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Social robot in service of the cognitive therapy of elderly people : Exploring robot acceptance in a real-world scenario

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Abstract

Ageing is a global demographic trend that is leading to an increase in the prevalence of cognitive disorders. Innovative healthcare solutions are needed to meet the growing demand for assistance. Robots equipped with advanced artificial intelligence, sensors and social interaction capabilities offer promising tools to address the challenges of cognitive decline in the elderly. The main objective of this study is to assess the acceptance of social robots in healthcare among elderly people. Specifically, we provide the social robot Furhat with the ability to greet patients and assess their cognitive function through neuropsychological tests. The experiment involves 26 elderly people interacting with the social robot Furhat in a clinical setting. A questionnaire is administered in order to carry out our results to understand the usability, perceived ease of use, perceived usefulness, intention to use and comfort in interaction. In addition, a group discussion highlights some opinions and feedbacks among the participants. Our results suggest that the integration of social robots into cognitive testing for the elderly has a positive outlook.

Keywords: social robot, elderly, psycological test

1. Introduction

Based on World Health Organization, the population ageing is a global demographic trend, so the number of individuals affected by cognitive disorders is constantly increasing. This growing demand for assistance has prompted the scientific and technological community to explore new innovative solutions, including Socially Assistive Robots (SARs) integration. In fact, according to Spoladore et al. (2023), monitoring, preventing and minimizing physical and cognitive decline in the elderly is one of the key challenges in healthcare 5.0. Robots, equipped with advanced Artificial Intelligence (AI), sophisticated sensors and social interaction capabilities, are emerging as promising tools to address the challenges of cognitive decay in elderly (Noble and Mende (2023), Chater (2023)). These devices can play multiple roles in the care process, from providing support in daily activities to providing cognitive stimulation, health monitoring and emotional companionship (Ma et al. (2023)). The research community refers to robots that participate in social contexts as social robots : a category of robots designed to interact and communicate with humans in social and everyday contexts (Breazeal et al. (2016)). According to Fong et al. (2003), a social robot should have a set of "human-like social" characteristics that lead to :

1. Establish/maintain social relationships ;
2. Exhibit distinctive personality and character ;
3. Learn/develop social competencies ;
4. Express and/or perceive emotions ;
5. Use natural cues (e.g. gaze gestures) ;
6. Communicate with high level dialogue ;
7. Other agents perception and modeling ;
8. Recognition and understanding of social situations.

Social robot are designed to perform several tasks, ranging from simple conversation and assistance in domestic activities to emotional and social support (Laban (2023)). According to many studies, like Belpaeme et al. (2018), Lytridis et al. (2019) or Ragno et al. (2023), their main objective is to facilitate human interaction, improve people's quality of life and play a significant role in various areas, including health care, education, entertainment and much more. Social robots incorporate advanced technologies, such as natural language recognition, emotional information processing, and perception of the surrounding environment, in order to create more natural and meaningful interactive experiences for humans (Fong et al. (2003)).

We create a new skill for the Furhat social robot [1], enabling it to perform

1. https ://furhatrobotics.com/

cognitive assessments using neuropsychological test. Previous studies, such as Rossi et al. (2020) or Cobo Hurtado et al. (2021) have demonstrated the ability of robots to perform cognitive tests or stimulation. However, the devices used to date have often lacked empathy. This primary concern led us to the Furhat social robot, which was chosen for its unique feature of having a projector on its face, allowing for highly authentic facial expressions. Our research has the following main objectives :

1. Findings to enhance the user experience, ensuring positive interactions between patients and social robots ;
2. A design approach that takes into account the emotional sensitivities of end-users, fostering more empathetic and human-like interactions between patients and social robots ;
3. Enable the social robot to perform neuro-psychological tests on elderly people to assess their cognitive status, to evaluate the feasibility of this approach.

To achieve our goal, we need to pay particular attention to maintain social relationships, develop social competencies, express and perceive emotions, use of gestures, communicate with high level of dialogue, and recognize social situations.

We are conducting a study in a real-world scenario with individuals aged 60 and above. We have established four rooms for the experiment (see Figure 2). In the Room 1, we provide a comprehensive briefing on the tasks to be performed in the other rooms. In Room 2, participants interact privately with a social robot named Furhat, which acts as a psychologist while they carry out presentation phase and cognitive tests. After completing the tests, participants go to Room 3 to complete a questionnaire to assess their comfort level with the social robot. At last, participants proceed to Room 4 where a group discussion is conducted. The results show that participants responded positively to the robot interaction, with a high level of comfort, appreciation, and benefit perception.

Our study has outlined some insights that are crucial for other research. Providing clear instructions from social robots is paramount to enhance the user experience. Moreover, acknowledging the emotional nuances of end-users is essential to facilitate empathetic and human-like interactions. In addition, considering the prevalence of local dialects among elderly populations underscores the challenge robots face in understanding spoken language, especially with speech recognition systems that rely on standardized models.

The paper is structured as follow : in Section 2 we present an overview of the literature. In Section 3 we delve into the materials used in the study. In Section 4 our attention shifts to the methodology employed in this research and to the experiment design. The Section 5 delves into the results analysis. Closing, in Section 7 attention is turned to the critical evaluation of limitations and conclusions.

2. Related works

This section presents overview of the literature, divided into two main parts. The first part asserts the effectiveness of social robots with the elderly population, as well as in relation to cognitive disorders. The second part highlights the suitability of various types of standardised cognitive tests that can be used with the elderly population.

2.1. Social robots, elderly and cognitive disorder

Breazeal (2004) define a social robot as one that "is able to communicate and interact with us, understand and even relate to us, in a personal way". Social robots are increasingly being considered for elderly care to address challenges such as loneliness, the need for companionship, and assistance with daily activities. Social robots are designed to interact socially with humans and may contribute to the health and psychological well-being of the elderly, taking into account their specific needs and characteristics (Battistoni et al. (2023a), Salichs et al. (2016)). Several article explore the potential of social robot with the elderly. Salichs et al. (2020) present a robot platform and describe a software architecture, by focusing on the human–robot interaction. Sharkey and Sharkey (2011) explores the potential of robots as companions and caregivers for the elderly, while also considering the ethical implications of promoting the illusion of meaningful relationships between robots and humans.

The literature review suggests that through interactive activities, mental exercises and games, social robots can provide cognitive stimulation to older people. Social robot can create customized programs that adapt to the needs and individual abilities of patients. This stimulation can help keep the mind active, slowing cognitive deterioration. (Cantone et al. (2023)).

Randomized Controlled Trials (RCTs) suggest that social robots may have positive impacts on agitation, anxiety, and quality of life for older adults Pu et al. (2018). According to Palumbo and Paternò (2020), the use of robots to mitigate and measure cognitive decay in the elderly provides a valuable opportunity to improve the quality of life of patients and facilitate the management of cognitive conditions. Sophisticated robots can assist the elderly with cognitive decay in daily activities, such as preparing meals or taking medications (Wang et al. (2017), Salichs et al. (2018)).

Castillo et al. (2014), Iroju et al. (2017), and Cavallo et al. (2018) independently demonstrate the effectiveness of humanoid robots in the healthcare sector. The key is to provide personalized care through adaptive social capabilities.

According to Rossi et al. (2020), the social robot can perform some neuropsychological tests and collect data for evaluation through a pre-programmed human-robot interaction. They also underline that the social robot used in their study lacked facial expressions, which may affected the robot's perceived sociability.

Several authors, like in Thunberg et al. (2021) and Thunberg et al. (2022), use Furhat Social Robot [2] as a robotic therapist. The Wizard of Oz system developed by Thunberg et al. (2021) uses the Furhat robot interface for patient interaction and a graphical user interface for the therapist. Thunberg et al. (2022) find that older adults have relatively low social acceptance of Furhat and relatively negative attitudes towards robots after meeting Furhat.

Socially Assistive Robots (SAR) are designed to assist the elderly in interacting with digital technology and improving their quality of life through companionship. However, there is limited evidence of their effectiveness, and more robust research is needed Broekens et al. (2009). SAR could have potential benefits in therapy, cognitive training, social facilitation, companionship, and physiological therapy for the elderly. However, methodological issues in studies limit the conclusiveness of these findings Abdi et al. (2018).

Ihamäki and Heljakka (2021) refer to robotic pets as 'serious toys'. These pets have been shown to enhance the social and emotional experiences of the elderly, especially when used in inter-generational group activities. This can lead to an improvement in elderly overall well-being.

2.2. Assessment of Cognitive Functions

Assessment of Cognitive Functions takes place through the evaluation of executive functions or the assessment of the global cognitive profile of pa-

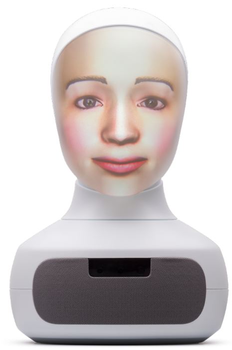
2. https ://furhatrobotics.com/furhat-robot/

tients. The administration of tests is preceded by data collection aimed to providing relevant information and creating a welcoming environment for patients to ensure their comfort during the tests. Several neuropsychological tests can be used to assess cognitive abilities in patients with cognitive impairment or dementia. These assessments can test the specific executive function (e.g. Trail Making Test by Ashendorf et al. (2008), Digital Clock Test by Chan et al. (2021), Memory Span by Belleville et al. (1996), etc.) or be organised into a standardised battery. The most common batteries used to test older people are Mini-Mental State Examination (Folstein et al. (1975)), Brief Neuropsychological Examination (Bisiacchi et al. (2003)), and The Montreal Cognitive Assessment (Nasreddine et al. (2005)).

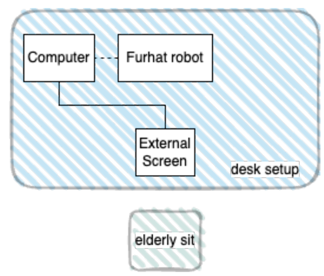
3. Furhat Social Robot and Neuropsychological Tests Battery

The robot choice for our experiment is the Furhat robot, developed by Furhat Robotics. The Furhat robot is an advanced social robot designed to have a human-like appearance. It has an expressive face displayed on a screen, capable of conveying a wide range of emotions and expressions to enhance human-robot interaction. Furhat can understand and respond to spoken language naturally, facilitating seamless communication. With its emphasis on natural interaction, the robot engages users through gestures, facial expressions, and verbal communication, creating a lifelike interaction experience. The customizable appearance of Furhat's face allows for adaptation to different applications and preferences. Furhat robots are designed to be versatile and customizable, with the ability to be programmed with various skills and applications to suit different use cases. These skills can range from simple interactions like greeting people and providing basic information, to more complex tasks such as conducting interviews, delivering presentations, or even providing therapy. To achieve our objective, we have equipped the robot with a new skill[3] that enables it to conduct cognitive tests with the elderly. The development of skills for Furhat robots involves programming using various software tools provided by Furhat Robotics, including their proprietary software development kit (SDK). This SDK allows developers to create custom applications and behaviors for the Furhat robot, integrating features.

3. https ://docs.furhat.io/skills/



(a) Furhat Social Robot



(b) Devices Schema

FIGURE 1 – Overview of the robot used, and the communication between the devices used.

Unlike other robots such as DARwIn-OP [4], Pepper [5], QTrobot [6] or NAO [7], Furhat has a human-like face also in terms of both shape and dimensions. Furhat allows developers to control the voice, personality, expression, and spatial awareness of the robot. These factors are considered paramount for this study. Furthermore, we use a computer and an external screen to ensure the proper execution of tests between the robot and participants. The external screen enables participants to perform some items with ease. Figure 1 shows an overview of the communication between the devices used.

The Furhat robot is equipped with a range of neuropsychological tests that are included in the most commonly used battery (MoCA, MMSE and BNE). These tests assess the following cognitive domains :

Visuospatial and Visuoconstructive domain. It assesses mental flexibility, which is a key factor in processing speed, sequencing, and visual-motor skills. To asses this domain we use :

1. The *Trial Making Test* (TMT) by Reitan (1958) and Bowie and Harvey (2006), in which the subject is instructed to connect a set of numbers and letters as quickly as possible while maintaining accuracy. In

4. https ://en.robotis.com/model/page.php ?co_id=prd_op
5. https ://www.aldebaran.com/en/pepper
6. https ://luxai.com
7. https ://www.aldebaran.com/en/nao

alignment with the MoCA guidelines, we opted for the utilization of the short version of the TMT for our assessment.

Language Domain. It assesses the linguistic ability to form sentences, use semantic memory, understand and follow oral and written instructions. To asses this domain we use :

1. The *naming* item assesses the proficiency in using semantic memory upon the presentation of a familiar picture the elderly has to named it.
2. The *sentence repetition* item assesses language capabilities relate to working memory and attention.

Executive domain. It tests a set of cognitive processes known as executive functions, which are necessary for the cognitive control of behaviour. These functions include attention, cognitive flexibility, working memory, and fluency. Additionally, this domain includes items that assess temporal and spatial orientation, as well as abstraction ability. To asses this domain we use :

1. The *attention* is tested through two items : a series of 7 subtractions starting from 100 ; and an auditory attention trial where the subject has to press a hand on the table when he hears the letter A.
2. The *digit span* test measure verbal short term and working memory. It tests both Forward Digit Span and Reverse Digit Span. The first test involves repeating a sequence of numbers in the same order as spoken by a robot, while the latter requires the subject to repeat the sequence of numbers in reverse order.
3. The *verbal fluency test* test demands the coordination of lexical and semantic knowledge, the ability to transition between words, working memory, strategic searching, and the suppression of irrelevant words. The individual is asked to generate as many words as possible that starts with letter F in one minute.
4. The *abstraction* task requires the subject to identify similarities between two words, using semantic knowledge.
5. The *memory* task involves repeating a series of names to test short-term memory and then recalling them after 5 minutes to test long-term memory.

6. The *orientation* in time and space test confirms the subject's awareness of their location and the current day, month and year.

4. User Evaluation and Experiment Design

The methodology employed is outlined in this section, starting with the inclusion and exclusion criteria for participant selection, followed by a detailed description of the experiment design.

4.1. Participant selection

Care facilities, social centers, and health networks collaborated to recruit older participants who met the inclusion criteria highlighted in this section. Potential participants, their families, or assistants were informed about the study objectives, procedures, and the opportunity to participate voluntarily through information sessions. The primary sample comprises 30 subjects, ranging in age from 60 to 84 (with a mean age of 65.08). Among them, 17 participants are female, and 13 are male. Unfortunately, four individuals were unable to complete the test as they spoke in their local dialect, which the social robot could not comprehend. So, the final sample consists of 26 participants : 16 female and 10 male. All participants are informed that they will be observed during the experiment. Signs have also been put up for clarification. All procedures performed in studies involving human participants were submitted to the ethical standards of the institution.

4.1.1. Inclusion Criteria

The study's objective is to include individuals aged 60 and over who live in assisted living facilities, community environments, or their own homes.

4.1.2. Exclusion Criteria

Participants with a history of severe psychiatric illnesses or with a diagnosis of dementia were excluded from the study. In addition, individuals who are unable to communicate effectively or engage in basic interactions have been excluded from the study due to the nature of the study's assessment methods, which require a certain level of basic communication.

4.2. Experiment Design

To achieve our goal, we rely on the expertise of two psychologists, who confidently embrace the use of new technologies to enhance the quality of life for their patients. The experimentation was scheduled for three sessions in a single day, with different numbers of participants in each session : 9 in the first, 10 in the second, and 7 in the third (see Table 1). The experiment is designed in one of the offices of the psychologists. Four rooms (as shown in Figure 2) are chosen for the experiment, in order to divide each session into four main phases, as follows :

1. Phase 1 in **Room 1** (see Figure 3a). The participants are welcomed with refreshments and briefed on the next two phases of the test. They are informed that they will be alone with the Furhat robot during the cognitive tests. Individual entrance and exit times of participants are recorded upon entering the room.
2. Phase 2 in **Room 2** (see Figure 3b). When participants enter the room, they are greeted by the Furhat robot's gaze and its smile. The robot requests the participant's name and uses it in subsequent questions. Futhat tells the participant to sit in front of him, and as soon as the participant follows the instruction, the Futhat robot starts the interaction. Furhat gives to the participant the instructions to start the cognitive tests.
3. Phase 3 in **Room 3**. After completing the cognitive tests, the Furhat robot directs the participant to proceed to the other room to answer a questionnaire. We use a modified version of the questionnaire used in the study by Battistoni et al. (2023b), who use the *Technology Acceptance Model* (TAM) questionnaire. We discuss this in more detail in the section 4.2.3. We will describe all the items of the questionnaire in the Table 2.
4. Phase 4 in **Room 4**. After completing the questionnaire, the participant goes to Room 4, where he/she meets their relatives and the other participants who have already completed the cognitive tests. Also in this Room, the participants are welcomed with refreshments and briefed. In this room, a psychologist observes and listens to the participants' feedback on the experience.

These phases and Rooms create a structured experimental design, enabling seamless progression of participants through various interactions and assessments.

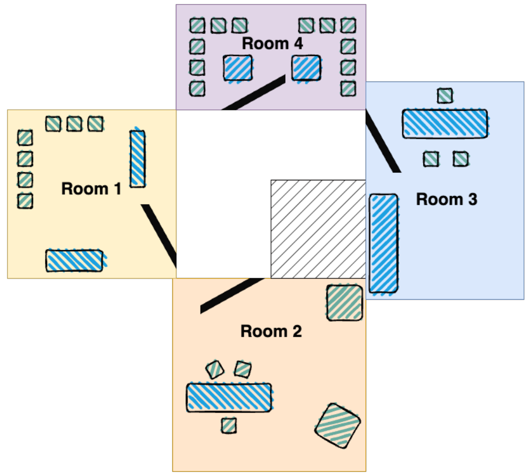


FIGURE 2 – Four rooms draw setup

In the next subsections 4.2.1, 4.2.2, 4.2.3 and 4.2.4 we describe in detail each phase in each Room.

4.2.1. Participant welcomed (Room 1)

In Room 1 (see Figure 3a), we aim to encourage a first moment of socialization by providing participants with refreshing drinks and information on the next steps of the test. This creates an informal and comfortable environment, allowing participants to become familiar with each other. This first phase is strategic as it facilitates group discussion in Room 4. In fact, this first interaction promote an open and collaborative discussions. Familiarity among participants can help to reduce communication gap, leading to a more open and collaborative atmosphere during discussions in Room 4.

No data is collected during this phase.

4.2.2. Interaction with Furhat (Room 2)

Upon entering Room 2 (see Figure 3b), participants are greeted by the Furhat robot's gaze and smile. This intentional design of the social robot aims to facilitate a more natural and pleasant interaction with participants. This creates a welcoming and comfortable environment, encouraging participants to engage in interaction in a positive manner. This approach is strategic in ensuring that the interaction with the robot is not only technically effective, but also leaves the participants feeling comfortable and satisfied with their overall experience. Moreover, the robot's ability to follow the participant with its eyes adds a feeling of vitality, making the interaction more engaging and authentic.

The interaction begins with the robot requesting the participant's name and using it in subsequent questions or sentences. This personalised approach aims to establish a more empathetic connection between the participant and the robot, contributing to greater comfort during the cognitive testing phase.

In this phase, we collect engagement duration metrics (see Table 1), measuring the total duration of interaction between each participant and Furhat. This rating allows us to examine the arrangement and ease with which participants interact with the robot over time. Specifically, after several external tests, we define an optimal duration for a successful interaction is 20 minutes or less. If an interaction exceeds 20 minutes, it may indicate that the robot had difficulty understanding the person, suggesting that something went wrong during the interaction. The 20 minute time-frame includes the following key stages of interaction with the social robot in Room 2 :

1. The social robot starts the interaction by recognising the participant as he or she enters Room 2.
2. The participant is guided to take a seat in front of the robot after a previous request from the social robot.
3. The robot starts the interaction phase, which aims to "getting know" the participant better. At the same time, it aims to create a comfortable environment for the participant.
4. The cognitive test is carried out.
5. At the end of the cognitive test, the robot asks the participant to leave Room 2 to continue of the experiment in Room 3.

After the 20 minute interaction limit, other factors may affect the length of engagement. The factors that could affect the interaction could be related to the older person's non-acceptance of the technology or a difficulty in communicating with the social robot, which may not understand the participant's responses.

4.2.3. Questionnaire (Room 3)

Depending on the participants' difficulties in completing the online questionnaire on tools as Google Form, we print out each questionnaire. This allows older people to answer the questions in a very simple way, using the common 'x' symbol to check their answers. If one of the participants has

	Start	Finish	Engagement duration
I Group	11 :08 :16	11 :30 :00	21m 44s
	11 :34 :58	11 :45 :25	10m 27s
	11 :50 :25	12 :06 :17	15m 52s
	12 :11 :17	12 :26 :32	15m 15s
	12 :31 :32	12 :44 :48	13m 16s
	12 :49 :48	12 :58 :47	08m 59s
	13 :03 :47	13 :18 :36	14m 49s
	13 :23 :36	13 :42 :33	18m 57s
	13 :47 :33	13 :59 :24	11m 51s
II group	14 :10 :00	14 :19 :56	09m 56s
	14 :25 :30	14 :38 :45	13m 15s
	14 :48 :22	15 :03 :18	14m 56s
	15 :08 :10	15 :21 :44	13m 34s
	15 :30 :03	15 :47 :11	17m 08s
	15 :55 :55	16 :05 :22	09m 27s
	16 :15 :40	16 :30 :15	14m 35s
	16 :35 :22	16 :52 :09	16m 47s
	17 :00 :30	17 :15 :05	14m 35s
	17 :20 :40	17 :35 :18	14m 38s
III group	17 :47 :22	18 :02 :55	12m 33s
	18 :15 :10	18 :30 :09	14m 59s
	18 :40 :30	18 :50 :15	09m 45s
	18 :55 :22	19 :12 :19	16m 57s
	19 :25 :40	19 :40 :18	14m 38s
	19 :50 :22	20 :05 :05	14m 43s
	20 :17 :30	20 :29 :55	12m 25s

TABLE 1 – Engagement duration of interaction

difficulty understanding the question, a psychologist will enter Room 3 to provide an explanation and then promptly leave to avoid causing stress during the response. To make impossible for us to recognise their answers, each participant has a unique identifier. The questionnaire shows in Table 2 is administered to the participants in Room 3, immediately after their cognitive test in Room 2. The aim of the survey is to assess participants' perceptions and ease of interacting with a social robot in a clinical scenario.

The questionnaire we use is based on the Davis et al. (1989)'s TAM and it is also modified by Battistoni et al. (2023b) to evaluate the user's experience in interacting with the social robot. In general, the TAM implies that the more an application or device is expected to be easy to use, the more likely it is to be seen as useful to the user and the more likely it is to encourage adoption of the technology. The main item in the TAM is the user's intention to use a technology, and this intention is shaped by their *Perceived Usefulness* (PU) and *perceived Ease of Use* (EU). We add *Comfort in Interaction* (CI) and *Robot-Human Comparison* (RH) to carry out our study. We developed these additional scales in collaboration with a psychologist to increase the depth and scope of our analysis. Through iterative discussions and feedback sessions, we refined the scales to ensure their validity and reliability in capturing relevant variables. This collaborative process enabled us to tailor the scales specifically to our research objectives.

The final refined questionnaire consists of 15 items divided into five scales :

1. **EU** : this subscale consists of 4 items and measures the extent to which a person believes that using a particular system is effortless ;
2. **PU** : this subscale is composed of 2 items and measures the subject's perception of the usefulness of SARs in their daily life ;
3. **IU** : this is a single item subscale and measures the participant's intention to use the SARs.
4. **CI** : this subscale is composed of 6 items, it tests the comfortable feeling in interacting with the robot ;
5. **RH** : this subscale consists of 2 items. The participant evaluates their current level of attention and anxiety when approaching the robot compared to what they would experience when interacting with a human.

The questionnaire responses are recorded on a five-point Likert scale, ranging from 1 to 5 (*strongly disagree* to *strongly agree*). Please note that for specific items (E03, C01, and HR2) a reverse scoring mechanism is applied. This means that a higher score reflects disagreement or a negative response, while a lower score indicates agreement or a positive response. In the Table 2 we use a symbol **(*)** to indicate questions with reverse scoring. We consider this reversal scoring in the data analysing, to ensure accurate representation of results.

Based on the literature, the five-point Likert scale enhances response rates and quality while decreasing respondent frustration Samuels (2017).

4.2.4. Group discussions (Room 4)

During a group discussion in Room 4, a psychologist asks two open questions to the participants regarding their experience with a robot and their thoughts on the potential of having a robot at home to manage their cognitive health. The questions are the follows :

1. *How was your experience interacting with a robot ?*
2. *What did you think about the opportunity to have a robot at home ?*

Open-ended questions do not restrict participants to pre-defined categories. This allows for a more detailed and contextually rich exploration of participants' thoughts and feelings.

(a) Photo of Room 1 (b) Participant in Room 2

FIGURE 3 – Photos of Rooms 1 and 2

The first question allows participants to share their personal and subjective experiences. This type of question allows for the expression of emotions, perceptions, and aspects of interactions that may not be captured by predefined responses.

The second question asks participants to consider how they feel about the potential benefits and difficulties of integrating robotic technology into their home environment.

5. Results analysis

We divide the results session into two main subsections in order to provide a clearer visualisation of the results. In the first Section 5.1 we analyse the results of the questionnaire administered by the psychologist in Room 3. In Section 5.2 we report the qualitative analysis of the group discussion carried out in Room 4. All of the authors of this paper work together with a qualified psychologist to conduct comprehensive analyses. This interdisciplinary approach ensures a rigorous examination of the data, incorporating both technical expertise and psychological insight. By drawing on the different perspectives and specialised skills of each contributor, our analyses are complemented, resulting in robust findings and refined interpretations.

5.1. Analysis of the questionnaire (Room 3)

Table 2 reports the results of the questionnaires : the first column reports an alphanumeric code used to label the items ; the second column describes the item ; the third column reports the mean (M) ; and the last column reports the coefficients of variation (CVs). All participants completed the questionnaire, resulting in a total of 390 responses collected from 26 individuals. It is important to note that all EU items show a low coefficient of variation, indicating that all participants agree and give scores around the mean. Participants found interacting with the robot to be easy, as indicated by the mean scores of all the items on the EU subscale (excluding the reverse item EU03) being greater than 4 points. Additionally, item EU03 suggests that interacting with the robot required little effort. The CI scale assessed the participants' level of anxiety. All participants reported feeling comfortable and enjoying their interactions with the robot. They felt they were not being judged by the robot and it put them in a relaxed state. The high agreement among the participants was indicated by the coefficients of variation and mean.

There was a disagreement regarding the reverse item CI01 (CVs=0.60), CI04 (CVs=0.37), and CI05 (CVs=0.37). This disagreement reflects different opinions about the perceived empathy of robots and the discomfort felt when a robot fails to understand responses. The results of the study demonstrate a high level of agreement among participants, with both items on the PU scale showing a mean greater than 4, particularly 4.50 and 4.83. This indicates a strong recognition among participants of the usefulness of a SAR to support wellness and healthcare for themselves and their relatives. Also the low CVs' value on both items indicating a high level of agreement among all participants. At the end of the study, participants were asked to choose between being tested by a human or a robot. The results showed no agreement among them (RH1 mean = 2.42 with CVs = 0.49). However, participants reported feeling more focused when being tested by a robot (M = 4.25, CVs = 0.27).

Moreover, the Table 3 shows the tests' duration metrics.

5.2. Analysis of the group discussion (Room 4)

This section aims to analyse and highlight the dynamic interactions and reflections observed during the group discussion, providing valuable insights into participants' perceptions and experiences of robot interaction in the context of cognitive testing.

The participants' positive response on entering Room 4, as evidenced by their smiles and bright eyes, suggests a positive impact of the robotic interaction. The spontaneous comments, such as «*Very nice experience*», «*It's like a magic*» and «*It would be nice to have this at home*», confirm that

Item	Description	M	CVs
EU 01	Communicating with the robot was simple.	4.83	0.08
EU 02	It was easy to understand what the social robot wanted to know from me.	4.08	0.21
EU 03	I took a lot of effort in talking to the social robot. (*)	1.41	0.45
EU 04	Robot interface made interaction easy and enjoyable	4.50	0.14
CI 01	I felt tense and agitated while talking to the social robot. (*)	1.42	0.60
CI 02	Talking to the social robot made me feel comfortable.	4.25	0.17
CI 03	I enjoyed interacting with a social robot.	4.33	0.11
CI 04	Sometimes I felt that the social robot understood me.	3.58	0.37
CI 05	I did not feel so worried or uncomfortable when I did not know how to respond.	3.58	0.37
CI 06	In taking the test with the social robot I had little anxiety, I did not feel judged.	4.75	0.09
PU 01	I think it could be useful to do some training for my mind with a robot at home.	4.50	0.25
PU 02	I would recommend to other people the use of these robots to train their minds.	4.83	0.08
IU 01	I think I would do cognitive exercises daily with the social robot.	3.91	0.26
RH 1	I would feel more comfortable with a human operator. (*)	2.42	0.49
RH 2	Doing these tests with the Robot made me concentrate more than with a human operator.	4.25	0.27

(*) item reverse

Table 2 – Questionnaire results.

Metrics	Values
Total test duration	366,016667m $\simeq$ 06h 10m
Average test duration	366,016667m/26 $\simeq$ 14m 07s
Maximum test duration	21m 44s
Minimum test duration	08m 59s

Table 3 – Tests' duration metrics

they found the interaction enjoyable and potentially valuable in a domestic setting.

The participants' enthusiasm suggests a positive emotional response to the robot, indicating engagement and pleasure. These reactions are important indicators of the success of the robotic interaction and potential openness to similar technologies in daily life.

> *It could be useful to have a personal assistant at home to keep the mind active and have someone to converse with. This would be beneficial for mental stimulation.*
>
> - Participant 9

A group of 25 participants reported conversing with robots easily and found the experience positive for mental fitness, and recommendable for training. They described the conversation as fluid, but 2 of them found the robot's voice artificial.

> *I will share this experience to my friends and my relatives. It is an effective way to maintain brain health.*
>
> - Participant 16

Social robot technology is often considered the future and is being embraced by many. It has been shown to provide good companionship for elderly individuals who live alone at home.

> *I gave it* - refer to a social robot - *a score of 4 out of 5 for ease of use. There was one instance where the instruction was unclear [...], overall there were no difficulties in conversation.*
>
> - Participant 20

The social robot received a good evaluation for EU, indicating a generally positive assessment. However, the evaluation highlights the critical importance of clear instructions for a positive user experience. According to the participant, some commands need to be spoken more slowly.

> *The robot asks me to repeat the name of my deceased wife, it makes me feel uncomfortable.*
>
> - Participant 1

Accurate language comprehension is crucial for robots. This is exemplified by two participants' discomfort when robots struggled to comprehend and requested repetition of their deceased partner's name. Therefore, it is crucial to ensure that social robots have precise language comprehension skills. Precision in comprehending and responding to participants' language is essential for a comfortable and effective conversation. Improving the linguistic capabilities of social robots to address sensitive topics is crucial for enhancing the user experience and creating a more empathetic and accommodating environment.

We use thematic analysis (TA) to analyse the qualitative data and identify the main themes of participants' ideas and future prospects. As Clarke and Braun (2013) show, TA is a useful method for analysing qualitative data in both large and small datasets.

Category	**Subcategory**
Positive perception	Enhanced Mental Stimulation
	Brain Health Promotion
Emotional sensitivity	User-Friendly Interface
	Emotional Comfort
	Uncomfortable Interactions

Table 4 – Thematic analysis

The two main categories in the Table 4 summarise the key themes from the data collected in the Room 4. The categories providing insights into the potential benefits and user experience considerations when using social robots for cognitive testing with elderly individuals.

The *positive perception* category includes statements that express the potential benefits of social robots for cognitive well-being, such as the desire for mental stimulation, companionship, and the proactive promotion of positive experiences to others.

The *emotional sensitivity* category focuses on the evaluation of the user experience with social robots. It includes aspects related to EU, constructive feedback on unclear instructions, and sensitivity to emotional comfort, particularly in cases involving personal and sensitive issues.

6. Discussions

The distinctive feature of our study is the use of the Furhat social robot, which is characterised by its ability to project authentic facial expressions, setting it apart from other social robots used in cognitive testing studies. The critical role of empathy in human-robot interactions is underscored by our choice of the Furhat social robot. Its facial projection capabilities provide a level of expressiveness that is paramount in the social robotics landscape. Other robots have demonstrated their ability to perform cognitive tests. However, the emotional aspect of human-robot interaction is often overlooked (Rossi et al. (2020), Cobo Hurtado et al. (2021)). Furhat's ability to authentically convey facial expressions adds a new dimension to cognitive testing, potentially influencing participants' experiences and responses.

The data collected in Rooms 3 (questionnaire in Chapter 4.2.3) and Room 4 (group discussion in Chapter 4.2.4) provide insight into the multifaceted nature of the participants' interactions with the Furhat social robot during the cognitive tests. The questionnaire responses show that participants had a positive overall perception of the social robot used in the study. The low coefficients of variation in the EU items suggest that participants found it easy to interact with the robot. This is consistent with the observations in Room 4, where participants expressed enthusiasm, found the experience enjoyable, and even considered the presence of the robot in a domestic setting.

The high mean scores on the PU scale indicate that participants strongly recognize the social robot's utility in supporting wellness and healthcare. This aligns with the thematic analysis, which highlights positive perceptions and the desire for mental stimulation and companionship.

The varying opinions on the preference to be tested by a human or a robot underlines the diversity of user choices in cognitive testing scenarios. However, a potential advantage of using social robots for certain aspects of cognitive assessment is suggested by the observation in Room 4. Participants' positive emotional responses, as evident from their smiles and positive comments, suggest that the social robot had a positive impact. Participants expressed a desire for a home personal assistant, highlighting the potential practical applications of social robots across cognitive testing contexts.

However, there are concerns about the artificiality of the robot's voice and instances where it made participants uncomfortable by requesting repetition of sensitive topics. These issues highlight areas for improvement, which aligns with the thematic analysis. The analysis emphasizes the importance of emotional sensitivity in social robots, particularly when dealing with personal and sensitive issues.

We have to consider that this study is limited in its scope, in fact we have to consider that more elderly people speak in their local dialect and make difficult a correct dialogue with the robot. This leads to the exclusion of some elderly people from the sample. Another limitation is the small size of the sample, which does not allow us to make a statistical analysis of the quantitative data collected, even if it is supported by qualitative data collected during the group discussion.

7. Conclusions

The responses collected suggest that the integration of social robots into cognitive testing for elderly individuals has a positive outlook. The participants express a willingness to embrace such technology, as they see its potential benefits in maintaining mental activity and social engagement in their daily life. The participants emphasized the need for continuous technological improvement and a more precise understanding of emotional dynamics. Constructive feedback from participants highlights critical considerations : enthusiasm, recognition of practical benefits and positive emotional responses are significant skills that we need to include in a social robot.

Our study identified key findings that will be useful for future studies, highlighted in the Chapter 5.2. It is essential to provide clear instructions from the social robot to ensure a positive user experience [8] 5.2.Additionally, it is important to consider the emotional sensitivities of end-users to facilitate a more empathetic and human-like interaction [9] 5.2. We also find that it is important to remember that many older people speak in local dialects. This linguistic diversity underscores the complexity of human communication, particularly in contexts where regional variations significantly impact language understanding. This can make it difficult for robots to understand spoken language, especially when using speech recognition systems based on a standardised language model.

8. "*I gave it* - refer to the Furhat Social Robot - *a score of 4 out of 5 for ease of use. There was one instance where the instruction was unclear [...], overall there were no difficulties in conversation.*" (Participant 20) - Highlighted in the Chapter

9. "*The robot asks me to repeat the name of my deceased wife, it makes me feel uncomfortable.*" (Participant 1) - Highlighted in the Chapter

Future studies could explore the collection of more metrics concerning interactions with the robot.

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