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LONG PAPER

Older adults' user experience with introvert and extravert humanoid robot personalities

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Abstract
Humanoid robots can be an effective tool for the cognitive training of older adults. For this purpose, it is important that their interaction be engaging. In this study, we investigate whether proposing robots exhibiting extraverted or introverted personalities can improve user experience. In particular, we have designed and implemented a set of multi-modal cues for such personality traits, which have been exploited in an application proposing typical exercises for cognitive training through a Pepper robot. We report on a user test with 24 older adults (65+), which provided interesting and positive feedback regarding how the robot personalities have been exhibited and their impact on the experience of such users.

Keywords Humanoid robot · Personality · Older Adults · User experience

1 Introduction

Over the past 20 years, several studies have explored innovative interaction technologies to improve older populations' mental and physical health. From this perspective, there has been increasing interest in robots for usage in social contexts, such as assisting people at work or home with daily activities and healthcare scenarios. Several studies [1–3] have focused on how to improve robot usability in such scenarios by promoting a more natural human–robot interaction (HRI). The goal is to attract people's attention to the robots, engage them, and improve the user experience (UX) by expressing emotions, communicating through high-level dialogues, using natural cues, developing social skills and exhibiting distinctive personalities [4]. These capacities can allow the robots to be employed to interact more naturally and socially rather than be considered mere instrumental tools. In particular, personality represents those characteristics of people that account for consistent patterns of feeling, thinking, and behaving [5]. Various studies [6–11] have addressed the characteristics of personalities and have observed a close relationship between personalities and the modes of interaction between humans and robots. Therefore, they suggest that the addition of personality can improve and make interactions more consistent, as well as heighten user engagement and user experience [12]. Moreover, different studies [7] [10, 11] found that a robot with different personalities can simplify the interaction, as happens in human–human interaction during cognitive training by a human therapist. This is particularly useful when the users are older adults, for example, for performing cognitive training exercises. Indeed, emerging humanoid robots may open up new possibilities in more effectively engaging mild cognitive impairment (MCI) older adults during repetitive cognitive training [13]. Hence, including a robot exhibiting personalities in cognitive training can simplify the interaction and engage the user to continue the therapy and provide emotional feedback [7]. Thus, it may be critical to take advantage of more engaging communication with robots, in other words, one that does not rely only on verbal communication but also considers nonverbal communication [14–16]. Incorporating the two types of communication may be helpful to maximise the expressiveness of behaviours in

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humanoid robots and facilitate human–robot interaction for cognitive training.

In psychology, several theories about personality have been conceptualised in various ways. One of the most popular approaches is trait-based, in which the trait is a component that characterises an individual personality that is stable across time [17]. For such reasons, a robotic system should incorporate different personality traits to modulate its behaviour for interaction with users through more natural and social interaction. For this purpose, we have considered the Big Five Factors model with the OCEAN paradigms [18] that classify personality according to five main dimensions.

We identify various cues which enable humanoid robots to manifest two distinct personalities and show how to apply them in tasks for cognitive stimulation. This has led to identifying verbal and non-verbal cues to represent such robot personalities when supporting cognitive stimulation tasks for older adults. We implemented two contrary personalities (extravert and introvert) in a humanoid robot. They have then been applied in the interactions with a serious game, which was tested with 24 older adults in a within-subject study experiment. During the test, qualitative and quantitative data were collected to investigate how older adults respond to the robot manifesting extraversion or introversion through verbal and nonverbal cues and if the robot personalities impact the user experience during the interaction. Finally, we have considered whether there is any relation between the user's personality and the robot's representation in the user experience. The goal was to contribute to addressing the following research questions.

- **RQ1. Was the robot's representation of extraversion/introversion traits judged appropriate to either personality?** Various theories have found that different cues can project extraversion and introversion. However, verbal cues, in particular voice, language, pitch, speech rate, and non-verbal cues such as gestures, and body movement, were found to be most prominent in the representation of personality [19, 20]. Therefore, in this study, we combined verbal and non-verbal cues of a humanoid robot (a Pepper robot) and tested if the representations of the robot personalities were considered appropriate by older adults during a cognitive training scenario.
- **RQ2. How can robot personalities impact the user's UX?** Nowadays, an additional issue is how to create and maintain the interest of individuals both in short and long periods of interactions with social robots during healthcare training scenarios. Understanding the user experience and, in particular, engagement could help make steps towards a more natural, engaging interaction during cognitive training scenarios [21]. Lee, Peng Jin, and Yan [7] believe that personality is a key element for creating socially interactive robots and that studies on this dimension will facilitate enhanced human–robot interaction. Thus, the personality of a robot can provide users with better affordance and experience, making it more intuitive and natural for the users to understand the robot's behaviours [22].
- **RQ3. Can the user's personality affect the robot's personality preference?** Nass and colleagues discovered that individuals did not identify a computer agent's personality unequivocally. They also applied the similarity and complementarity hypotheses of personality attraction within their interactions [19]. Furthermore, some studies [6, 23] explored how to match and mismatch robots' personalities with user personalities and evaluate which variable might affect them. However, there is no evidence of any correlation between older adults' personalities and user experience with the robot personality representation. Therefore, this study aims to investigate if there is any relation between user personality and the perception of the robot's representation of personalities in the experience that the user lived during the interactive sessions.

2 Related work

Different studies have investigated obtaining robot personalities using various cues to test their systems with a wide age range of users. Most studies tested the robot personalities with children or young adults.

Esteban et al. [6] conducted a study with 46 participants to explore how parents of children (between 29 and 54 years old) reacted to using social robots with personalities in an educational context. The personalities were simulated by modulating verbal and non-verbal cues from the literature and implemented in a Pepper robot. In the experiment, the robot took turns explaining diabetes. As a result, the authors found that most participants were extraverted and preferred to interact with the extraverted robot. However, they did not find any significant correlation between the participant's personality score in the Big Five questionnaire and their robot's personality preferences.

Min Lee et al. [7] evaluated Sony AIBO's introverted and extraverted personalities in a between-subject experiment with 48 participants (ages 19–34). Participants were randomly assigned to interact with an extravert or an introvert robot for 25 min. A list was given to the participants containing 17 verbal commands to communicate with the robot. The robot reacted according to the commands received. As a result, they found that participants could accurately recognise the robot's personality based on its verbal and non-verbal behaviours. Moreover, some users considered a robot with a complementary personality more intelligent, attractive, and socially present than a similar one. They also enjoyed the interaction more when they interacted with a robot with a complementary personality than with a similar personality.

Celiktutan et al. [12] focus on human participants, the robot's personalities, and their impact on human–robot interactions. A Nao robot was used for the test, in which they manipulated the robot's behaviour to obtain extravert and introvert behaviour. The test was performed with PhD and post-doc students. During the test, the robot performed a pre-established script with eight questions regarding mainly the user's interests and the user's feelings. In this work, a significant correlation was observed between the participant's extraversion traits and the subjects' perceived enjoyment of the extraverted robot. However, the interaction was controlled using a Wizard-of-Oz setup.

Andrist et al. [24] explored the development of two gaze behaviour models for socially assistive robots. The aim was to enable the robot to align with the user's personality and determine if this design can enhance user motivation and engagement during a therapeutic task. The researchers conducted a laboratory study involving 40 healthy adults aged 20–50. The study compared two conditions of the robot (extraverted vs introverted), with the robot's gaze behaviour being the only distinguishing factor. The Meka robot was used for implementation. The findings demonstrate the positive impact of personality matching on user engagement in repetitive tasks.

Another important element is to investigate the role of robot personalities in specific contexts, such as educational settings, therapy for post-stroke patients, and social mediation. In particular, how robot personalities can assist, interact, and engage users in these particular contexts.

Fu et al. [25] conducted an initial investigation into human–robot mental comforting conversations, aiming to enhance the perception of empathy in the ERICA robot by enabling it to demonstrate an understanding of the user's situation through sharing similar emotional experiences. To achieve this, they utilised a CycleGAN-based emotional voice conversion model to generate emotional speech for the robot. The participants recruited in the user test were young adults and evaluated the robot's ability to express emotions and also assessed ERICA's personality. The experimental results indicated that this method could potentially enhance ERICA's ability to convey encouragement and low spirits, particularly in terms of emotion, empathy, and extraversion, especially among female users.

Tapus et al. [10] conducted a study with 19 participants, young adults between 18 and 30 years old, and investigated the role of the robot's personality in a therapy process for the rehabilitation of post-stroke users. The study used an ActiveMedia Pioneer 2-DX mobile robot to assist, encourage, and socially interact with the patients engaged in rehabilitation exercises. As a result, they found the first evidence of its effectiveness in therapy performance. This work has some limitations. The main limitation was the limited interaction with the robot due to the restricted set of words that the robot recognised. Another limitation is that the system was designed for post-stroke users but tested with young adults.

Little work has been dedicated to analysing the impact of robots exhibiting some level of personality on older adults. Noguchi et al. [26] present design guidelines for social mediator robots, drawing from the findings of two studies involving a total of 741 elderly participants. In one study, the researchers examined the viability of a social mediator robot for the elderly, focusing on its ability to encourage self-disclosure on various topics. The results indicated that the social mediator robot effectively facilitated self-disclosure among the elderly, particularly on subjects they typically hesitated to discuss with others (e.g. experiences of loss). In the other study, which involved 720 users aged over 65 years, the aim was to identify the optimal personality traits for the social mediator robot. The researchers employed pre-recorded video clips that simulated human–robot conversations from a first-person perspective. The outcomes of this study yielded more detailed recommendations for designing the personality traits of mediator robots. However, an empirical study with actual interaction with the robot has not been performed to validate the designed recommendations.

Focusing on the cognitive interventions including robots, it is important to analyse the attitude of older adults towards this technology and the importance of positive feedback. Pino et al. [27] propose an intervention strategy aimed at slowing down the progression of cognitive decline in MCI individuals through the use of a NAO humanoid robot, used to assist in tasks derived from conventional memory-training programmes. The collected data revealed that memory training with the NAO robot resulted in increased visual gaze of the patients and enhanced therapeutic behaviour compared to the alternative condition with only the psychologist. Notably, the study emphasized the positive reaction of users to reinforcement phrases provided by the robot as feedback upon task completion, underscoring the significance of such feedback. However, the study had some issues: the robot–user interaction took place in group settings, and the NAO robot's ability to recognise individuals by facial recognition was not consistently successful. In our study, each user interacted with the Pepper robot showing different personalities, and providing more reliable opportunities for personalised and more engaging training and interaction.

The objective of Bechade et al. [28] was to establish an objective methodology for evaluating dialogues (jokes, persuasion and negotiation style) with a social robot by gathering data directly from end-users. To achieve this, they employed two data collection approaches: the first involved a Wizard of Oz system utilising the Nao robot, while the second employed an autonomous system with the Pepper robot. The findings indicated that young and older adults generally held a positive perception of the dialogues with the robots. However, it should be noted that some potential users declined to participate in the study due to their reluctance to interact with a robot. This highlights the need for cautious introduction of robots among seniors, as they may not be accustomed to engaging in conversations with technological devices.

Kidd et al. [29] conducted a comparative study to assess whether human–robot interaction (HRI) promotes increased social activity. The study involved two nursing homes and included 23 participants. The research team employed a placebo versus interactive robot in their investigation. During the on-field study, participants had an opportunity to interact with the robot, Paro (placebo or an interactive version), for twenty minutes. The findings revealed that the robot Paro has characteristics that can enhance social interactions. Moreover, the presence of caregivers or moderators who actively engaged in the interactions further amplified this effect. Such interactions with the robot provided pleasurable, positive experiences, as well as evocative experiences for older adults.

Specifically on the importance of the role of feedback in training games, Burgers et al. [30] studied the role of feedback as intrinsic motivation to play a training game. They found that positive feedback can enhance a positive willingness to engage in the continued play of serious games. Users receiving positive feedback, on the other hand, felt more competent and autonomous and desirous of playing the future. This suggests that positive feedback may be good for sustaining long-term play. In fact, as result, they found that the users receiving positive feedback would feel themselves to be more competent and autonomous, which, in turn, would increase intrinsic motivation.

Previous studies show that some parameters can be modulated to manifest extraverted and introverted personalities in robots. In this work, we present a way to represent such personalities in a humanoid robot and investigate the effect of the two robot personalities in supporting serious games for older adults. While in the literature, there has been some previous work analysing the use of social robots in cognitive training [27, 28], the effects of different personalities in a humanoid robot for cognitive training scenarios with older adults have not yet been investigated. Additionally, while most studies have used the Wizard of Oz approach to simulate autonomous robot behaviour while relying on hidden humans to control it remotely, in our study, we have implemented a software architecture that automatically modulates robot personality parameters without external manual human control.

3 Design of robot personality

Various psychological theories about personality are used in robotics research, but the most widely adopted is the big five personality model [18] in the OCEAN paradigm. It is composed of five dimensions: openness to experience refers to the degree of curiosity and imagination; conscientiousness, which reflects the extent to which the person is self-aware, deliberative and careful; extraversion, which is the tendency of someone to be talkative, outgoing, energetic and convivial; Agreeableness represents a person who is cooperative and friendly; neuroticism is the degree to which someone quickly becomes prone to psychological stress, angered and insecure. From this model, we decided to focus on the extraversion dimension for four main reasons. Firstly, a considerable amount of research indicates that extraversion is the most observable dimension among the big five factors [19, 31–33]. Secondly, this dimension is proven to be important in human–robot interaction [7, 34, 35]. In particular, Isbister and Nass [34] found that extraversion–introversion is the salient dimension in non-verbal cue research. Thirdly, this dimension affects users' quality of life and satisfaction during the interaction [36, 37]. Fourthly, verbal and non-verbal parameters used to represent extraversion and introversion are discussed in the literature and can be efficiently modulated in robots [7, 34, 35]. Different studies have identified various cues for the extravert personality. Extraverts tend to speak louder, faster, and with a higher pitch [34, 38]. Usually, they use less extensive vocabulary and are more inclined to talk more about themselves. Body movements are generally broader and faster and occur more often than those performed by an introverted person [7]. Extraverts are usually restless and perform idle movements [34]. Instead, introverts tend to be more socially anxious and speak slowly [39], which could manifest in taking longer to answer [40]. Therefore, according to prior research, non-verbal and verbal cues effectively manifest extraversion in synthesised speech [19] and social robot behaviour [7]. In particular, Nass and Moon [41] focus on the extraversion–introversion dimension in linguistics. In particular, they investigate how personality can be expressed through the style of utterance. Various studies [9, 20, 38, 42] identified various vocal features associated with extraversion, such as loudness, frequency range, pitch, speech rate and additional features related to the style of the speech. They suggest that extravert people speak with a wider frequency than introvert people [4, 38]. According to Nass and Lee [19, 41], voices are perceived as more extraverted when spoken at a high volume, faster, and high-pitched. The introverted robot voice should have the opposite characterisation of such cues. The vocal parameters identified for the robot personalities representation that has been designed and implemented are: speech rate, pitch, volume, style, and feedback provided as suggested by previous studies [4, 15, 20, 39, 40].

Pitch, volume and speech rate In the introverted condition, we have slightly lowered the pitch, with a slow speech rate and low volume, to simulate a robot's demure behaviour. In the extravert condition, the pitch is higher, with a faster speech rate and higher volume: this was done to make the robot seem more enthusiastic and to create a robot's welcoming behaviour [9, 20, 39].

Speech style In the introverted condition, we used a kind and polite dialogue to make the robot's behaviour shyer. The robot speaks using polite manners and simulating hesitation and anxiety through pauses and hesitant interjections. The robot never addresses the user directly using informal expressions but mainly via modal expressions and neutral feedback. In this condition, we use modal verbs in the past forms (e.g. "could" instead of "can") to be politer or less direct, as well as modal expressions (such as "be likely to" and "be supposed to be") to express a more hesitant attitude further. On the other hand, in the extravert condition, the robot addresses the user more directly, using primarily present tenses with shorter and more direct sentences and exclamations.

Feedback Both robot personalities provide encouraging and positive feedback. The use of positive feedback in the context of cognitive training is an important element to feel the user more competent and autonomous and desirous of playing in the future [30]. For example, with the extraverted personality, after the robot asks a question (using a high-volume, high-pitched voice), and in turn, the user provides the correct answer, the robot reacts with enthusiastic feedback, saying, i.e. "You totally nailed it! I would have given the same answer!". On the contrary, the introverted robot is shyer. For example, after the robot asks a question (using a lower pitched voice, volume and speech rate), and the user provides the correct answer, the robot reacts with hesitant feedback, such as e.g. "Mhm…Good!…the answer is right", and providing this answer after a few seconds.

The verbal feedback provided by the robot in both personalities aims to maintain a positive mood in the user and encourage communication and the establishment of a bond with the robot. The robot offers feedback that positively influences the user's experience regarding correct and wrong answers. Furthermore, the robot provides assistance feedback when the user struggles to understand the game's rules. Both personalities emphasize the importance of verbal feedback in maintaining a positive, supportive, and motivational context in the interaction.

The verbal content of the extraverted and introverted robots provides the same information; however, the manner in which the robots delivers the sentences differs with the extraverted personality being more straightforward and enthusiastic. In contrast, the introverted robot exhibits hesitations and pauses.

In summary, the robot in the extravert condition tends to speak louder, faster, and with a higher pitch, takes fewer pauses during the dialogue, and uses shorter and more encouraging sentences. In contrast, the robot in the introverted condition appears more reserved, with a tendency to speak more quietly, slower, and with a neutral pitch. During the dialogue, it uses longer pauses and various utterances of hesitation. The extravert traits are manifested through happier and more active interaction, while the introvert with a more neutral and calm interaction. Furthermore, we modelled the extravert and introvert conditions also by modulating non-verbal parameters. Nonverbal cues, such as gestures, posture, and body movement, are elements for the representation of extraversion/introversion [7, 43, 44]. Isbister and Nass [34] modulate the extravert behaviour of virtual agents by adjusting their gestures: generating broader movements (with a higher range of angle) and in the listener's direction. Conversely, the introverted robot performs movements close to its body and uses fewer wide gestures. In summary, the non-verbal parameters chosen to design the two personalities are gestures, speed movements, and motor movements.

Gestures Gestures consist of robot joint movements that aim to convey information or intentions to a user; a gesture can be composed by changing the joint's angle and the gesture's dynamics. In this category, we also include some robot body movements, which can be obtained by modulating different robot joints and actuators (the head, left and right arms, hips and knee). Speed movements consist of the manipulation of single gesture execution speeds. Motor movements are concerned with manipulating the 'mobile' trajectories the robot can make. In particular, the orientation and the direction of the robot's motor movement are manipulated to approach or move away from the user. For the extraversion condition, the robot's gestures are more expansive, with broad gestures to simulate openness towards the user. The gestures generated in this condition usually involve the elbows and hands moving away from the body using larger angles. In addition, the robot's movements are more dynamic than those created for the introverted and are faster and wider.

Conversely, for the introvert condition, the robot's gestures tend to be more limited and contained in such a way as to appear reserved towards the user. The gestures generated in this condition usually involve the arms positioned close to the body, determining smaller angles in the introvert. Another gesture implemented in this condition involves the robot's head. Specifically, the robot lowers its head and avoids the user's gaze to convey shyness. In addition, the animations created are slightly less dynamic than those created for the extraverted.

Speed movements and motor movements The robot's motors are activated in both conditions so that small movements can be simulated to make the representation of the robot more "human-like". The robot in the extravert condition performs movements, in general, faster, leading to higher gesture rates and dynamics. It also follows more articulated trajectories composed of lateral, forward, diagonal and slightly backward displacements. In the introverted condition, the robot's (gesture and motor) movements are slightly slower and restricted in terms of angles. The robots in the introvert condition perform movements, in general, slightly slower and make less articulated trajectories composed mainly of lateral, forward, and more accentuated backwards displacements. The introvert robot uses more inward-directed movements, while the extravert robot uses outward-directed movements. This was done because the outward-directed movement conveys an opening message to the user, simulating an opening and warmth behaviour, while inward-directed movements tend to convey a message of closure and shyness. Table 1 summarises the aspects used to represent the two personalities. They have been implemented in the humanoid Pepper robot developed by Aldebaran. Pepper is a 1.2 m- tall wheeled humanoid robot with 17 joints for expressive body language and three omnidirectional wheels to move around. Pepper has multi-modal interfaces for interaction: touchscreen, speech, tactile head, hands, bumper, LEDs and 20 degrees of freedom for motion in the whole body. The robot is supplied with an LG CNS screen of 10.1 inches with a resolution of 1280 × 800 for supporting touch interaction. In addition, Softbank robotics provides a library called QiSDK and an android studio plugin called Pepper SDK, and libraries to control the robot's behaviour [45].

3.1 Personality parameters implementation

As discussed, verbal and nonverbal cues manipulate Pepper's personality. To control verbal parameters, we have used the Speech Synthesis Markup Language (SSML), whose tags allow programmers to customise the pitch variation, the volume of the robot, the speech rate, and the duration of the pauses during speech. A combination of SSML tags and feedback is used to modulate the verbal cues of each personality. As further support for verbal cues, we created a different set of phrases, sentences, and exclamations for each personality. The robot has been programmed with a distinct set of feedback to create a more natural and social interaction. In this manner, the answers and sentences reproduced by the robot should vary according to the personality. Various exclamations using a more straightforward and enthusiastic dialogue style (such as "Hey, what is the first ingredient?") are used for the extravert condition. Also, in this condition, the robot refers directly to the user using primarily personal pronouns and present tenses. Instead, for the introvert, a set of hesitant interjections such as ("Ehm, could you please tell me the first ingredient?" and "Might I ask if you…") and a dialogue style that manifests hesitation are used. In this condition, the robot refers indirectly to the user using a more formal language. For manipulating nonverbal cues, we used the animation editor provided by QiSDK. In particular, the animations modulating different robot's joints and actuators (the head, left and right arms, hips and knee) have been produced. A further modulation for non-verbal cues concerns the robot's movements. For this, we used the Trajectory Editor to define a robot trajectory, modulating speed, orientation, and duration and combining more than one path. For the extravert condition, the trajectories developed are four. In the first, the robot approaches the user closely in a forward trajectory. This trajectory is mainly performed when the robot asks a question. In the second trajectory,

Table 1 Personality cues identified for extravert and introvert personality

	Extravert	Introvert	Literature
Pitch variation	80% of maximum	60% of maximum	[39, 20, 9, 38]
Volume	90% of maximum	70% of maximum	[34, 9, 38, 35]
Speech rate	~ 200 wpm	~ 180 wpm	[39, 34, 20, 38]
Dialogue style	More direct	Polite	[41]
Pauses	few pauses (400–600 ms)	longer pauses (600–900 ms)	[40]
Tenses	present tenses	use past tense form	
Sentences	shorter and direct sentences	longer and formal and hesitant sentences	[39, 20]
Feedback	reinforcement and encouraging feedback	neutral feedback and positive feedback	[20]
Gesture	gesture with big angles more dynamic	gesture with smaller angles less dynamic	[43, 34, 7, 44]
Speed movements	faster movements more dynamic	slower and longer movements less dynamic	[7, 35]
Motors movements	outward-directed movements, faster trajectory laterals, diagonal& forward	inward-directed & forward movements slower trajectory backward	[43, 34]

the robot moves diagonally to the left, returns to the origin and then moves diagonally to the right. In this trajectory, the robot's orientation varies from − 15 to 16 degrees with lateral movement. The second trajectory is used in the more discursive parts of the vocal interaction for the application (for example, when the robot explains the recipe). The third and fourth trajectories are mainly performed when the robot provides feedback after the user answers the question. The robot moves, respectively, diagonally to the left for the third trajectory and to the right for the fourth trajectory. These trajectories were created primarily to simulate human-like movement in the robot so that it does not always remain stationary and static in its original position. All trajectories return to their point of origin. During diagonal trajectory, the robot turns slightly towards the position where it is going. Instead, the main trajectory used for the introvert condition is moving away from the user. The robot goes back and then slowly returns to its initial position. The other trajectories for the introvert robot are trajectories in which the robot changes its orientation. The robot turns slightly left and right. Figure 1 shows examples of how the robot exhibits personality traits when providing users with ending feedback. In Fig. 1-up, Pepper shows a closer animation, and it slightly goes back to convey a feeling of shyness. In Fig. 1-down, the robot generates a more expansive gesture to convey a feeling of openness and welcome.

Example application: **A serious game for cognitive training.** We applied the design of the robot personalities to a serious game for the cognitive stimulation of older adults. It supports some typical tasks for a serious game aiming to stimulate various cognitive resources, such as attention, visual and short-term memories. It consists of a cooking game where users have to perform various exercises to recognise the sequence of ingredients in a recipe and the weight of each ingredient. The serious game is organised into five states: introduction, recipe instruction, question state, answer state, and ending feedback. When the application starts, the robot greets the user and asks if it is ready to play, showing a neutral personality. When the cooking game starts, the robot's personality is exhibited, and the robot shows and vocally synthesises the ingredients for the selected recipe. The robot emphasises the sequential ingredients' order and weight during the recipe instruction. Then, it starts the quizzes, during which the user should use visual attention and working memory to recognise the right ingredients and select them among other options available.

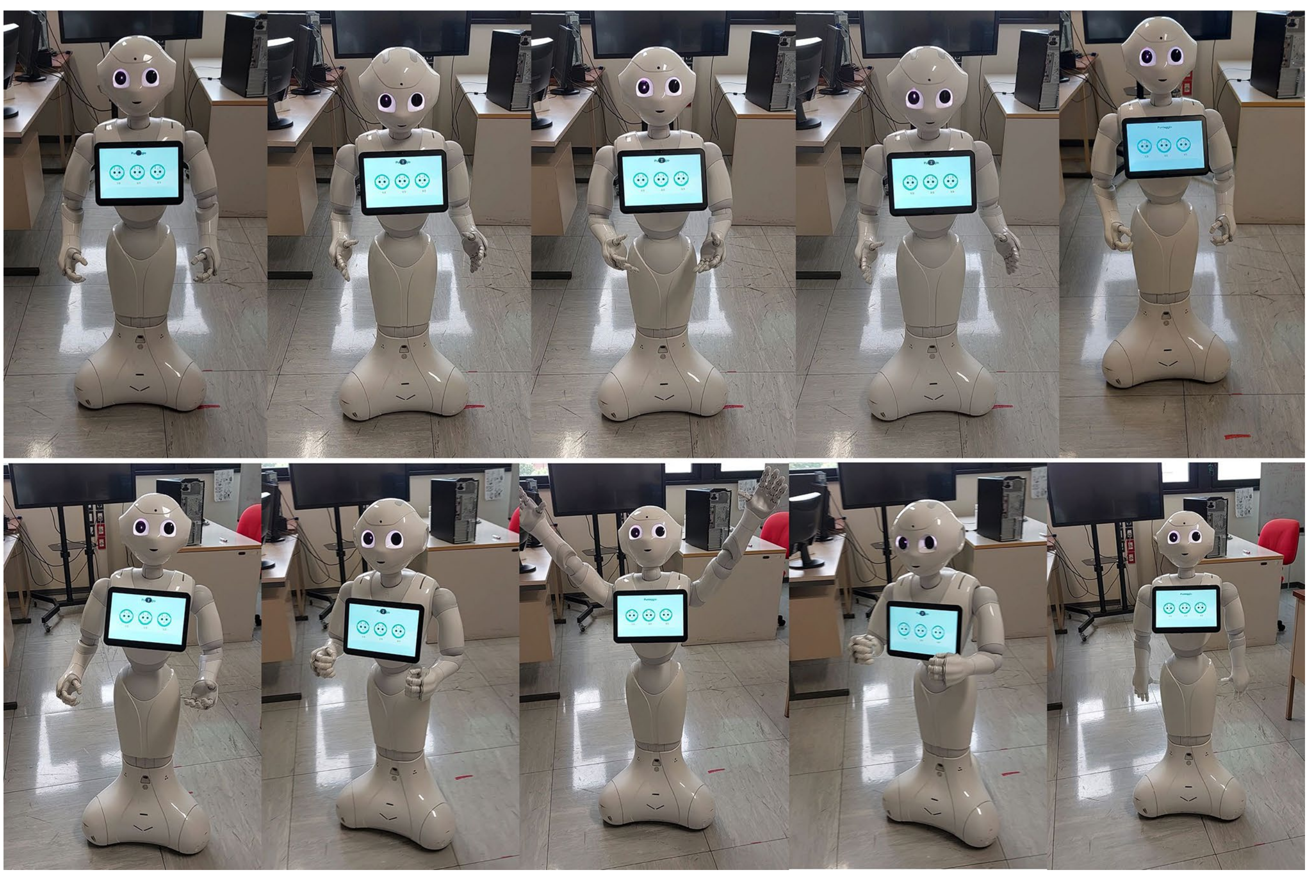

Fig. 1 Animations example for introvert personality (upper image), for extravert personality (lower image)

Finally, the user has to select the right answer among the four options proposed. The user can interact through voice. The game has been designed and developed by applying the guidelines for designing accessible interfaces for older adults [46, 47]. As for the visual communication, supported through the screen on the robot's chest, we maximised the contrast, using only one main and saturated colour. Roboto font has been used for faster reading and to maximise the legibility of essential text and a large font size [46]. We provide a consistent layout, and the labels used in the buttons are semantically distinctive. Additionally, the writing style is concise and plain, using simple and common words. Two neuropsychologists interacted with the robot exhibiting the two personalities and the application's design. They found the exercises proposed and how to represent the personalities relevant to our goals and asked to use them for their cognitive training programme to engage the older adult participants better.

4 User test

The test was conducted in a laboratory in June–July 2022. Participants were recruited with notices posted in places such as pharmacies, hospitals, clinics and through word of mouth. The requirements for enrolling were to be at least 65 years old and Italian-speaking. For the test, the users interacted one by one in the lab, sitting in front of the robot at a distance of about 80 cm to prevent the robot's movements from inadvertently reaching the user. The experiment took an average of 40' for each user (test + questionnaires). A moderator was present and took notes of user feedback, user behaviour and any significant event occurring during the test. After the end of the test, the users were rewarded with some chocolates.

Participants In total 24 (11 females) senior adults between 65 and 83 years old ($M = 72.4$, SD = 6.08) were enrolled. Twelve had a high school degree, seven had a university degree, four had a middle school diploma, and one had an elementary school diploma. The majority, 79% (21 users), had no experience with robots. Only three had previously seen a Pepper robot. One of them had a Roomba robot and liked talking and using it at home.

The mini-mental state examination (MMSE) was used to assessing user's cognitive abilities: The MMSE score ranges between 0 (= severe cognitive disorder) and 30 (= no cognitive deficit). One user scored 23 (mild dementia), another one scored 18 (moderate dementia). All the others scored 25–30, indicating normal cognition.

The user's personality was evaluated using the mini-IPIP. The internal consistency of the mini-IPIP was assessed with Cronbach's alpha ($\alpha = 0.75$). We considered the extraversion trait of the mini-IPIP: based on the associated scores, we divided the users in 2 groups: if the score was 3 they were classified as "extravert", otherwise as "introvert"; 18 participants were considered "extravert", 6 "introvert".

Test organisation It was a within-subjects test: all users were exposed to both conditions (interacting with an introvert/extravert robot). The reason for the within-subject design is mainly related to the difficulty in recruiting the target audience (65 + older adults), also considering the pandemic. In compliance with the regulations prevailing in Italy during the testing period, individuals aged over 65 were classified as "fragile persons". These individuals were subject to a set of restrictions, which posed challenges in recruiting participants from this specific user category in Italy. To avoid the limitations of the within-subjects study, the conditions to which the subjects were exposed were counterbalanced.

The performance order was controlled for: half users (randomly selected) first interacted with the introverted robot, then with the extraverted one; the others did the opposite. The test was organised into five steps (see Fig. 2) as follows:

- *Step 1: Introduction and user cognitive analysis.* At the beginning of the study, participants were provided with

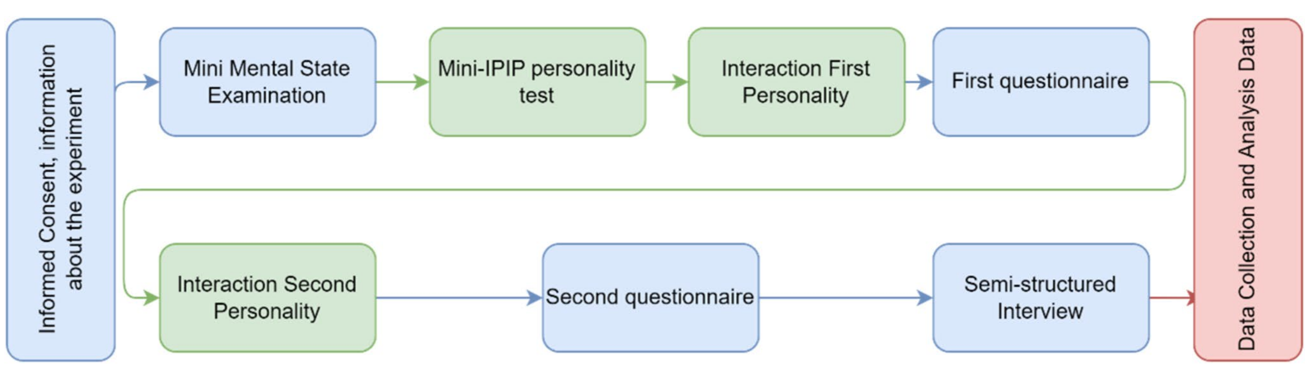

Fig. 2 The steps followed in the test. The blue rectangles are tasks performed with the moderator, and the green one are task performed with the robot

an introduction to the main goals of the experiment, which included a presentation of the Pepper robot, and an explanation of the tasks to carry out during the session. To prevent any potential bias in the participants, the specific two robot personalities were not discussed throughout the duration of the session. This approach aimed to maintain a neutral environment and ensure that participants' responses and behaviours were not influenced by preconceived notions or expectations. Then, they signed a written informed consent indicating the purpose of the research, the procedure of the research study, duration, personal data processing information following the European Data Protection Regulation, the possibility to request the release of the data and how they are processed. Afterwards, they performed a cognitive analysis using the Mini-Mental State Examination (MMSE) [48].

- *Step 2: Questionnaire about user personality.* The mini-IPIP shortened measures of the big-five domains [49] questionnaire were administered to understand the main traits of the personality of each user.
- *Step 3: First session with a robot personality and evaluation of robot behaviour*. In this step, there was an interaction with the robot showing a specific personality during a game about the preparation of a recipe. After, the users had to compile a questionnaire about socio-demographic data, information about previous experience and familiarity with robots, a statement that asked them to choose the robot personality perceived, four statements evaluating the perception of the robot personality using Wiggins adjectives [50], four statements regarding the user experience, and the user engagement scale-short form (UES-SF) questionnaire [51]. The UES-SF considers four dimensions of engagement: FA = focused attention (tendency to be absorbed and losing track of time), PU = perceived usability (Users' affective (e.g. frustration) and cognitive (e.g. effort) responses to the system), AE = aesthetics (the attractiveness of the interface), RW = reward (tendency to be rewarded during the interaction). The additional four statements aimed to receive user feedback on more specific aspects relevant to our study. Socio-demographic data, including age, gender, education level, and prior experience with robots, were gathered to obtain a comprehensive profile of the user sample.
- *Step 4: Second session with a robot personality and evaluation of robot behaviour.* During the 2nd session, the application proposed the same game but involving a different recipe, while the robot exhibited the other personality. After the 2nd session, the same questions used in the 1st interaction were administered. However, those about demographic information were excluded, while a question asking the preferred robot personality was added
- *Step 5: Semi-structured Interview and Final Feedback.* In the semi-structured interview, we asked a number of questions regarding whether users had perceived differences between the two types of robot behaviour, the likeability of the two types of robot behaviour, and to what extent, in the user's view, the behaviour shown by the robot conveyed an introvert or an extravert personality.

5 Results

We collected the number of errors and session time from the recipe's introduction in all the sessions. On average, users interacted with the extraverted robot for about 2:45 min and the introverted robot for about 2:13 min. The average session duration for the extravert case is longer than that for the introvert one and can be explained by the intrinsic characteristics of the personalities. The extravert personality speaks faster but articulates longer sentences. In addition, extravert gestures are more articulate and longer in duration. While the introverted robot speaks more slowly but utters shorter sentences, and the duration of the introvert's gestures is shorter. Users made 5.12 errors on average (max = 17, min = 0, SD = 4.39) in the session with the extravert robot, while with the introvert robot, they made an average of 3.5 errors (max = 17, min = 0, SD = 3.43). Two different users made the maximum number of errors for each condition. The higher average number of errors in the extraverted condition could be due to the rapid speech of the extraverted robot, which did not allow users to acquire the recipe information quickly.

Table 2 provides a comprehensive overview of the research questions, the corresponding data sources for addressing them, and the methods employed to analyse the collected data. This information highlights the research design and methodology utilised in the study, aiding readers in understanding the approach taken to investigate the research questions.

5.1 RQ1: Was the robot's representation of extraversion/introversion traits judged appropriate to either personality?

After the 1st and 2nd interactions with the robot, we asked users for feedback about the robot's personality by asking "The robot with this personality looks like: Extravert or Introverted". The users then had to indicate the type of personality (extravert and introvert) they judged more appropriate.

Table 3 shows the answers. For the recognition of the extraverted robot personality, there was a higher consistency: 20 users identified the robot personality in a manner consistent with the extravert robot personality conditions, while

Table 2 Research questions addressed, data used to answer the research questions and statistical methods

Research questions	Data	Methods
RQ1	Statements: "The robot with this personality looks like…" Four statement with Wiggs' adjectives	Fisher's exact test and paired t test
	Open questions	Qualitative Analysis
	Semi-structured Interview	Thematic Analysis
RQ2	UES questionnaire	UES score, Paired t test
	Statements about UX	Wilcoxon test, Paired t test
RQ3	Mini-IPIP questionnaire results	Mini-IPIP score and Chi-square Test
	Statement: "I prefer interact with the robot…"	

only 4 did not. Similarly, 15 users correctly recognised the introverted robot, while 9 users said that the robot exhibited an extravert personality while the robot's behaviour actually intended to represent an introvert one. In total, 80% of the user correctly identified the robot personality with whom they interacted.

We used Fisher's exact test to assess whether the difference in robot perception between the two experimental conditions was statistically significant. Results showed a significant association between the designed personality of the robot and the robot's personality as perceived by the user ($p = 0.0027$).

Furthermore, we assessed the correctness of participants' perceptions regarding the robot's personality in both conditions by evaluating four statements designed with Wiggs' adjectives [50] in Italian [52]. The adjectives employed were "silent" and "shy" for the introverted condition and "enthusiastic" and "vivacious" for the extraverted.

The participants' ratings for the statement "The robot seemed shy to me" met the assumption of normal distribution (Shapiro–Wilk test, $W = 0.93506$, $p = 0.1265$). A paired t test showed a significant difference in perceptions of the robot's shyness between extraverted and introverted conditions ($t = -3.14$, $p = 0.005$).

Similarly, a paired t test compared participants' perceptions of the robot's 'silence' in both conditions. The normality of the difference scores was assessed (Shapiro–Wilk test, $W = 0.948$, $p = 0.247$), indicating no significant deviation from normality. The paired t test revealed a significant difference in perceptions of the robot's 'silence' between extraverted and introverted conditions ($t = -2.40$, $p = 0.024$). Participants perceived the robot as less 'silent' in the extraverted condition compared to the introverted condition. For the statements "The robot seems enthusiastic" and "The robot seems vivacious", the data followed a normal distribution (Shapiro–Wilk test). A paired t test compared participants' ratings before and after an interaction. No significant difference was found for enthusiasm ($t = 1.27$, $p = 0.217$). However, for vivaciousness, there was a significant difference in ratings ($t = 2.13$, $p = 0.044$), with participants perceiving the robot as more vivacious in the extravert condition.

Table 3 A summary of the frequency counts of the robot's personality as perceived by users, specified in the two conditions (extravert and introvert robot personality)

	User answer: extravert robot	User answer: introvert robot
Condition: extravert robot	20	4
Condition: introvert robot	9	15

The findings suggest that participants' perceptions of a robot's personality can be influenced by its behaviour. Participants perceived the robot as shy and silent in the introverted condition and less silent in the extraverted. Additionally, participants perceived the robot as more enthusiastic after interacting with it, suggesting that the robot's behaviour influenced participants' perceptions of its enthusiasm.

These results suggest that participants were able to differentiate the robot's personality based on its exhibited traits in the two different conditions.

5.1.1 Qualitative analysis

We employed a qualitative analysis methodology to examine the user feedback from open-ended questions incorporated in the questionnaire after the first and second interactions. Furthermore, a thematic analysis was conducted on the transcripts of semi-structured interviews to identify prevailing patterns among users' perceptions regarding specific aspects of the interactions observed in both conditions.

5.1.1.1 Analysis of open questions Additional qualitative feedback questions have been collected in the questionnaire.

Personality Perception The analysis focuses on the participants' perceptions of the extravert and introvert robot conditions, examining the specific personality traits and behaviours that influenced their experiences during the interaction.

Users expressed positive feedback regarding the robot's voice, describing it as sweet, musical, easily understandable, and natural (ID24 "…because its pitch put me at ease, it had a cheerful voice"). Furthermore, participants perceived the extraverted and introverted robot's behaviour as sympathetic and affectionate, with a sense of humanity conveyed through its movements and gestures (ID8 (introvert robot) "…it seemed to cuddle with me"), which simulated expansive and welcoming behaviour (ID25 (extravert robot) "…because it was more affectionate, it expressed more humanity as if it were a friend, and wanted more contact"). Notably, one user even mentioned developing a friendship with the robot. In contrast, users who preferred the introverted robot appreciated its measured and fluid gestures, which created a welcoming atmosphere. The behaviour of the introverted robot fostered a comfortable environment where users did not feel judged or uncomfortable (ID2 "it did not make me uncomfortable and wrong. Its behaviour seemed respectful because it behaved professionally").

User Emotion Additionally, the analysis delves into the impact of the robot's behaviour on users' emotions. During interactions with the introverted robot, participants experienced various emotions, including tranquillity, sympathy, curiosity, feelings of ease, inattention, coldness and shyness. Most participants valued the experience of interacting with the introverted robot, as it conveyed trust, sympathy, and calmness and put them at ease without encountering any problems or difficulties. However, some participants expressed inattention, coldness, anxiety, and rigidity regarding the robot's introverted behaviour expressions. During the interaction with the extravert robot, the emotions experienced by the participants were variously described as: openness, trust, more affective, more commanding, more welcoming, cheerful, more human, less theatral, closer.

Overall HRI evaluation In the extraverted robot condition, some users noted that the robot's personality appeared similar to that of a human, contributing to their comfort during the interaction. The majority of the users appreciated the simplicity of the interaction in both robot's conditions and the absence of judgement towards their mistakes. However, some users observed that the robot's movements were occasionally overly agitated or excessive, leading to feelings of anxiety or inattention in the extravert robot.

5.1.1.2 Thematic Analysis We conducted a thematic analysis based on the feedback that users provided during the semi-structured interview. The approach involves a systematic process of coding and categorising data to uncover underlying themes, patterns, and meanings. Braun and Clarke [53] propose a six-step process for conducting thematic analysis. This approach enables to explore the richness and complexity of qualitative data, providing a deeper understanding of participants' experiences, perspectives, and interpretations. We also considered some notes collected by test evaluators during the interactive sessions with the robot (i.e. users' comments during interactions). In the end, two main themes were identified: one referred to the relationships between the interaction and communication modalities exploited by the robot and the robot's personality; the second regarded the emotions conveyed to users by the robot's behaviour and associated with extravert and introvert traits.

5.1.2 Relationships between robot's interaction modalities and robot's personality

Vocal Modality In the extravert robot, several users found the vocal communication pleasant, warm, friendly, relaxing and cheerful ("… the way of speaking makes it very likeable, I liked that the tone of voice seemed bright and friendly"). Additionally, some users specified that the modulation of the vocal feature gives the impression that the robot was intelligent ("There is a liveliness in its voice! It has a nice joking voice and is not petulant"). The users appreciated the robot's speech style, the feedback provided, and the dialogue style encouraged the user to interact with it ("…I liked how it spoke and responded to me with those catchy sentences. It expressed itself in a beautiful way for me. It seemed almost human. I want to continue talking with him"). However, some users found the extravert personality too talkative and had difficulty focusing on the flow of the robot's speech. Another aspect noted was the limited use of so-called 'paraverbal' aspects. According to some users, "…these aspects make our speech natural, such as laughter, pauses, and some interlude expressions such as "it doesn't sound like it, does it?". Most users perceived the robot's voice as "calmer, quieter, more human and more soothing" as associated with an introvert robot. Another aspect noted by users was the use of conditionals that made the robot's behaviour as seeming shyer "…the voice is less metallic than the first one (extravert), and the use of conditionals makes the robot as appearing insecure". In contrast, four users considered the introvert less fluid, metallic, and artificial, with a deeper voice.

Gestures In the extravert condition, several users stated that the gestures performed are friendly, natural, welcoming, open, "more articulated and quicker". Most users liked the animations and particularly enjoyed the gestures where the robot opened its arms towards the user because they conveyed "a feeling of welcoming and openness toward me. It made me feel comfortable". Several users liked the outward-directed trajectories because they conveyed a feeling of approachability by the robot. "It approached as if it was a person who wanted to ask for something. The first time, the robot approached as if it wanted to have contact". In addition, the users highly appreciated the gestures shown after the user had answered the question because the gestures reinforced the message of a positive or incorrect answer.

At the same time, the gestures did not make the user feel uncomfortable when they got the answer wrong: “The robot did not make me uncomfortable, even though I was wrong. I felt a bit accepted”. In contrast, a few users noted that the robot moves too much, and some animations looked like “gymnastics-like exercises”. Generally, the gestures generated in the introvert condition were considered more measured, polite, formal, natural, but also static and closed. Most users said the introvert robot “moves less and slowly but with human-like gesturing”.

Additionally, many users stated that the robot’s movements conveyed self-enclosure and shyness because the robot “did not look at my face, but looked down and to the side very often”. All users noticed significant differences between the two robot personalities. The extravert’s vocal features and gestures were recognised as joyful, expansive and playful. Also, the forward movements toward users did not bother them. The expansive animations were perceived as expressing openness and availability to the user. Similarly, the introverted robot was perceived as more closed and shyer.

5.1.3 The emotion conveyed by the robots

Emotions We collected some feedback regarding which emotion the robot personalities transmitted to the users during the interaction. Some users stated that when the extraverted robot approached the user, it conveyed a feeling of affection, and was more interactive and energetic. Several users said that the robot was perceived as having emotions: “the robot seemed open and affectionate, almost human because it had its own emotions. In this way, I felt it was closer to me. It gave many expressions of humanity because it approached when a person wanted to ask for something”. During the interaction with the extraverted robot, the robot seemed like it had “…a real conversation with me. It seemed as if the robot was interested in me. I liked the answers it gave me”. In addition, they liked its friendly and open manner because the users did not feel rejected but made them “…enter into its world with its way of doing things”. Further, the extraverted robot was perceived to be empathetic and social: “there was socialization between us. The sympathy conveyed with its movements and answers conveyed a lot of empathy to me”. In general, the majority of users did not feel anxiety or fear when interacting with the extravert robot; instead, the most experienced emotions were calmness, curiosity, serenity, warmth, and trust towards the robot: “…I enjoyed talking to Pepper and did not feel alone. I felt very good and welcomed, not because of the game, but because its open and welcoming gestures made me feel welcome”. However, some users perceived the extraverted robot agitation, and it seemed to them more hurried. The introverted robot was perceived by most users more silent than the extravert one, giving the impression of being more detached and unsociable. Several users appreciated the behaviour of the introverted robot because it conveyed calm and tranquillity, which generated greater self-confidence and peace in users: “…this surprised me and gave me confidence. I felt calm”. Nevertheless, its closing gestures and inward-directed trajectories gave the user a feeling of closure. Overall, the two robot personalities conveyed different emotions to the users. The extravert personality generally expressed feelings of openness and interest towards the users. The introverted robot gave positive emotions to the users, who felt comfortable interacting with it because of its calm and relaxed manner. The users did not feel agitated but relaxed in both conditions. Users detailed the extraverted and introverted traits in line with the parameters identified in the design of the robot’s personalities. In addition, the feedback collected provided us with suggestions to characterise the two personalities further. For example, in the extraverted personality, we can slow down the speed of speech to make the voice more understandable and emphasize the robot’s extraverted traits more. While for the introverted personality, the closing gestures can be better marked and new gestures can be added.

Encouragement and Motivation Users emphasized various aspects that highlight the importance of providing encouragement and motivation during activities involving the robot. One key aspect highlighted by the users is the clear feedback provided by the robot when they made mistakes. As stated by ID3, the robot effectively conveyed the message when an error occurred, utilising gestures, head movements, and eye expressions to indicate the mistake, which is crucial in helping individuals understand and rectify their errors. Furthermore, when users gave incorrect answers, the robot seemed genuinely disappointed and typical human characteristics of disapproval and encouragement were attributed to the extraverted robot. In fact, ID3 stated that “He seemed to get serious when I got it wrong as if he was not happy that I got it wrong…”. ID3 further highlighted that also the robot’s hand and head movements conveyed a sense of awareness regarding users’ incorrect answer. This created a sense of effective interaction and made users feel that the robot truly understood the situation. As emphasized by ID8, ID11, the introvert robot also managed to convey calmness and surprise, instilling confidence in the individual and motivating them to continue the activity. While ID12 and ID4 liked more the confidence of the extraverted robot perceived a “more affectively closer”. This element is essential in creating a supportive environment and inspiring users to perform at their best. Not only did the robot provide encouragement and motivation during the activity, but it also created a sense of welcoming. As described by ID12, the desire to continue playing with the (extravert) robot stemmed not only from the game itself but also from the feeling of being welcomed and comfortable that the robot was able to convey. This aspect demonstrates how the interaction with the robot personalities can generate a sense of pleasure and emotional well-being. Finally, both robot's personalities actively spurred users to improve their performance. As reported by ID23, the robot employed gestures, increased its speed, and appeared dissatisfied when a mistake was made, motivating the individual to strive for better results.

The robot's clear feedback, emotional expression, recognition of errors, transmission of calmness and confidence, creation of a welcoming environment, and active encouragement were all significant factors in motivating and inspiring users during their interactions with both robots.

5.2 RQ2. How can robot personalities impact the user's UX?

To answer RQ2, we used the UES questionnaire to assess the impact on the UX since engagement is an important UX dimension. Thus, we evaluated if there was any significant difference between the overall UES scores of the introvert and the extravert. The Shapiro–Wilk test for normality ($W = 0.87$, $p = 0.005$) gave a p value less than the significance level (0.05), so we could not assume the normality. Thus, we used a paired samples Wilcoxon test ($V = 115$, $p = 0.2062$), which resulted in the two data being not significantly different. We also evaluated users' UX through four additional statements on which they had to rate their level of agreement on a 5-point scale about how much they liked: (i) interacting with the robot on a general level, (ii) how the robot gesticulates, (iii) how the robot speaks, and (iv) comfort in interacting with it (see Fig. 3). Those statements, for the 1st session obtained internal consistency of $\alpha = 0.73$, while for the 2nd one $\alpha = 0.80$. Figure 2a, b shows related results: users felt more comfortable interacting with the extravert robot and liked the gesture more and the vocal feature of the extravert personality. A paired samples t test was carried out to see whether the robot personality had an impact on the UX calculated as the overall score obtained from these four UX-related statements. The Shapiro–Wilk's test ($W = 0.97$, $p = 0.72$) gave a p value higher than 0.05; thus, we can assume normality. Then, a paired t test ($t = 2.13$, $p = 0.044$) showed a significant difference between the two conditions. In particular, the extravert condition (Mean = 16.4, SD = 4.51) was judged better than the introvert one (Mean = 13.9, SD = 5.63). Table 4 reports the UES scores (1*st* interaction: $\alpha = 0.81$; 2nd interaction: $\alpha = 0.94$), for the 1st interaction: the subscale with the highest value was PU, both in the introvert and in the extravert condition. The overall

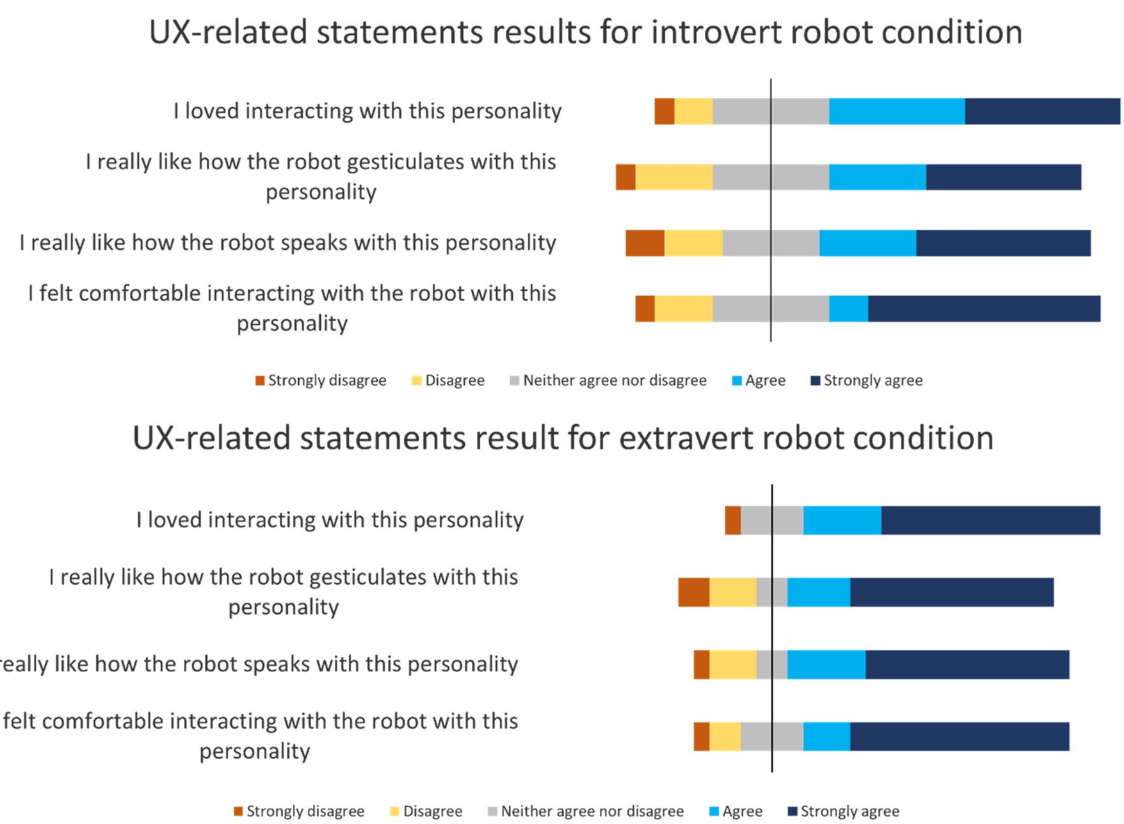

Fig. 3 Users' agreement levels (top part: introvert robot, bottom part: extravert robot)

Table 4 UES values, 1st interaction with the robot

Scale	*M* (SD) introvert robot	*M* (SD) extravert robot
FA	4.13(0.96)	4.55(0.73)
PU	**4.83**(0.37)	**4.69**(0.66)
AE	4.04(0.8)	4.33(0.63)
RW	4.36(0.79)	4.55(0.69)
Overall score	4.37	**4.55**

engagement score was 4.37 (introvert robot) and 4.55 (extravert robot). Table 5 shows the UES scores for the 2nd interaction. The subscale with the highest score was still PU, in the extravert condition. In the 2nd interaction, the overall score was 4.18 (extravert), 3.91 (introvert).

5.3 RQ3: Can the user's personality affect the robot's personality preference?

As Table 6 shows, 15 users preferred to interact with the extravert robot, 9 with the introvert one.

Relationships between User Personality and Preferred Personality In Table 6, we show the preferences of users for a specific robot's personality (columns) according to user's own personality (rows). 13 users (corresponding to 54% of the total) prefer a similar robot's personality while the others chose the complementary one. We also evaluate if there is a relationship between the mini-IPIP questionnaire results and the preference for the robot as collected in the question ("With which personality of the robot you prefer interacting with?"). In particular, we performed a chi-square test to see if there is an association between the type of user personality (introvert vs. extravert user) and the preferred type of robot's personality (introvert vs. extravert robot). We found out that the null hypothesis (namely: there is no association between the two) could not be rejected ($p = 0.97$), showing no significant differences in preference of robot personality depending on user's personality. However, several users highlighted that similar personalities were appreciated.

Table 5 UES values, 2nd interaction with the robot

Scale	*M* (SD) introvert robot	*M* (SD) extravert robot
FA	3.66 (1–43)	3.97 (1.3)
PU	4.02 (1.23)	**4.58** (0.83)
AE	**4.41 (0.65)**	4.04 (1.08)
RW	3.72 (1.36)	4.11 (1.2)
Overall score	3.91	**4.18**

Table 6 A summary of the counts of users' preferences for robot's personalities

	Extravert robot	Introvert robot	Total
Extravert user	11	7	18
Introvert user	4	2	6
Total	15	9	24

6 Discussion

This study suggests that the participants' perceptions of the robot's personalities were significantly influenced by the traits they exhibited. The majority of participants identified the extraverted robot as actually extraverted. This finding suggests that the robot's personality traits were discernible to users and influenced their perception of the robot's character.

Participants perceived the extraverted robot as less shy compared to the introverted one. These perceptions align with the characteristics typically associated with extraversion and introversion, suggesting also that users were able to attribute personality traits to the robots based on their interactions.

These results were in line with the fact that by manipulating the robot's verbal and non-verbal social cues, it was possible for the users to recognise the robot's personality traits. Similar results were obtained by Lee et al. and Esteban et al. [7] [6], who argued that by properly modelling robot social cues, it was possible to convey to humans the robot's overall personality.

From our evaluation, and consistently with previous work [34], it came out that users appeared sensitive to abstract behavioural cues involving gestures, movements and speech-related features, which were generally interpreted consistently with our design intentions. For instance, the extravert robot was judged as wanting to have more contact, being more open, with a bright and friendly tone of voice (and indeed, outward movements and higher pitch were used in our design). In contrast, the introvert robot was judged as calmer, quieter, more measured, and polite (for that personality, the speech rate was lower, and the movements were narrower). In addition, users perceived positive emotions from both personalities (for different reasons): both the openness of the extravert and the calm conveyed by the introvert one were appreciated by users, as they gave them the feeling of interacting in a quite pleasant and natural manner with the robot in both cases.

The use of positive feedback in both robots as suggested in the literature [30] and highlighted by the thematic analysis, encouraged users to continue the interaction and felt fulfilled and understood by the robot. However, the study also revealed that users made more errors on average when interacting with the extraverted robot. Its fast-paced speech may have posed challenges for users, making it more difficult for them to quickly grasp and retain the information provided by the robot.

While we have not found any significant difference between the UES overall scores obtained for the two conditions, the robot personality seems to have affected the rates that the users gave to specific aspects of the interaction (namely: how much they liked the comfort and the overall quality of the interaction with the robot, and how robot gesticulates and speaks). In this regard, users seem to like interacting more with the extravert robot; maybe because (as also highlighted by the thematic analysis), the introvert one conveyed a closed attitude which does not encourage interaction. However, it should be further investigated whether such results would be confirmed in more prolonged sessions.

Furthermore, the users' UX was evaluated through four additional statements. Results indicated that users felt more comfortable interacting with the extraverted robot and preferred its gestures and vocal features.

An overall UX score was calculated from the four statements to examine the impact of robot personality on UX. Normality assumptions were met, and a paired t test revealed a significant difference between the two conditions. Specifically, the extraverted robot condition was rated better compared to the introverted robot.

These findings highlight the influence of robot personality traits on user experience. The extraverted robot was generally preferred and perceived as more engaging, while users valued the perceived usefulness in both conditions. These results contribute to our understanding of how robot personalities can impact the user experience in the context of human–robot interaction for cognitive training.

For the relationships between user personality and preferred robot personality, prior work does not show any clear association in this regard: some studies have shown a preference for a robot that is consistent with their own personality [19], while others have shown a preference for a robot with a complementary personality [34]. Our work confirms this, as we have not found a clear trend apart from a slight users' tendency to prefer the robot personality that more resembles themselves.

While our study has yielded valuable insights, it is essential to consider the limitations inherent in this work. One limitation worth noting is the relatively small sample size of participants involved in the study. Due to the restricted number of participants, the generalizability of the findings may be limited, and caution should be exercised when applying these results to different contexts.

Furthermore, the study highlights the impact of robot personality traits on user performance. The way in which a robot presents itself and interacts with users can have implications for task performance and cognitive outcomes. For instance, a robot that exhibits an extraverted personality may encourage users to be more confident and proactive in completing tasks, potentially leading to improved performance. Conversely, an introverted robot's more measured approach may create a relaxed environment that promotes focused attention and concentration, resulting in enhanced cognitive performance.

Overall, this study highlights the significance of considering personality traits in robots for human–robot interaction in the context of cognitive training. By understanding the influence of these traits on users' engagement, performance, and perception, we can enhance the design and implementation of robots to optimize their effectiveness and user experience in cognitive training scenarios.

7 Conclusion and future work

We have presented a study in which we have provided design indications for representing two personalities in humanoid robot behaviour, and the design criteria that have been implemented in a Pepper application for cognitive training. We report on its impact on a group of older adults, which has been analysed through qualitative and quantitative data. In this study, participants perceived trait differences between the extravert and the introvert robot, which reflected our design intentions.

Additionally, the research seeks to obtain a first appraisal of the robot personalities applied to a serious game scenario.

The data collected in the user test provide some indications as to how well the two robots' personalities have been implemented and if the robot personalities have some effect on the user experience during the HRI. Furthermore, the present study offers promising cues that the two personalities are well distinguished and representative of both conditions and that the users were engaged with the interaction with the robot performing both, preferring the extravert condition. Future work will be dedicated to applying the robot personalities to different cognitive training exercises and for longer trials in order to have more empirical feedback and validation.

APPENDIX

Questions asked to the users after the first interaction, and after the second interaction.

- The robot with this personality looks like (Extravert/Introvert)
- The robot seems silent (1–5)
- The robot seems shy (1–5)
- The robot seems enthusiastic (1–5)
- The robot seems vivacious (1–5)

- The robot's personality is similar to mine (1–5)
- I felt comfortable interacting with the robot with this personality (1–5)
- I really like how the robot talks with this personality (1–5)
- I really like how the robot gestures with this personality (1–5)
- Briefly describe the sensations that the robot transmitted to you
- I really enjoyed interacting with this personality (1–5)
- Justify why you liked or disliked interacting with this personality?
- <UES short form> [51]

Questions asked to the users after experiencing both robot's personalities:

- Which robot personality did you most enjoy interacting with? (Extravert/Introvert)
- Justify why you preferred the first robot
- Justify why you preferred the second robot
- Further comments

Author contributions EZ and FP have designed the proposed methodology. EZ and MM have implemented the prototype. EZ and CS have carried out the data analyses. EZ, CS and FP wrote the manuscript text. All authors reviewed the manuscript.

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Data availability The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

References

1. McColl, D., Nejat, G.: Meal-time with a socially assistive robot and older adults at a long-term care facility. J. Hum. Robot Interact. **2**(1), 152–171 (2013)
2. Pino, O., Palestra, G., Trevino, R., De Carolis, B.: The humanoid robot NAO as trainer in a memory program for elderly people with mild cognitive impairment. Int. J. Soc. Robot. **12**(1), 21–33 (2020)
3. Shibata, T.: Therapeutic seal robot as biofeedback medical device: qualitative and quantitative evaluations of robot therapy in dementia care. Proc. IEEE **100**(8), 2527–2538 (2012)
4. Aronovitch, Charles D.: The voice of personality: Stereotyped judgments and their relation to voice quality and sex of speaker. J. Soc. Psychol **99**(2), 207–220 (1976)
5. Cervone, Daniel, Pervin, Lawrence A.: Personality: theory and research. Wiley, Hoboken (2015)
6. Esteban, P.G., Bagheri, E., Elprama, S.A., Jewell, C.I.C., Cao, H.L., De Beir, A., Jacobs, An., Vanderborght, B.: Should I be introvert or extravert? A Pairwise Robot Comparison Assessing the perception of personality-based social robot behaviors. Int. J. Soc. Robot. **14**(1), 115–125 (2022)
7. Lee, K.M., Peng, W., Jin, S.A., Yan, C.: Can robots manifest personality? : an empirical test of personality recognition, social responses, and social presence in human–robot interaction. J. Commun. **56**(4), 754–772 (2006)
8. Looije, R., Neerincx, M.A., Cnossen, F.: Persuasive robotic assistant for health self-management of older adults: design and evaluation of social behaviors. Int. J. Hum. Comput. Stud. **68**(6), 386–397 (2010)
9. Scherer, K.R.: Personality inference from voice quality: the loud voice of extroversion. Eur. J. Soc. Psychol. **8**(4), 467–487 (1978)
10. Tapus, A., Ţăpuş, C., Matarić, M.J.: User—robot personality matching and assistive robot behavior adaptation for post-stroke rehabilitation therapy. Intell. Serv. Robot. **1**(2), 169–183 (2008)
11. Woods, S., Dautenhahn, K., Kaouri, C., te Boekhorst, R., Koay, K.L., Walters, M.L.: Are robots like people?: relationships between participant and robot personality traits in human–robot interaction studies. Interact. Stud. **8**(2), 281–305 (2007)
12. Celiktutan, O., Gunes, H.: Computational analysis of human-robot interactions through first-person vision: personality and interaction experience. In: 2015 24th IEEE international symposium on robot and human interactive communication (RO-MAN), IEEE, 815–820 (2015)
13. Manca, M., Paternò, F., Santoro, C., Zedda, E., Braschi, C., Franco, R., Sale, A.: The impact of serious games with humanoid robots on mild cognitive impairment older adults. Int. J. Hum. Comput. Stud. **145**(2021), 102509 (2021)
14. Mead, R., Matarić, M.J.: Autonomous human–robot proxemics: socially aware navigation based on interaction potential. Auton. Robot. **41**(5), 1189–1201 (2017)
15. Paradeda, R.B., Hashemian, M., Rodrigues, R.A., Paiva, A.: How facial expressions and small talk may influence trust in a robot. In: International conference on social robotics, pp. 169–178. Springer, New York (2016)
16. Salichs, M.A., Encinar, I.P., Salichs, E., Castro-González, Á., Malfaz, M.: Study of scenarios and technical requirements of a social assistive robot for Alzheimer's disease patients and their caregivers. Int. J. Soc. Robot. **8**(1), 85–102 (2016)
17. Robert, L.P., Jr., Alahmad, R., Esterwood, C., Kim, S., You, S., Zhang, Q., et al.: A review of personality in human robot interactions. Found. Trends Inf. Syst. **4**(2), 107–212 (2020)
18. Goldberg, L.R.: The structure of phenotypic personality traits. Am. Psychol. **48**(1), 26 (1993)

19. Nass, C., Lee, K.M.: Does computer-synthesized speech manifest personality? experimental tests of recognition, similarity-attraction, and consistency-attraction. J. Exp. Psychol. Appl. **7**(3), 171 (2001)
20. Pittam, Jeff: Voice in social interaction, vol. 5. Sage (1994)
21. Türker, B.B., Buçinca, Z., Erzin, E., Yemez, Y., Sezgin, T.M.: Analysis of engagement and user experience with a laughter responsive social robot. In: Interspeech, 844–848 (2017)
22. Hara, F., Kobayashi, H.: Use of face robot for human-computer communication. In: 1995 IEEE international conference on systems, man and cybernetics, intelligent systems for the 21st century, vol. 2, IEEE, 1515–1520 (1995)
23. Moon, Y., Nass, C.: How "real" are computer personalities? psychological responses to personality types in human-computer interaction. Commun. Res. **23**(6), 651–674 (1996)
24. Andrist, S., Mutlu, B., Tapus, A.: Look like me: matching robot personality via gaze to increase motivation. In: Proceedings of the 33rd annual ACM conference on human factors in computing systems (2015)
25. Fu, C., Deng, Q., Shen, J., Mahzoon, H., Ishiguro, H.: A preliminary study on realizing human-robot mental comforting dialogue via sharing experience emotionally. Sensors **22**(3), 991 (2022)
26. Noguchi, Y., Kamide, H., Tanaka, F.: Personality traits for a social mediator robot encouraging elderly self-disclosure on loss experiences. ACM Trans. Hum. Robot Interact. (THRI) **9**(3), 1–24 (2020)
27. Pino, O., Palestra, G., Trevino, R., De Carolis, B.: The humanoid robot NAO as trainer in a memory program for elderly people with mild cognitive impairment. Int. J. Soc. Robot. (2019). https://doi.org/10.1007/s12369-019-00533-y
28. Bechade, L., Dubuisson-Duplessis, G., Pittaro, G., Garcia, M., Devillers, L.: Towards metrics of evaluation of pepper robot as a social companion for the elderly. In: Eskenazi, M., Devillers, L., Mariani, J. (eds.) Advanced social interaction with agents lecture notes in electrical engineering, p. 510. Springer, Cham (2019)
29. Kidd, C.D., Taggart, W., Turkle, S.: A sociable robot to encourage social interaction among the elderly. In: Proceedings 2006 IEEE international conference on robotics and automation, ICRA 2006, IEEE, pp. 3972–3976 (2006)
30. Burgers, C., Eden, A., van Engelenburg, M.D., Buningh, S.: How feedback boosts motivation and play in a brain-training game. Comput. Hum. Behav. **48**, 94–103 (2015)
31. Dryer, D.C.: Getting personal with computers: how to design personalities for agents. Appl. Artif. Intell. **13**(3), 273–295 (1999)
32. Jensen-Campbell, L.A., Gleason, K.A., Adams, R., Malcolm, K.T.: Interpersonal conflict, agreeableness, and personality development. J. Personal. **71**(6), 1059–1086 (2003)
33. Lippa, R.A., Dietz, J.K.: The relation of gender, personality, and intelligence to judges' accuracy in judging strangers' personality from brief video segments. J. Nonverbal Behav. **24**(1), 25–43 (2000)
34. Isbister, K., Nass, C.: Consistency of personality in interactive characters: verbal cues, non-verbal cues, and user characteristics. Int. J. Hum. Comput. Stud. **53**(2), 251–267 (2000)
35. Tay, B., Jung, Y., Park, T.: When stereotypes meet robots: the double-edge sword of robot gender and personality in human–robot interaction. Comput. Hum. Behav. **38**(2014), 75–84 (2014)
36. Kim, S.Y., Kim, J.M., Stewart, R., Kang, H.J., Kim, S.W., Shin, Il.-S., Park, M.S., Cho, K.H., Yoon, J.S.: Influences of personality traits on quality of life after stroke. Eur. Neurol. **69**(3), 185–192 (2013)
37. Koh, J.S., Ko, H.J., Wang, S.M., Cho, K.J., Kim, J.C., Lee, S.J., Pae, C.U., Serretti, A.: The association of personality trait on treatment outcomes in patients with chronic prostatitis/chronic pelvic pain syndrome: an exploratory study. J. Psychosom. Res. **76**(2), 127–133 (2014)
38. Scherer, K.R.: Personality markers in speech. Cambridge University Press (1979)
39. Cheek, Jonathan M., Buss, Arnold H.: Shyness and sociability. J. Personal. Soc. Psychol. **41**(2), 330 (1981)
40. Eysenck, M.W.: Anxiety, learning, and memory: a reconceptualization. J. Res. Personal. **13**(4), 363–385 (1979)
41. Nass, C., Moon, Y., Fogg, B.J., Reeves, B., Dryer, D.C.: Can computer personalities be human personalities? Int. J. Hum. Comput. Stud. **43**(2), 223–239 (1995)
42. Apple, William, Streeter, Lynn A., Krauss, Robert M.: Effects of pitch and speech rate on personal attributions. J. Personal. Soc. Psychol. **37**(5), 715 (1979)
43. Allport, Gordon W.: Studies in expressive movement. Read Books Ltd. (2016)
44. Riggio, R.E., Friedman, H.S.: Impression formation: the role of expressive behavior. J. Personal. Soc. Psychol. **50**(2), 421 (1986)
45. Pandey, A.K., Gelin, R.: A mass-produced sociable humanoid robot: pepper: the first machine of its kind. IEEE Robot. Autom. Mag. **25**(3), 40–48 (2018)
46. Johnson, J., Finn, K.: Designing user interfaces for an aging population: towards universal design. Morgan Kaufmann (2017)
47. WCAG. Understanding Success Criterion, W3C. Retrieved from https://www.w3.org/WAI/WCAG21/Understanding/non-text-contrast.html (2021). Accessed 29 Sept 2022
48. McIntyre, N.J., Tombaugh, T.N.: The mini-mental state examination: a comprehensive review. J. Am. Geriatr. Soc. **40**(9), 922–935 (1992)
49. Brent Donnellan, M., Oswald, Frederick L., Baird, Brendan M., Lucas, Richard E.: The mini-IPIP scales: tiny-yet-effective measures of the big five factors of personality. Psychol. Assess. **18**(2), 192 (2006)
50. Wiggins, J.S.: A psychological taxonomy of trait-descriptive terms: the interpersonal domain. J. Pers. Soc. Psychol. **37**(3), 395 (1979)
51. O'Brien, H.L., Cairns, P., Hall, M.: A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. Int. J. Hum. Comput. Stud. **112**(2018), 28–39 (2018)
52. Di Blas, L., Forzi, M.: The circumplex model for interpersonal trait adjectives in italian. Personal. Individ. Differ. **24**(1), 47–57 (1998)
53. Braun, Virginia, Clarke, Victoria: Using thematic analysis in psychology. Qual. Res. Psychol. **3**(2), 77–101 (2006)