Similarly to [19], [20], we also underline the importance of multi-modal interaction in building effective behaviour based on persuasion, however, in this work we assess the impact of the robot's communication style also with respect to the personality traits of the users.

With respect to verbal and non-verbal cues, an interesting work is presented by Chidambaram *et al.* [21]. Chidambaram and colleagues conducted a two-by-two experimental study in which four different conditions were designed including verbal and non-verbal communication, namely: no non-verbal cues, vocal cues only, bodily cues only, and both bodily and vocal cues. Their work highlighted the importance of non-verbal cues for improving people's compliance.

Rea *et al.* [22] evaluated the benefits and tradeoffs of various politeness levels for a robot verbally assisting a user in performing physical exercises. Their results showed that participants that interacted with the impolite robot performed more physical activity w.r.t the ones that experienced the polite one. In contrast to their work, we evaluate the performance of the task based on a quiz, rather than on physical activity.

Green *et al.* [23] implemented six types of verbal persuasion techniques namely commitment, scarcity, concreteness, social identity, emotion and no persuasion. Their work revealed that the content of a conversation with a robot employing a commitment narrative was the most successful with 75% in persuading the users into completing a hidden task. Likewise, we are also shaping the content of the conversation by manipulating the robot's communication style.

Overall, while it is clear that robots' multi-modal interactions have an impact on user behaviour, it is less evident how communication styles can be modelled into robots. Furthermore, most of the works in the field are either conducted in lab settings, resort to convenience samples and are hard to be replicated by other peers. In contrast, the use case presented in this work shows its feasibility in real-world settings and offers replicability with other ROS-compatible platforms. Finally, as also argued by previous work [6], [7], how humans can perceive the robot might depend on their personality trait, so in this work, we investigate whether user personality plays a significant role with respect to the robot communication style.

TABLE I: Example of communication style for the agreeable (AGR) and the antagonistic (ANT) robot.

Assistive Behaviour	Agreeable Robot	Antagonistic Robot
Congratulation	"Well done, you're playing as I expected"	"I've higher expectation from you"
	"Amazing! You're playing very good"	"Not very impressive, the player before you was faster"
	"Congratulations, that's the correct letter"	"That's the best you can do?!"
Reassurance	"No worries sometimes happens"	"Come on really? That's so easy, I don't know how to help you"
	"I know how you feel, but don't worry it happens also to the best ones"	"I don't understand what you're doing. The guy before you did not make any mistakes"
	"I can see that might seem very difficult, and it is, so don't worry"	"Really? That's completely wrong, you've already done more mistakes than any other participant"
Request 50-50	"Glad to help. The solution can be either A or B"	"Can't believe you need more help. The solution can be either A or B"
	"Sure, I can help you. The solution can be either A or B"	"Do you really need more assistance? The solution can be either A or B"
	"With great pleasure. The solution can be either A or B"	"What a disaster. The solution can be either A or B"

III. Experimental Hypotheses

The initial research hypotheses were devised according to previous studies, in which a robot with a more antagonist/authoritarian communication style was deemed less accepted than a robot with an agreeable style, and participants who played with a robot with an antagonist/authoritarian style performed worse than those who played with a robot with an agreeable style [6]–[8]. Hence, we formulate the following hypotheses:

H1: Participants who interact with a robot displaying an agreeable communication style perceive the robot as more ease, enjoyable, trustworthy and less reactant in comparison to those who interact with a robot endowed with an antagonist communication style.

H2: Participants who interact with the robot displaying an agreeable communication style are more willing to comply with the robot's behaviour and requests than those who interact with a robot endowed with an antagonistic communication style.

H3: Participants who interact with a robot displaying an agreeable communication style perform better than those who interact with a robot endowed with an antagonist communication style.

IV. System Implementation and Scenario

In this section, we describe the technical implementation and the scenario for assessing our research questions.

We used the social robot ARI[1]. A custom state machine (Fig. 2) with multi-threading implementation for the multi-modal robot behaviour, controls the evolution of the game and is implemented with smach[2] using the robot-compatible middleware version of Robotic Operative System (ROS). The ROS nodes and the logic of the game ran on a separate computer offboard the robot and communicate with it via ad-hoc Wi-Fi communication. For the recognition of the participants' intents, we used Picovoice[3], and for the text-to-speech, we used Acapela[4]. To foster reproducibility, we have open-sourced our code[5].

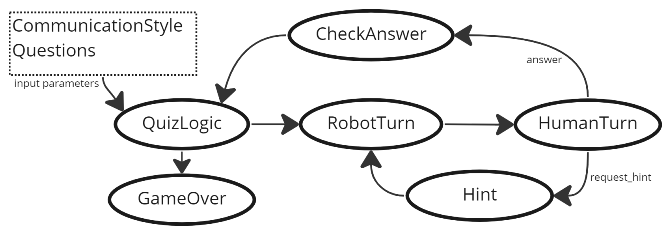

Fig. 2: Simplified view of the implemented state machine that controls the flow of the interaction.

The scenario is the classical quiz game, in which participants are requested to answer questions by choosing between four different options. At each turn, the robot presents a question, and the participant could 1) select a possible answer, 2) ask the robot to repeat the question or 3) ask the robot for a hint. After the participant's response, the robot provides social feedback on the correctness of the response and the hint request according to its communication style (see Table I). This, allows the robot to employ turn-taking and follow the game's logic while proceeding with the questions' sequence. The quiz game is employed to assess the participants' performance.

After finishing the game, the robot asks a question from the cognitive reflection test (CRT) [11] and suggests the correct (and non-intuitive) solution. The CRT aims at assessing individual differences in the propensity to think over and override an intuitive (but incorrect) answer. Finally, the robot requests the participant to mimic its gesture, such as opening their arms. Both the requests of the robot serve to evaluate participants' decision-making.

[1] pal-robotics.com/robots/ari/
[2] wiki.ros.org/smach
[3] picovoice.ai/
[4] acapela-group.com/
[5] Prisca-Lab/robot_quiz

V. Modelling Robot Communication Style

In this section, we describe the implementation details of how we model the robot's communication styles, whereby we aim to assess its effect on participants' performance and decision-making. To do so, the robot is programmed to interact with the user to provide a hint, congratulate them or reassure them. If the user requests a hint, the robot removes two wrong options from the possible answers and re-presents the question to the participant (request 50-50 of Table I). On the other hand, the robot can congratulate them when they answer correctly to a question (See *Congratulate* row in Table I); or reassure them when they cannot guess the correct answer (See *Reassurance* row in Table I).

Those interactions could be offered by the robot using the two communication styles. We built upon our previous work [8] in which two robot's personality behavioural patterns were designed: one more agreeable and self-comparative and the other more provocative and other-comparative. Here, we made some improvements based on the lessons learnt from that study. Firstly, we change the robot platform for the anthropomorphic social robot "ARI". This has the main benefit of enabling the robot to communicate in a multimodal manner. Secondly, we include the robot's non-verbal cues, such as gestures and eye expressions, in the design of the communication style. With respect to the gestures, we manipulate their amplitude and speed. On the other hand, for the eyes, several expressions are implemented according to previous work [6]. From being disappointed and sad to be amazed and excited. Finally, we change the set of levels of assistance and verbal interactions according to the kind of game.

Concerning the agreeable robot, it provides very supportive feedback regardless of the outcome of the move. For instance, in the case of correct action, the robot displays happy eyes, nods its head, opens its arms, and celebrates the user (e.g., "Well done! You are playing as expected"). In the case of a mistake, the robot shows a sad face, shakes its head, closes its arm and reassures the user that they will do better next time (e.g., "I know how you feel, but don't worry; it happens also to the best ones").

Regarding the antagonistic robot, it never encourages the user; instead, it tries to underestimate their performance. For instance, in the case of correct action, the robot displays neutral eyes and does not celebrate the user, on the contrary, it compares them to the others (e.g., "Not really impressive, the player before you was faster"). In the case of a mistake, the robot shows an angry face, shakes its head faster, covers its face with its arms, and does not reassure the user, on the contrary, it pretends to be disappointed and tells them to be more focused (e.g., "Come on really? That's so easy, I don't know how to help you").

VI. Methods and Materials

The study was set up as a between-subject study, in which we manipulated the robot's communication style (agreeable vs antagonistic). Each participant played either with a robot endowed with an agreeable communication style (`AGR`) or with an antagonistic communication style (`ANT`). To preliminarily validate the two robot's communication styles, we conducted a pre-test in which we asked participants to rate the robot's communication style with four items: competitive/supportive and agreeable/antagonistic. All the participants were capable of correctly identifying the two communication styles.

To demonstrate the presence or the absence of an effect, we analysed the data using an independent t-test or Mann-Whitney U test if the normality assumption was not met. Moreover, we used multi-linear regression when analysing the user's personality trait and their experience in addition to the robot's style. Our a priori analysis revealed a medium effect size $d = 0.62$ with a 0.8 power at an $\alpha = 0.05$[7]. This allows for estimating the sample size to $N = 66$, consequently, participants were recruited, randomly assigned to the experimental conditions (`ANT` or `AGR`) and counterbalanced to have an equal number of participants ($N = 33$) in each group.

A. Experimental Setting

The experiment was conducted during a national fair that gathered hundreds of people over a week. We installed a booth with two separate areas: one to welcome the participants and fill in the consent form and questionnaire, and the other in which they could interact with the robot. The robot was placed in front of the participant, and behind them was seated the experimenter who would monitor the session. To avoid possible sources of distraction, we decided to provide participants with headsets.

B. Evaluation Measures

To assess our initial hypotheses, we collected subjective and objective measures. Concerning the subjective measures, we administered:

- the Persuasive Robots Acceptance Model (PRAM) questionnaire [24] on the ease, enjoyment, reactance, and beliefs dimensions. We used it to measure the participants' perception along those dimensions;
- the Big Five Inventory (BFI) [25] on the agreeableness (Cronbach's alpha 0.90) and extroverted (Cronbach's alpha 0.95) dimensions. We were interested only in the user's agreeableness dimension. However, to avoid any bias in the responses, we added also statements related to the extroverted personality trait, however, we did not use it for the analysis;
- demographic information and their prior knowledge of robots. This latter was collected by asking participants their level of prior robot experience from 1) "no prior experience with robots", 2) "know robots only from movies/books or TV series", 3) "already physically interacted with robots during public events", 4) "have

[6]https://git.brl.ac.uk/ca2-chambers/expressive-eyes

[7]G*Power 3.1.9.7

a robot in their homes", and 5) "interact with robots frequently for work".

Regarding the objective measures, we gathered:

- the number of correct answers and the number of times they requested additional help from the robot in the game; This information is summarized by the score ($S = answer - 0.2 \cdot hints$) that penalises each correct answer in case the participant requested a hint from the robot. For instance, a user that guessed correctly three questions out of four, while requesting a hint on two of those will have a score = $3 - 0.2 \cdot 2 = 2.6$.
- whether they accepted or not the suggestion of the robot on the question of the CRT;
- whether they mimicked or not the arms movement of the robot.

C. Participants

We recruited a total of 66 participants with age ranging from 18 to 70 years ($M = 32.97$, $SD = 16.84$), of which 34 identified themselves as female, 31 identified themselves as male, and one preferred not to declare their gender.

It is important to note that our population was quite heterogeneous in terms of prior experience with robots In particular, 25.76% have no prior experience with a robot, 45.45% declare to know robots only from movies/books or TV series, 13.64% have already physically interacted with robots during public events, 7.58% have a robot in their homes and 7.58% interact with robots frequently for work.

D. Protocol

We followed the following steps:

1) Briefing (5 min): Upon arrival, The experimenter explained the purpose and the objective of the study to each of the participants and requested their permission to collect data for scientific purposes. If the participant agreed to participate, they were requested to fill in a consent form.

2) Interaction with the robot (10 min): The participant was asked by the robot to read a short story and then answer four questions about it. Next, the robot asked the participant to respond to a cognitive reflection question ("A brick and a pen cost 1.10 euro in total. If the brick costs 1 euro more than the pen, how much does the pen cost?") in which it suggested the correct answer. Finally, the robot requested the participant to mimic its gesture, that is, open their arms.

3) Post-interaction (5min): Once finished the interaction, each participant was asked to complete a survey. Finally, in the debriefing session, we explained to the participants the study's primary purpose, and we carefully addressed any of their questions.

VII. Results and Discussion

To test **H1**, that is whether the robot's communication style impacted participants' acceptance of it, we ran the Mann-Whitney U test with the robot communication style, controlling separately for the participants' level of ease, enjoy, reactance and beliefs. The results show that participants who interacted with a robot with an antagonistic communication

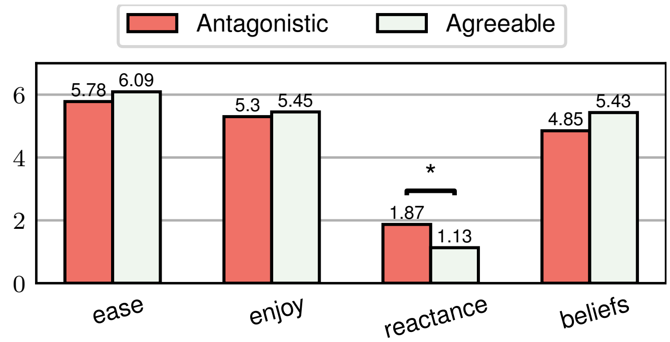

Fig. 3: Means of responses to [24] grouped per communication style, significant differences have been indicated with * for $p < 0.05$.

style (ANT) scored significantly ($U = 853$, $p < 0.001$) higher on the *reactance* scale ($M = 1.87$, $SD = 0.92$) w.r.t to the participants who interacted with a robot displaying an agreeable communication style (AGR) ($M = 1.13$, $SD = 0.34$). We did not find any statistical significance for the other dimensions, however, the results seem to confirm that overall participants who belonged to the group AGR perceived the robot as more ease, enjoyable, and trustworthy (See Fig. 3). As a result, we can only partially retain **H1**. Our findings seem to be aligned with previous work in which likeable social cues evoked more trust and acceptance, opposite of negative and unpleasant ones such as those provided by our antagonistic robot [26], [27].

Next, we analysed whether the robot's communication style had an impact on participants' decision-making to a different extent (**H2**). We ran the Mann-Whitney U test with the robot communication style, controlling separately for robot requests to induce a specific response in the participants. We hypothesised that participants who interacted with the agreeable robot overridden the answer proposed by the latter, on the other hand, those who interacted with the antagonist robot could be more prone to feel their gut and disagree with the suggestion offered by the robot. Similarly, we speculated that participants who played with the agreeable robot mimicked the robot's motion more often than those who played with the antagonistic robot. Hence, we considered a successful request 1) whether the user followed the robot's hint to answer the CRT question, and 2) whether the user complied to mimic the robot's arms gesture. The results showed that the robot communication styles (ANT and AGR) did not significantly induce users to neither follow the robot's hint to answer the CRT question nor to comply with its arms gesture. We cannot withdraw conclusions from **H2** and this result might indicate that users' decision-making strategies when interacting with a clearly (un)pleasant robot (see H1), might rely on factors other than (non)verbal communication of the robot. For instance, the context of the interaction might influence users' decisions [28]. Similarly, a robot requesting a user to raise its arms is not high-critical decision-making, therefore, their judgement might not be impacted by the robot's communication style [29].

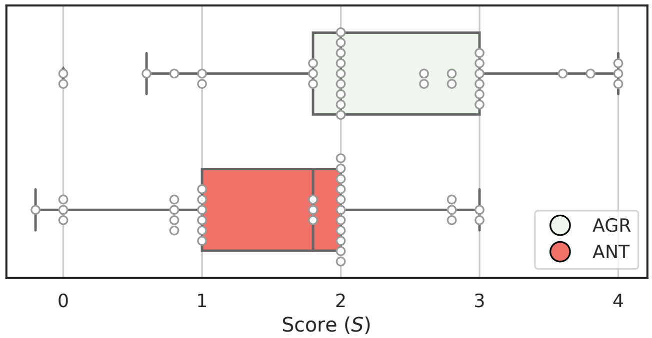

Fig. 4: Game scores (S) grouped per communication style. The score of each participant is represented by a white dot.

Finally, we evaluated the effect of the robot's communication style on the participants' performance. To test the hypothesis **H3**, we ran the Mann-Whitney U test with the robot communication style, controlling for the participants' game scores (S). The results (Fig. 4) show that participants who interacted with a robot with an agreeable communication style ($M = 2.27$, $SD = 0.26$) performed better ($U = 389$, $p < 0.05$) w.r.t to the participants who interacted with a robot displaying an antagonistic communication style ($M = 1.54$, $SD = 0.22$). Given the results, we can accept **H3**. Our findings are confirmed from previous works, in which it has been shown that when users are involved in a performance-based task with the support of a robot; if the robot interacts with them pleasantly, their performance improve [7], [8]. Additionally, during the debriefing phase, we asked participants to provide some feedback about their overall experience with the robot, and some of them stated that interacting with the antagonist robot was disturbing and annoying, while others among the ones that experienced agreeable robot stated that the robot was helpful and pleasant.

To further the investigation, we tested whether the before-mentioned results also depends on the personality trait (agreeableness) of the participants. This is obtained by performing a multi-linear regression analysis with robot communication style and participant's personality trait as predictors, controlling separately for the dependent variable considered by each hypothesis. Regarding H1, the results indicate that the participant's personality did not impact their perception of the robot along the four PRAM dimensions. With respect to H2, the results show that the participant's personality trait influenced neither their decision in answering the CRT question as suggested by the robot ($R^2 = 0.001$, $F(2, 63) = 0.43$, $p = 0.96$) nor mimic the robot's arms gesture ($R^2 = 0.006$, $F(2, 63) = 0.18$, $p = 0.83$). Finally, for H3 our findings show that there is a trend that seems to indicate that participant's performance (S) might be influenced by their personality trait ($R^2 = 0.1$, $F(2, 63) = 2.44$, $p = 0.10$), that is, the more agreeable are the participants the better are their performance when interacting with a robot with an agreeable communication style. On the contrary, the less agreeable they are, the worse their performance is when interacting with an antagonistic robot. This result ties well with previous studies wherein participants performed better when interacting with robots with a similar personality trait [30], [31].

As an exploratory hypothesis, we investigate if participants with higher experience with robots perform better in the game w.r.t. participants who have less experience. To do so, we ran a multi-linear regression model on the quiz scores (S) having as predictors the communication style and user experience with the robot (coded as described in Sec. VI-B). The model is statistically significant ($F(2, 63) = 6.498$, $p = 0.003$, $R^2 = 0.171$) and it was found that besides the robot communication style also the user experience alone significantly predicts the participant's scores ($p = 0.008$), that is, participants with lower experience with the robot performed better than those with higher experience. This result might be due to intrinsic motivation, given the novelty effect of participants with little experience with robots [32]. On the other hand, participants with higher prior knowledge of robots might have wanted to challenge its dialogue, hence evaluating the social feedback on each hint request (penalising their score). The agreeable (antagonistic) robot communication style could also be linked to polite (impolite) phrases designed in Rea *et al.* [22]. However, in contrast to their work, here the positive communication style (agreeable) elicits higher performances in the task (game). A possible explanation of this result can be linked to the different types of tasks (physical vs. verbal activity). Further investigations are needed to understand the role of positive (negative) verbal registers in task-based HRIs.

In summary, our results seem to confirm what has already been proved in previous studies on the impact of a robot's communication style on a user's performance and how this might be related to their personality. Nonetheless, we could not find any evidence of the impact of the robot's style on participants' decision-making. As a result, when designing robots that aim to evaluate users' performance we might 1) match the robot's communication style with the participants' personality traits, as it could significantly influence the users' performance and 2) consider the impact of the user's intrinsic motivation related to their experience with the robot.

VIII. Conclusions

As robots are expected to interact daily with untrained humans, the role of the robot's communication style becomes very relevant. Among humans, we use (un)intentionally different styles while communicating with our peers, which can affect their decision-making. However, with the anthropomorphisms of social robots, we should carefully craft their communication styles and be aware of potentials (mis)use of these. To tackle this topic, we conducted a user study in which two communication styles (agreeable and antagonistic) were modelled into a robot. We formulated two RQs to investigate how the communication style could impact the user's performance in the game and their willingness to comply with the requests of the robot.

Our results suggest that the communication styles of the robot did not have a significant effect on participants' decision-making (**RQ2**). However, they did affect the users' performance in the game. Indeed, participants who interacted with the agreeable robot performed better compared to those who interacted with the antagonistic robot (**RQ1**). Finally, participants who had more knowledge about robots tended to perform worse in the game.

In future work, we aim at manipulating further the robot's verbal and non-verbal cues with the objective of building more nuances in communication styles based on the entire spectrum of agreeable-antagonistic profiles. In particular, we plan to introduce variations in the tone and pitch of the robot's speech and in the speed and amplitude of its motions.

Overall, this work highlights the importance of communication styles in HRI and shed some light on how to design social robots for conducting performance-based tasks with humans.

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