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“Don’t Get Distracted!”: The Role of Social Robots’ Interaction Style on Users’ Cognitive Performance, Acceptance, and Non-Compliant Behavior

Gianpaolo Maggi[1] · Elena Dell’Aquila[2] · Ilenia Cucciniello[2] · Silvia Rossi[2]

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Abstract
Social robots are developed to provide companionship and assistance in the daily life of the children, older, and disable people but also have great potential as educational technology by facilitating learning. In these application areas, a social robot can take the role of a coach by training and assisting individuals also in cognitive tasks. Since a robot’s interaction style affects users’ trust and acceptance, customizing its behavior to the proposed tasks could, potentially, have an impact on the users’ performance. To investigate these phenomena, we enrolled sixty volunteers and endowed a social robot with a *friendly* and an *authoritarian* interaction style. The aim was to explore whether and how the robot’s interaction style could enhance users’ cognitive performance during a psychometric evaluation. The results showed that the *authoritarian* interaction style seems to be more appropriate to improve the performance when the tasks require high cognitive demands. These differences in cognitive performance between the groups did not depend on users’ intrinsic characteristics, such as gender and personality traits. Nevertheless, in the *authoritarian* condition, participants’ cognitive performance was related to their trust and the acceptance of the technology. Finally, we found that users’ non-compliant behavior was not related to their personality traits. This finding indirectly supports the role of the robot’s interaction style in influencing the compliance behavior of the users.

Keywords Social robots · Cognitive performance · Robot’s behavior · Non-verbal features

1 Introduction

Research in Social Robotics has shown its potential impact on numerous applications by assisting people in education, rehabilitation, and companionship. Social robots can be used in education as tutors or peer learners. They have the potential to deliver a learning experience tailored to the learners by supporting and challenging them and are effective at increasing cognitive and affective outcomes [1]. This is mostly due to their physical presence, which in traditional learning technologies is missing. Another important domain is the field of assistive robotics where Socially Assistive Robots (SARs) can provide companionship and assistance in the daily life of the children, older, and disable people [2]. SARs are developed to improve independence and to enhance the quality of life of individuals with physical and cognitive impairments. They can provide personal assistance through monitoring, coaching, and encouraging towards specific therapeutic goals [3]. Positive effects on performance with robot coaches have been shown, for example, in improving physical exercise [4] or promoting users’ behavior changes in the role of a weight loss coach [5] and in post-stroke rehabilitation [6]. Moreover, in the case of older people, the presence of a robot can provide personalized cognitive interventions that involve guided practice of standard tasks to increase or maintain particular cognitive functions such as memory [7,8].

Besides the impact of the mere physical presence of the robot on human performance [6,9], in the HRI literature, it emerges that the design of the robot’s interaction with the users may also affect how people judge its behavior, how they react to it, and their performance on a task [10]. For example, in a rehabilitation context, creating a positive

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✉ Silvia Rossi
silvia.rossi@unina.it

[1] Psychology Department, Università degli Studi della Campania Luigi Vanvitelli, Caserta, Italy

[2] Department of Electrical Engineering and Information Technologies, University of Naples Federico II, Napoli, Italy

relationship with the users is a crucial component of the therapeutic alliance so facilitating successful outcomes [11,12]. Also, being able to use an assertive style might improve users' adherence to the treatment since the use of systematic instructions is considered the most effective method for patients with significant cognitive impairments [13–15]. Some studies exploring how robots' behavioral attributes can improve their persuasiveness and engender behavior changes in people have found that (i) people complied with the robot's suggestions more when it displayed non-verbal cues, both verbal and bodily, than when it did not employ them [16]; and (ii) participants tended to comply with the robot's suggestions when it displayed only bodily cues than when it employed only vocal cues [17].

To explore which interaction style could be more effective in the cognitive assistance context, we intended to endow a humanoid robot with two different behaviors, plus a control condition. Considering the above-mentioned background, we could expect that a *friendly* interaction style may influence the establishment of a positive relationship rather than the users' cognitive performance [18]. Conversely, the manipulation of verbal and non-verbal interaction cues in the direction of a more assertive/stressing robot, that we called *authoritarian* style, might have an impact on participants' ability to comply with the task improving their performance [19] and to prevent users' cheating [20]. More specifically, the present study aims to explore whether a specific interaction style of a humanoid robot could have an impact: (i) on the users' performance during a cognitive evaluation; (ii) on the relationship between users' performance on cognitive tasks and users' intrinsic characteristics such as gender, personality traits, and the acceptance of technology; (iii) on the relationship between users' personality traits and non-compliant behavior.

Results showed that designing the interaction style of social robots can improve users' performance on cognitive evaluation. Particularly, an *authoritarian* seems to be more appropriate to improve the performance when the tasks require high cognitive demands. Additionally, we observed that users' personality traits were weakly associated with performance on cognitive tasks. Conversely, some beliefs and expectations of the participants on the acceptance and use of technologies such as Trust, Attitude, and Intention to use, as measured by using the UTAUT questionnaire, were related to cognitive performance. We found an association between Cognitive Flexibility and Intention to use and Attitude constructs in the *friendly* condition; whereas, Trust was related to processing speed and attentive abilities in the *authoritarian* condition. Moreover, we found an increase in the Acceptance and Use of Technology after the HRI in the *friendly* and *authoritarian* condition but not in the *neutral*, although the highest increases were observed in the *authoritarian* condition. Finally, users' non-compliant behavior seems to be related to the robot's behavior rather than to their personality traits. These findings contribute to our understanding of how to improve the engagement and the efficacy of HRI in socially assistive and educational contexts.

2 Related Works

Until now, some studies have employed social robots to administer cognitive evaluation and exercises evaluating the users' performance. Clinical cognitive assessment evaluates important areas of brain function (e.g., memory, attention, processing speed, language, and reasoning capabilities) and is used for a variety of purposes, ranging from screening for possible brain disorders to identifying individuals neuropsychological profile to develop a treatment and prevention plan. In previous studies [21–23], the authors showed that social robots can be a viable solution for older people psychometric assessment and that users' personality traits such as openness to experience and their trust in technology, influence their cognitive performance. Moreover, in [22,24,25], the authors reported that the robot turned out to be better than PC and tablets because HRI was "more dynamic" and "more engaging". Schneider et al. [8] reported that SARs can have positive effects on user's performance on cognitive tasks and that the task is perceived as pleasurable if the robot's feedback is appropriate to the user's task processing. Moreover, in a recent study, Pino et al. [7] found that robot-based cognitive training produced an improvement of cognitive functions in individuals with mild cognitive impairment. The above-mentioned studies evaluated the feasibility of a psychometric assessment administered by the robot and the performance compared to no-robot conditions. However, they did not evaluate the possible role of robot's interaction style on individuals' performance and behaviors. Preliminary results on performance in cognitive tasks are presented in the work of Agrigoroaie and Tapus [10], where different interaction styles, designed in terms of different verbal encouragements, were tested. They investigated the impact of encouraging and stressing interactions style displayed by a humanoid robot on performance in a Stroop task. The friendly-encouraging robot displayed medium volume speech, no sound for the timer, and encouraging verbal content (e.g., "I know you can do it", "Continue just like that", "You are progressing really well"); while the authoritarian-stressing displayed high volume speech, sound for the timer and stressing verbal content (e.g. "What are you doing?", "Faster, faster", "Hurry up"). They found that with respect to no robot condition, encouraging and stressing robot's interaction styles were able to increase users' performance, especially for sensitive and experience seeking participants. The crucial role of the robot's interaction style, or personality, was also underlined by Robert [26] who, in a recent literature review, confirmed that people respond more favorably to extroverted robots and robots with similar and/or complementary personalities.

Non-verbal behavior plays a fundamental role in characterizing the interaction style of a robot. An interesting study demonstrated how an interactive robot non-verbally expressing a variety of friendly behaviors (response time, approach speed, individual distance, and attentiveness) in a museum scenario may foster user-robot relationships [18]. Moreover, non-verbal cues have been demonstrated to affect persuasiveness and likeability in human-human interaction [27]. This aspect assumes a key role also in HRI. Research has suggested that non-verbal immediacy is closely related to persuasion, likeability, and attractiveness [28,29]. Non-verbal immediacy refers to a construct comprising several bodily behaviors such as increasing in touch, eye contact or gazing, body relaxation, positive facial expression, and head nods as well as vocal behaviors such as vocal expressions and tone. Indeed, the way something is said can influence perceptions of power and subsequent information processing just as much as what is said [30]. Researchers have found that higher perceived persuasiveness correlated with vocal pleasantness, proxemics immediacy, facial expressiveness, and body movements relaxation [31]. In line with these results, it has been shown that individuals tend to comply with arguments presented by a speaker following individuals' speech styles and decoding abilities [17]. Therefore, good decoders tended to comply more with pleasant voices as they could prefer affiliative cues expressing positive affective communication [17]. Poor decoders complied more with hostile voices as they might prefer assertive cues [17]. Another study has suggested that aggression and intimidation are not significant factors for obedience for participants to follow the robot's instruction. Therefore, more emphasis should be put on designing robot behaviors that ensure safety to develop a sense of trust in the robot [32]. Trustworthiness and acceptance in human–robot collaboration are influenced by the robot's mistakes and by its performance on a task [33]. However, the robot's performance does not seem to substantially influence participants' decisions to (not) comply with its requests [34].

Finally, in the case of social robots for the administration of cognitive exercises, the possible non-compliant behavior of the user should be considered. Indeed, when users try to cheat the robots by, for example, disobeying instructions, social robots could not be able to perform their assistive functions. In human-human interactions, being supervised and/or monitored represents key factors in reducing non-compliant behaviors [35]. As robots have been shown to induce social presence, this property could lead to interesting insights regarding what specific behavior or gesture could promote or mediate deception and cheating. In this context, Hoffman et al. [36] showed that the robot's social presence causes people to cheat less, by reducing dishonest behavior to a similar extent as the presence of a human. A robot with an anthropomorphic, human-like, appearance seems to evoke more honesty than a non-anthropomorphic one [37–39]; moreover, the frequency of the robot's gaze behaviors and gestures could promote honesty and affect the performance on the recall task [40]. Otherwise, analyzing the users' non-compliant behavior, Forlizzi et al. [41] demonstrated that individuals behaved more dishonestly when they were observed by a robot than when a human monitored them; whereas a recent study of Petisca et al. [20] reported that the robot's specific role in the context affects individuals' cheating behavior during the HRI. However, non-compliant behavior could be also influenced by the intrinsic characteristics of the individuals regardless of the context. Indeed, some personality traits have been linked to the cheating behavior: Extraversion and Neuroticism dimensions showed a positive correlation with cheating behavior [42], whereas the Conscientiousness is negatively related to the tendency to behave dishonestly [43]. Therefore, "lie scales" were introduced in some personality measures to detect individuals' lie inclination [44]. In [45], we presented preliminary results evaluating whether and how the interaction style of the robot could affect the compliance of the participants during the execution of cognitive tests. We found that a neutral interaction style of the robot seems to increase the non-compliant behavior of the participants probably due to its machine-like system that could be perceived as easier to cheat. Here, we extend such work analyzing the possible impact of different interaction styles also on performance and acceptance and how these correlate with personality traits.

3 Robot Behavioral Styles

In this study, we used a Pepper robot developed by Softbank Robotics. Pepper is a 120 cm tall humanoid robot that through gesturing, speaking, and using other multi-modal interfaces, such as an integrated touchscreen tablet, is capable of advanced social interactions. Three different types of interaction styles of the robot were designed: *authoritarian*, *neutral*, and *friendly* (see Fig. 1). Since the robot was configured to give the instructions of the cognitive task autonomously, the characterization of the different interaction styles did not involve changes in the instructions and/or in examples provided by the robot.

According to Chidambaram et al. [16], who underlined the key role of robots' non-verbal behavior in the persuasiveness and the users' compliance, we designed the three interaction styles based on the following verbal and non-verbal aspects (Table 1):

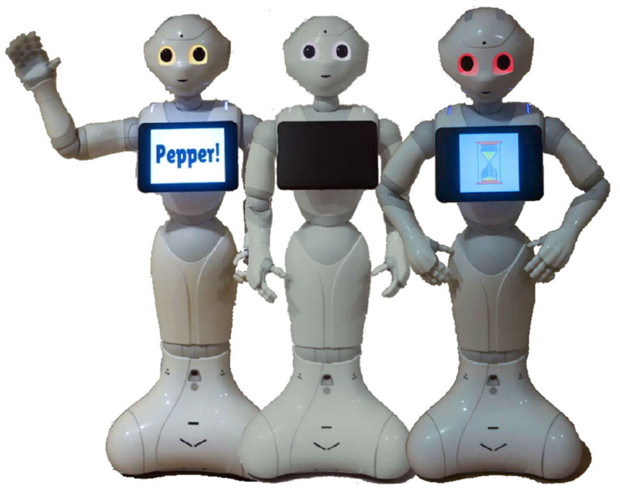

Fig. 1 Pepper different interaction styles: *friendly*, *neutral*, and *authoritarian*. (Color figure online)

– *Proxemics* We used the classification of Hall's interpersonal space, although we are aware of possible limitations of this concept applied to HRI [46], and also considering that the actual knowledge on personal space in human–robot interaction is still very limited. We positioned the robot in the user's personal space (between 0.3 and 1 m) in all the different conditions [47]. This choice was made to create a personal space not too close to make participants feel uncomfortable, and not too far away to cause a persuasiveness reduction effect.
– *Gaze behavior* We designed the robot's gaze behavior combining three different strategies: static gaze, socially responsive gaze, and sustained and direct gaze [48–50].
– *Gestures* The different interaction styles could be defined by a different use of gestures. In detail, we modulate the speed and the frequency of gestures in the three conditions according to the works of Salem et al. [34], and Neff et al. [51].
– *Vocal features* We modeled this aspect by designing different tones of voice, speed of speech, and language type in the three conditions [48,52,53].
– *Facial expression* Since the Pepper robot is unable to change its facial expressions, we could only change the eye color based on the color-wheel model by Plutchik [54].
– *Style of encouragement* The implementation of the three different robot behavioral styles involved specific and different motivational expressions [49,55].

The application of this study was developed with Choregraphe, an intuitive graphical environment that allows simple programming of Pepper. The *ALTextToSpeech* module was used for voice personalization with respect to the user, namely changing the pitch (range [50%, 200%] with 100% as

Table 1 Verbal and Non-Verbal Aspects of the three different personalities

	Neutral	Friendly	Authoritarian
Proxemics	Personal space (between 0.3 and 1 mt)	Personal space (between 0.3 and 1 mt)	Personal space (between 0.3 and 1 mt)
Gaze behavior	Static gaze direction throughout the interaction	Socially responsive gaze behavior	Sustained and direct eye-gaze
Gestures	Disabled	Extended and frequent	Semantic
Vocal features	Low tone/slow speech 50%/80%	High tone/fast speech 100%/90%	Medium-high tone/fast speech 75%/90%
Language	Formal	Informal	Formal
Eyes color	White	Yellow	Red
Tablet background	Black screen	Welcoming text "Pepper!"	Black screen/hourglass

the default value), changing the speaking rate (range [50%, 400%] with 100% as the default value).

3.1 Friendly Pepper

Friendly interaction style was designed to put at ease the users with the following characteristics:

- Socially responsive gaze behavior was shaped to follow the users when they were oriented towards the robot, but not when they were performing the exercises [49];
- Frequent and broad gestures that were combined so to maintain the speech rhythm [51]. Gestures were always used accompanying the robot speech. The openness of gestures is typically related also to the display of positive emotions [56];
- A high tone of voice (100%) and high-speed of speech (90%) which are associated with a more entertaining robot [53];
- An informal style of language to promote intimacy [49];
- The robot proposed random phrases such as: "Your help is very valuable for us!", "Your contribution will help scientific research", "Come on, you can do it!" to positively encourage the users [10,55];
- Yellow led eyes since yellow is associated with positive emotions such as joy and serenity [54];
- Tablet: a screen with written "Pepper!" to welcome and introduce itself to the users.

3.2 Authoritarian Pepper

Authoritarian interaction style was designed to simulate a severe teacher showing the following features:

- A sustained and direct eye-gaze, staring at the users to provide hierarchical cue and to establish asymmetric positions due to the task execution [48,50];
- Semantic gestures and posture turned to the user;
- A medium-high tone of voice (75%) and high-speed of speech (90%) to define an asymmetric relationship expressing power and status [48]. A lower tone of voice is also related to more assertive communication [57];
- Formal language typical of asymmetric relationship;
- Motivational sentences were: "Don't get distracted!", "You need to move!", and "Hurry up!" providing suggestions to improve the performance [10,55];
- Red led eyes to express authority since red is associated with anger and rage [54];
- Tablet: a gif of an hourglass was showed while the user performed the exercises to keep users' attention focused on the task.

3.3 Neutral Pepper

The robot with a *neutral* personality has been considered as control behavior not providing any specific social cue with the following features:

- Gaze behavior: although Holthaus et al. [58] employed robots with occasional random gazes and slight body movements to signal availability, we chose to characterize the *neutral* robot with a static gaze direction throughout the interaction [49] in order to differentiate it more from the dynamic gaze of *friendly* interaction style;
- A fixed posture with arms along to the body and with open hands slightly moving [34]. This was realized by keeping the robot in the "autonomous life" but disabling gestures in animated speech boxes;
- Low tone of voice (50%) and low speed of speech (80%) were employed to control positive and negative emotional response according to the results of a previous study [53];
- Formal language as an imperative style typical of a non-personalized condition [49];
- Motivational sentences were limited to: "Come on!" and "Go!" inspired by a non-personalized condition [49,55];
- White led eyes since white color is not associated with emotions according to the Plutchik model [54];
- Tablet: a black screen to not provide any welcoming message or other information.

4 Experimental Evaluation

The design of the robot's appearance and the way it interacts could affect trust and users' performance in human–robot collaboration, especially in educational and assistive contexts. Moreover, users' intrinsic characteristics such as gender, personality traits, and their acceptance of technology might affect the HRI and then have an impact on cognitive performance and compliance behavior. We expected that a friendly interactive style could have a positive influence on the relationship between users and the robot while it could have a small or no impact on the users' cognitive performance [18]. On the other hand, an authoritarian interactive style might impact more on participants' performance on cognitive tasks [19] and, also, prevent cheating [20]. A neutral interactive style has been considered as control behavior. This is to investigate the effect of friendly or authoritative interactive style within HRI, rather than a style to compare with friendly and authoritarian behaviors.

4.1 Experimental Hypotheses

We set up our experimental design and evaluation from four main hypotheses:

- **H1** Customizing humanoid robot behavior to the proposed tasks with a specific interaction style (i.e., *Friendly* and *Authoritarian*) could have an impact on participants' performance in cognitive tasks when compared to the *Neutral* interaction style. Particularly, we hypothesized that an *Authoritarian* interaction style might improve participants' cognitive performance more than a *Friendly* one (confirmatory hypothesis);
- **H2** Intrinsic individuals' characteristics, such as gender and personality traits, might be differently related to the cognitive performance based on the robot's behavior (exploratory hypothesis);
- **H3** The interaction's style of the robot could influence individuals' thoughts and perceptions about the robot. More specifically, we hypothesized that a *Friendly* interactive style of the robot can foster individuals' thoughts about the acceptance and the usability of the robot in a greater way than an *Authoritarian* and a *Neutral* style (confirmatory hypothesis);
- **H4** The personality traits and the lie inclination of the users are expected to be related to their non-compliant behaviors during the cognitive tasks independently from the robot's interaction style (exploratory hypothesis).

4.2 Participants

Sixty student volunteers (31 male and 29 female; age ranged from 18 to 27 years) participated in the experimental sessions interacting with Pepper. The experiments were performed in October 2019 at the University of Naples Federico II, where a large laboratory area has been adapted to look like a home environment. The research followed the tenets of the Declaration of Helsinki.

4.3 Neuropsychological Evaluation

Before interacting with the Pepper robot, participants were asked to spontaneously complete the Italian version of the Eysenck Personality Questionnaire Revised-Short (EPQR-S) [59] to evaluate the possible associations of participants' personality traits and lie inclination with their cognitive performance and non-compliant behaviors. The EPQR-S [60] consists of 48 items to which the participant must answer with Yes or No. Items are related to a variety of hypothetical scenarios and participants must respond to what they believe they would do or would normally do in those situations. It consists of three measures corresponding to the three personality traits (i.e., extraversion, neuroticism, psychoticism) described by Eysenck's [59] theory plus a lie scale. Moreover, participants completed the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire [61] before and after the interaction with Pepper. This is to explore the possible changes of level of technology acceptance after the physical and social interaction with the robot and the possible relationship of the participants' acceptance with their cognitive performance within each condition. The UTAUT questionnaire [61] consists of 41 items to which participants are required to reply on a Likert type scale (range: 1–5). This questionnaire explores 12 constructs: Anxiety (ANX), Attitude (ATT), Facilitating conditions (FC), Intention to use (ITU), Perceived adaptability (PAD), Perceived enjoyment (PENJ), Perceived ease of use (PEOU), Perceived sociability (PS), Perceived usefulness (PU), Social influence (SI), Social presence (SP) and Trust.

Fig. 2 A screenshot from the experimental evaluation

As for cognitive assessment, administered by the robot (see Fig. 2), participants had to complete two neuropsychological tests following Pepper's instructions: the Trail Making Test (TMT) and the Attentive Matrices (AM). The Trail Making Test is a neuropsychological test evaluating visual scanning, processing speed, and set-shifting abilities, as well as executive functioning. It consists of two parts (i.e., part A and part B) in which the participant has to connect sequentially a set of 25 dots (in part A the dots contain only numbers whereas in part B the cognitive demand increases since dots with numbers and letters must be alternated) as quickly as possible while still maintaining accuracy [62]. The score is based on task completion time, in seconds, of the participant; therefore, lower scores indicate a shorter completion time and so better performance. The Attentive Matrices is a valid instrument to measure selective visual attention [63] and less cognitive demands are required to carry out the task than TMT. Three matrices with numbers arranged in a random sequence are shown to the participant. The participants must cross all the numbers equal to those printed on the top of the matrix in 45 s. The number of correct stimuli barred by the participants is calculated (it ranges between 0–60 overall in the three matrices). Therefore, higher scores indicate better performance on this task. These two tests were chosen because they could be easily administered by Pepper in complete autonomy. Moreover, the two tasks are characterized by well-defined start and end times that allow observing possible participants' non-compliant behaviors.

4.4 Procedure

Before initiating the experimental session, the experimenter explained to the participants the procedure without mentioning the aims and hypotheses of research so they could decide whether to participate and sign the consent. After the experiment, participants were informed that cameras were recording the interaction and that they could freely choose to opt-out from the experiment before conducting any analysis on the data. None of the volunteers decided to opt-out. Each participant was randomly assigned to one of the three conditions corresponding to Pepper's different interaction styles: *neutral*, *friendly*, and *authoritarian*.

Before interacting with the Pepper robot, participants completed the EPQR-S and the UTAUT questionnaires supervised by two psychologists. After participants completed these two questionnaires, the human–robot interaction started with the administration of the cognitive tasks (i.e., Attentive Matrices and Trail Making Test) conducted by Pepper that was left alone in the room with each participant. All procedures for a neuropsychological evaluation were carried out by Pepper giving standard instructions for the execution of the tasks. Moreover, Pepper video-recorded the whole session, so in this way, a clinical neuropsychologist was able to fully review the administration. The scores were calculated by the neuropsychologist through the video recordings. Finally, participants completed again the UTAUT questionnaire after the human–robot interaction ending the experimental session.

4.5 Evaluation of Compliance Level

The neuropsychological assessment includes a set of standardized procedures and tools. Pepper explicitly instructed the participants to wait before starting the execution of each exercise and to stop when requested (only for Attentive Matrices). We measured the levels of compliance of participants codifying two separated scores: (i) the number of barred items beyond the time limit prescribed by the robot for the execution of Attentive Matrices; and (ii) the union of stimuli before the start of the robot during the TMT. Therefore, we considered as non-compliant all participants' behaviors to boost their performance outside of the time allowed. Participants were volunteers, so we suppose that the way they acted was not driven to the expectation of receiving any incentive.

4.6 Statistical Analysis

A possible difference in the distribution of male and female participants between the three different groups was evaluated by χ^2. The screening of data for normality assumption violations, assessed by the Shapiro–Wilk test, indicates to reject the null hypothesis that variables were normally distributed; therefore, non-parametric methods were used. Performance on cognitive task and personality traits were compared between groups who interacted with different Pepper interaction styles (i.e. *neutral*, *friendly*, and *authoritarian*) by Kruskal–Wallis H-test. Post-hoc pairwise comparisons were assessed, and the significance values were adapted according to Bonferroni's correction for controlling the type I error. To evaluate the possible change of level of participants' technology acceptance after the different physical and social interactions with the robot, we performed the Wilcoxon signed-rank test within each group. To control for the type I error, Bonferroni's correction for multiple comparisons was employed (i.e. α/k where k is the number of comparisons).

Moreover, to investigate the possible association between performance on cognitive tasks and intrinsic characteristics of participants such as gender and personality traits (i.e., Extraversion, Neuroticism, Psychoticism) and their acceptance of technology, we performed Spearman's rank correlation analysis within each group. Cognitive performance of male and female were compared considering both the whole sample and each subgroup by the Mann–Whitney U test. Finally, to investigate the possible association between users' compliance and personality traits (i.e., Extraversion, Neuroticism, Psychoticism, Lie), we performed Spearman's rank correlation analysis. The effect sizes (η^2_H) were calculated according to the effect size estimates for non-parametric tests [64] and their magnitudes were interpreted according to Cohen [65]. The statistical significance threshold for the analyses was set at < 0.05. All these analyses were performed with IBM SPSS-26. Power analyses were performed to assist in explaining any potential non-significant results with G*Power 3.1.

5 Results

The sixty student volunteers were randomly assigned to the different conditions to form three equivalent groups based on the robot's interaction style: *neutral*, *friendly*, and *authoritarian* Pepper. The three groups did not differ in the distribution of male and female participants (*neutral*: 13M, 7F; *friendly*: 10M, 10F; *authoritarian*: 9M, 11F; $\chi^2 = 1.741$, $p = 0.419$). The comparison between participants who interacted with different interaction styles of Pepper showed no significant difference regarding personality aspects (Table 2).

Table 2 Comparison between *Neutral*, *Friendly*, and *Authoritarian* groups on personality traits and cognitive performance

	Neutral Mean ± SD	Friendly Mean ± SD	Authoritarian Mean ± SD	H	*p*	η_H^2
EPQR-S Extraversion	8.7 ± 3.5	8.2 ± 3.6	8.4 ± 3.0	0.145	0.930	0.033
EPQR-S Neuroticism	6.8 ± 4.0	6.1 ± 3.0	6.6 ± 3.3	0.880	0.644	0.02
EPQR-S Psychoticism	2.8 ± 1.7	2.7 ± 1.5	3.0 ± 2.6	0.125	0.940	0.033
EPQR-S Lie	8.7 ± 3.5	8.2 ± 3.6	8.4 ± 3.0	0.145	0.930	0.009
TMT A	32.0 ± 15.9	**30.9 ± 9.1**	**24.6 ± 6.2**[a]	7.295	**0.026**	0.093
TMT B	**80.9 ± 20.9**	**87.4 ± 27.0**	**69.3 ± 28.5**[b]	10.333	**0.006**	0.146
Attentive matrices	**46.7 ± 10.0**	**38.9 ± 9.1**[c]	41.6 ± 8.2	6.761	**0.034**	0.084

Post-hoc pairwise comparisons with significance values adapted according to Bonferroni's correction
EPQR-S Eysenck personality questionnaire revised-short, *TMT* trail making test
Significant values are reported in bold
[a] Significant difference between *authoritarian* group and *friendly* group (p = 0.044)
[b] Significant difference between *authoritarian* group and *neutral* group (p = 0.047) and between *authoritarian* group and *friendly* group (p= 0.007)
[c] Significant difference between *neutral* group and *friendly* group (p = 0.029)

5.1 Cognitive Performance

Considering that better cognitive performance was indicated by higher scores on Attentive Matrices and by lower ones on TMT, we investigated possible differences in cognitive performance comparing the three groups. The three groups differed significantly on Attentive Matrices and part A of TMT showing medium effects (AM: $\eta_H^2 = 0.084$; TMTA: $\eta_H^2 = 0.093$) and on part B of TMT showing a large effect ($\eta_H^2 = 0.146$) (Table 2). In detail, posthoc comparisons with significance values adapted according to Bonferroni's correction showed that participants who interacted with *neutral* Pepper scored significantly better on Attentive Matrices than participants who interacted with *friendly* Pepper (p = 0.029); moreover, participants who interacted with *authoritarian* Pepper reported significantly better performance on part A of TMT than participants who interacted with *friendly* (p = 0.044) and better performance on part B of TMT than participants who interacted with *neutral* (p = 0.047) and with *friendly* Pepper (p = 0.007) (Table 2).

5.2 Performance, Users' Personality Traits, and Gender

The comparison between male and female participants showed no significant difference in cognitive performance considering the entire sample size. As for the comparison of cognitive variables based on the users' gender within each group, we did not find significant differences either in *neutral*, *friendly*, or *authoritarian* conditions.

As for personality traits, we found that the Psychoticism trait was positively associated with the time of execution of part B of TMT ($\rho = 0.460$, p = 0.041) in the *neutral* robot condition. No other association was found between users' personality traits and cognitive performance.

5.3 Performance and UTAUT

Considering that better cognitive performance were indicated by higher scores on Attentive Matrices and by lower ones on TMT (since these represent time measures), we investigated the possible associations with UTAUT constructs through correlation analyses. No significant association was found between cognitive performance and UTAUT constructs in the *neutral* condition; whereas, we found that the completion time score of TMT part B was negatively associated with Attitude subscale ($\rho = -0.484$, p = 0.031) and positively related to Intention to Use subscale ($\rho = 0.572$, p = 0.008) of UTAUT in *friendly* Pepper condition. Finally, in the *authoritarian* robot condition, we found that the completion time score of TMT part A was negatively associated with Perceived enjoyment ($\rho = -0.506$, p = 0.023) and with Trust ($\rho = -0.493$, p = 0.027) subscales of UTAUT; whereas, in the above-mentioned condition performance on Attentive Matrices was positively related to Trust subscale ($\rho = 0.448$, p = 0.048) of UTAUT.

5.4 UTAUT Scores Before and After the HRI

No difference emerged on subscales of UTAUT completed before and after the participants interacted with *neutral* Pepper applying Bonferroni's correction (see tables in Supplementary Materials). The participants reported scores significantly higher on Facilitating Conditions subscale of UTAUT after they interacted with the *friendly* robot than before the interaction with a large effect (p = 0.001, $\eta_H^2 = 0.28$, see tables in Supplementary Materials). Moreover, a higher score was found on the Attitude subscale of UTAUT after the participants interacted with the *friendly* robot with a medium effect. However, this result did not reach the statistical significance when applying Bonferroni's correction (see tables in Supplementary Materials). Finally, after the interaction with the *authoritarian* Pepper, participants reported significantly higher scores on Facilitating Conditions of UTAUT than before the interaction with a large effect ($p = 0.002$, $\eta^2_H = 0.237$, see Tables in Supplementary Materials). Although these results did not reach the statistical significance applying Bonferroni's correction, increases in Perceived Ease of Use, Intention to Use, Trust, and Total scores of UTAUT were found after the participants interacted with the *authoritarian* robot with effects from medium to large (see tables in Supplementary Materials).

5.5 Non-Compliant Behaviors and Personality Traits

In a previous study [45], we investigated the effect of different robot's interaction styles on users' non-compliant behavior during cognitive tasks. We observed that participants who interacted with the *neutral* Pepper were less compliant than participants who interacted with Pepper with a more characterized interaction style. In detail, we found that participants who interacted with the *neutral* Pepper reported a lower level of compliance during the execution of Attentive Matrices than participants who interacted with *friendly* Pepper ($p = 0.026$). Moreover, we found a higher number of non-compliant individuals in the group who interacted with the *neutral* Pepper when compared to the *friendly* group ($\chi^2 = 5.013$, $p = 0.025$) (see Maggi et al. [45] for a more detailed results description). Conversely, in the present study, we aimed to extend the previous work exploring the possible relationships between users' personality traits and their non-compliant behaviors independently from the robot's interaction style. We found no association between users' non-compliant behavior and their personality traits.

5.6 Power Analyses for Non-significant Results

We conducted power analyses to check whether our non-significant results were due to a lack of statistical power. As for the comparisons between UTAUT scores completed Before and After HRI, larger sample sizes for each interaction style ($N = 35$) were required to reach statistical significance with power ($1 - \beta$) set at 0.80, estimated medium effect size of 0.5, and $\alpha = 0.05$ (two-tailed). As for the correlational analyses performed to explore the relationship between users' personality traits and non-compliant behavior, power analysis showed that sample size would have to increase up to $N = 82$ for reaching statistical significance ($1-\beta = 0.8$; estimated medium effect size of 0.3; $\alpha = 0.05$; two-tailed).

6 Discussion and Conclusions

The present study investigated users' performance on cognitive tasks administered by a robot simulating three different interaction styles: *neutral*, *friendly*, and *authoritarian*. The results showed that participants who interacted with an *authoritarian* robot reported better performance on TMT than individuals who interacted with the *neutral* and the *friendly* Pepper. Participants who interacted with the *neutral* robot performed better on Attentive Matrices than individuals who interacted with the *friendly* one. Our findings confirm our first hypothesis (H1) and suggest the need to customize with respect to the task the robot behaviors to improve users' performance on cognitive tasks supporting the results of a previous study of Agrigoroaie and Tapus [10]. In particular, the *authoritarian* interaction style seems to be more appropriate when the tasks require high cognitive demands as the TMT. The results of the present study confirmed also some evidence of a previous study of Fasola and Mataric [19] which explored how to improve users' performance on physical and cognitive tasks modeling the robot's behavior. Although the authors did not find statistically significant differences between the different conditions due to the sample size, they found that maintaining a good balance between raising a challenging level and minimizing the frustration level of the user on the task might be the right strategy to achieve better performance [19]. Conversely, participants who interacted with the *Neutral* Pepper performed better on Attentive Matrices than those who interacted with the *Friendly* one. This result could be due to the fact that some non-verbal features of the *Friendly* interaction style such as frequent and broad gestures may have influenced individuals' performance in a purely attentional task. This idea is supported by findings of a previous study [66] that demonstrated how the robot's movements in the user's surroundings distracted the user from his/her current activity.

Moreover, to control the effect of the gender on the users' performance, we compared the cognitive outcomes reported by males and females in both the entire sample and within each group, but we did not find any significant difference. These results were confirmed by the correlation analysis which showed no significant association between cognitive performance and users' gender; whereas, we found only a positive correlation between the Psychoticism personality trait and performance on part B of TMT in *neutral* robot condition (which is in line with the evidence that greater psychoticism was associated with altered attentional and set-shifting abilities [67]). Furthermore, we did not find any relationship between users' intrinsic characteristics and cognitive performance (H2), therefore the differences in cognitive performance that emerged in the different conditions could not depend on users' gender and personality traits. The role of the users' gender or rather whether men or women are more likely to prefer or dislike robots has been widely investigated in HRI [68] revealing mixed results: Nomura [68], reviewing the literature about the impact of the human gender on HRI, suggested that females seem to have more negative attitudes toward interaction with robots than males. Ghazali et al. [69] reported that participants experienced higher psychological reactance when interacting with a robot of the opposite gender. However, we aim to explore the association between gender and users' cognitive performance during HRI in a future study with a larger sample.

Analyzing the association between UTAUT constructs and the users' performance, we found that reporting a positive attitude toward the robot (for example, thinking that the robot can make our life more interesting and that using a robot can be a good idea) was correlated to better cognitive performance in the *friendly* condition; moreover, individuals' intention to use the robot was associated with slower performance on a cognitive task in the *friendly* condition. Conversely, in the *authoritarian* condition, performance on Attentive Matrices and part A of TMT were associated with Trust suggesting that users' trust in the robot's role and its function could be crucial to improve the users' performance leading us to reject our third hypothesis (H3) that a *friendly* interaction style of the robot could be more suitable to increase some feelings and perceptions of the users about the robot such as the Trust. More specifically, taking into account the findings of better cognitive performance and significant associations between performance and users' trust in the *authoritarian* condition, we can assume that following the robot's instructions and trusting its advice might improve users' performance on cognitive tasks. This idea is in line with the results of a previous study [21] which found a relationship between the Trust construct and users' performance on psychometric tests. For this purpose, an assertive interaction style of the robot seems to be more effective in enhancing users' trust than the *friendly* or *neutral*. Pepper with an assertive style could affect users' acceptance of technology and then their engagement in the tasks. These hypotheses were also supported by the results that emerged by the comparison between the scores in UTAUT reported by the participants before and after the interaction with Pepper. Indeed, we observed increases in UTAUT scores after the individuals interacted with the robot both in the *friendly* and the *authoritarian* condition, but not in the *neutral* one. This is evident in the Facilitating Condition construct which reflects how much the users believe that they can more easily use the robot. These results are further evidence about the need for designing robots endowed with specific features (i.e., authoritarian and friendly), as this has a different impact on the users' response in terms of performance in cognitive tasks but also of technology acceptance. Moreover, although they did not reach the statistical significance, increases in Perceived Ease of Use, Intention to Use, Trust, and Total scores of UTAUT were reported by the participants after they interacted with the *authoritarian* Pepper. The lack of significance in the comparisons of UTAUT scores completed Before and After the HRI could be due to the sample size as confirmed by power analyses.

Finally, in the present study, we investigated whether and how the individuals' non-compliant behavior was related to their personality traits and lie inclination (H4) but we did not find any association between these variables. This result might be due to the exiguity of the sample size as proved by the power analyses. This represents a limit of the present study since, in literature, it has been demonstrated that high neuroticism and low conscientiousness are widely associated with individuals' non-compliant behavior [70]. However, these findings might indirectly support the results we reported in a previous study [45] which showed as the individuals' non-compliant behavior was greater when they interacted with a robot with a *neutral* interaction style since this could be perceived as a machine-like system and therefore easy to cheat (see Maggi et al. [45] for a more detailed discussion). Indeed, since being aware of the social presence of others can reduce the dishonest behavior of individuals [35], the robot's behavior and its capability to be perceived as a social presence seem to play a crucial role in promoting or mediating non-compliant behaviors. Also, in a recent study, Petisca et al. [20] found that the role of the robot in the context could influence users' cheating behavior. Particularly, participants were less compliant when they were interacting with a robot giving instructions then when they were interacting with a vigilant robot as its role was not to monitor deceiving behavior. According to the above-mentioned findings, it is essential to consider not only the individual's personality and characteristics but also the effect of the robot's interaction style on unethical behaviors.

In the present study, we aimed to explore the impact of a specific robot's interaction style administering a cognitive evaluation on users' performance. The design of the communication styles in Pepper is resulting from a few different variables (gestures, speech, language, gaze). This constitutes a limitation of our work since the results could be caused or confounded by any of the variables. As future work, we aim at investigating how the different robot's interaction styles are classified and perceived by the human participants. Moreover, the results must be interpreted with caution since the small number of participants limits this study as proved by power analyses; nevertheless, the present study offers promising evidence that customizing social robots' behavior might be crucial to improve the users' response in terms of performance in cognitive tasks but also of technology acceptance. For future works, we aim: (i) to collect data on the users' perception of the robot behavior to better label its interaction style; (ii) to explore the usefulness of cognitive assistance provided by a humanoid robot also in healthcare and educational contexts; (iii) to prove the feasibility of this robotic assistance application in home-care and daily living contexts.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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Gianpaolo Maggi received the M.Sc. degree cum laude in Psychology of Cognitive Processes in 2016. He spent one year as a researcher assistant at PRISCA Lab, Federico II, under the supervision of Prof. Silvia Rossi working in Cognitive Robotics field. Currently, he is a Ph.D. student in Sciences of the Mind at the University of Campania "Luigi Vanvitelli". His research interests include neuropsychology, cognitive neuroscience, and cognitive robotics.

Elena Dell'Aquila Ph.D. in Psychological and Pedagogical Sciences, has gained considerable expertise both in the field of HR and Academia. Her research has a strong focus on the development, design and adaptation of psychological models supporting educational, learning and assessment methodologies within innovative technologies applications, with a particular interest in serious, simulation-based, virtual role-play scenarios. Elena is the first author of a manuscript with Springer on Educational Games for Soft-Skills.

Ilenia Cucciniello got a Bachelor degree in Computer Science. She graduated in 2019 with a thesis on the development and testing of a robotic application for cognitive tests simulating different personalities. Now, she is currently studying for her Master in Computer Science at the University of Naples Federico II. Her main interests are robotics and artificial intelligence.

Silvia Rossi received the M.Sc. degree in Physics in 2001, and the Ph.D. in Information and Communication Technologies in 2006. She is an Associate Professor in Computer Science at the Department of Electrical Engineering and Information Technologies, University of Naples Federico II, where she is currently co-Chief of the PRISCA (Intelligent Robotics and Advanced Cognitive System Projects) Laboratory. Her research interests include Multi-agent Systems, Human-Robot Interaction, Socially Assistive Robotics, and Recommender Systems. She is an Associate Editor for IEEE Robotics and Automation Letters (RA-L), International Journal of Social Robotics, Pattern Recognition Letters, and Intelligent Service Robotics journal.