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Interaction Assessment of a Social-Care Robot in Day center Patients with Mild to Moderate Cognitive Impairment: A Pilot Study

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Abstract

As dementia-induced impairments of daily functioning escalate, novel cognitive stimulation techniques utilizing technological advances, like social robots, have surfaced. This study examines the interaction level of the EBO social-care robot with day center patients in Cáceres, Extremadura, Spain. The study uses systematic video analysis as a method of interaction assessment. This observational pilot study was performed on patients above 65 with mild to moderate cognitive impairment (Minimental State Examination $\geq$ 21) receiving cognitive therapy at the AZTIDE social and health center. Two individualized 10–15 min sessions, replicating the Wizard of Oz technique, were conducted per participant, with the human operator's commands being unnoticeably executed by the EBO robot. Of the six participants involved, all maintained complete eye contact with the robot, with 83.3% of the interactions recording maximum attention. Participants felt comfortable and calm, rating conversational factors such as attentiveness and naturalness as 'good' or 'excellent'. The high interaction level with the EBO robot suggests it as a promising tool for cognitive stimulation in patients with mild to moderate cognitive impairment. The systematic video evaluation also appears effective in assessing user–robot interaction, thus underscoring its potential utility in future social robotics research.

Keywords Social robotics · Cognitive stimulation · Robot acceptability

Abbreviations

JMIR:	Journal of Medical Internet Research
MMSE:	Mini Mental State Examination

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1 Introduction

The world's population is ageing. According to a United Nations report, 2018 was the first time that the 65+ population group outnumbered the under-5 s, and the estimates suggest that by the middle of this century, the over-65 s will outnumber adolescents and young people aged 15–24 [1]. While the population is expected to increase in all age groups within the European Union in the coming decades, estimates suggest that the over-65 age group will experience the greatest increase [2]. This demographic change will lead to an increase in neurodegenerative diseases [3]; consequently, the number of people living with dementia will

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also increase. Thus, it is expected that, by the beginning of the next decade, the total number of people with dementia will reach 82 million [4]. Dementia is a condition that progresses the most in older adults, making it one of the most dependency-generating diseases of the current century [5].

Dementia is a neurodegenerative disease of the central nervous system, which causes a progressive loss of brain function, affecting nerve cells and the interconnections between them. Depending on the area where it occurs, this will lead to alterations in one or other cognitive processes. In all dementia cases, there is a progressive loss of memory and other basic functions and the impairment of higher cognitive functions responsible for thinking and behavioural control [6]. Consequently, there will be a significant decline in autonomy to carry out activities of daily living, resulting in a decline in functional performance [6]. Therefore, it is essential to use appropriate communication strategies to interact with people suffering from dementia [7]. Non-pharmacological therapy is useful for improving symptomatology and slowing the progression of symptoms [6], with cognitive stimulation standing out among them as responsible for improving the functionality and quality of life as it is effective in improving cognitive ability [5].

Old age is a critical stage strongly influenced by the physical environment and other factors, such as physical and/or cognitive impairment and chronic diseases [8]. The environment can act by imposing restrictions or providing opportunities for ageing well [9]. The involvement of new technological solutions can enhance this positive impact of the environment on ageing [9].

Thanks to these technological advances, resources aimed at cognitive stimulation have emerged [10]. In fact, the importance of social robots is given by the ease with which they can promote interaction with older adults and the development of cognitive stimulation activities [10]. In recent years, a wide variety of robotic technologies have been developed in the field of elder adults' care. Thus, there are tools focused on ambient assisted living, which are represented by intelligent home environments [9, 11], robotic solutions for care, assistance and rehabilitation purposes whose use could improve the quality of life of older adults [12] and social robots, aimed at increasing the social interaction of the elderly by reducing isolation [11, 13] and loneliness through the development of conversational opportunities [14]. These solutions have become an important source of support for the primary caregiver. According to data from a literature review [15], interventions developed by robots in monitoring activities, managing risk situations and improving access to objects were identified as preferential [15]. However, in community activities, the preferred activities were related to alerting about taking medication and promoting healthy behaviours by motivating and reminding to do physical exercise, and maintaining data privacy when exchanging information with care teams was reported as positive [15].

Hence, many authors state that social robotics oriented to the therapeutic and conversational field is being considered as a novel intervention aimed at people with dementia and their caregivers [3, 16–18]. Some research shows that thanks to the use of these technological resources, there is an improvement in the mental health of older adults, in particular in the cognitive function [6, 19, 20], as well as in emotional response, physical contact and social participation [21]. All of them aim to improve human–robot interaction and communicative capacity. It is important to highlight the Nao robot from the Robsen project, which was conceived as a tool for cognitive stimulation in people with dementia [22–24], Brian 2.1 [25], the Ifbot communication robot [10], the Loomo robotic system, mainly intended for social assistance [7], the Mario robot [24] and Ludwig [25]. However, according to a recent review, the PARO seal robot has been identified as the most widely used among older adults [18, 25, 26].

One of the most critical aspects regarding implementing these technologies is the acceptance of the interaction by the user. According to research conducted in Sweden [26], different social actors suggest the existence of negative attitudes towards the use of assistive robots. The authors considered these may be determined by a lack of familiarity with technologies and fear of the unknown [26]. Numerous studies have found positive acceptance by older adults [13, 27], although, among assistive robots, these people prefer physical robots over virtual robots [28]. The results of a study involving elderly people with and without cognitive impairment rated the interaction with a communication-enabled assistive robot as interesting and enjoyable, with low to moderate levels of acceptance of the robot and high levels of perceived ease of use and enjoyment [13], scores that remained stable throughout the study. This interaction has important implications in the social area, and the results of robot use were seen as having high attractiveness and social presence [28], making older people less lonely [29] and improving mood [29]. In older adults with cognitive impairment, engagement, enjoyment of interaction, and verbalization of positive comments seem to reflect acceptance of interaction [30]).

This study aims to address this need by leveraging technological advancements, specifically through social robots. Our **main objective** is to examinate the interaction levels between dementia patients and the EBO social-care robot in a day center setting in Cáceres, Extremadura, Spain. By utilizing systematic video analysis as our primary method for assessing these interactions, we aim to provide a detailed and objective measure of the engagement and response of elderly patients aged 65 and above with mild to moderate cognitive impairment.

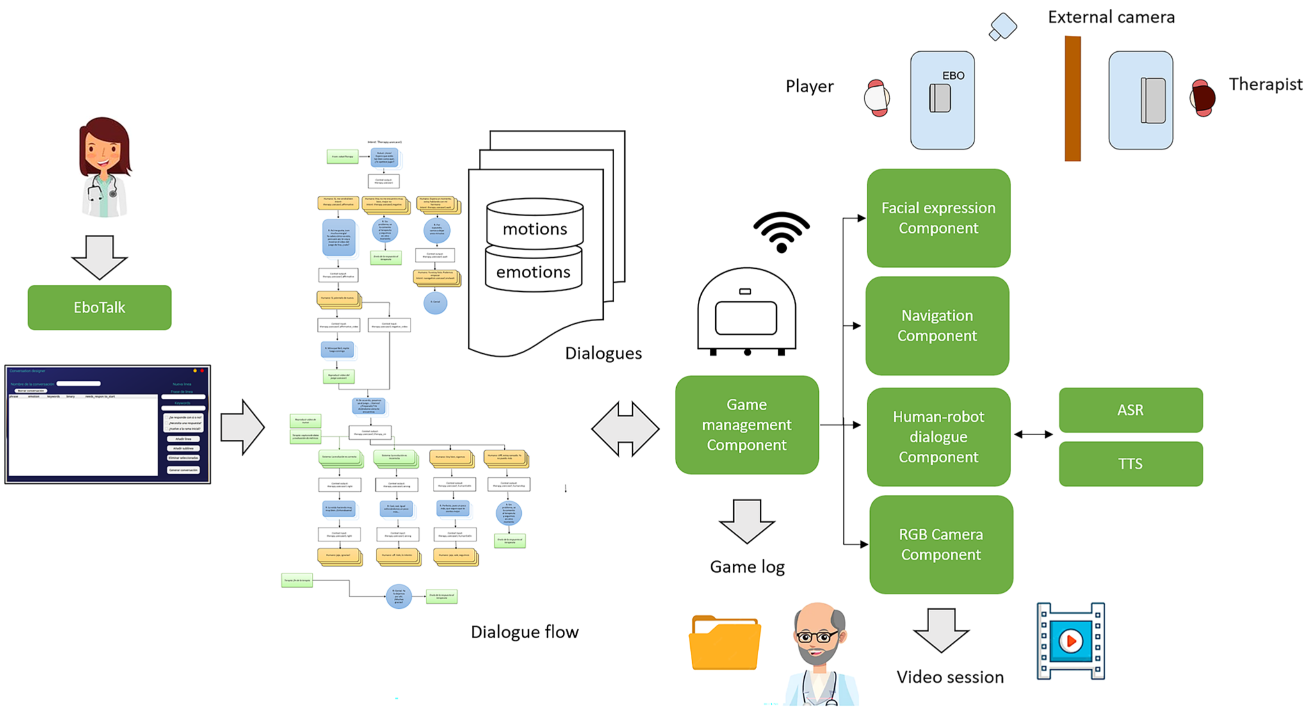

Fig. 1 Overview of the comprehensive system for cognitive therapies with older adults: Our proposal involves the utilization of EboTalk, a tool designed for professionals, to generate affective dialogues. All sessions are diligently stored for subsequent analysis purposes. Additionally, the session incorporates the Wizard-of-Oz technique to enhance the therapeutic experience

This paper is organized as follows: after this brief introduction, Sect. 2 presents a scheme of the proposed robotic system for our use case. Next, Sect. 3 details the methodology followed in our research. Section 4 presents the main results of the use of EBO in the day center, which are discussed in Sect. 5, including the limitations of the study. Finally, Sect. 6 summarizes the main conclusions and future works of our research.

2 Overview of the Proposed Robotics System for the Use Case

Our work presents the system outlined in Fig. 1, which involves several components and processes. Initially, a professional team utilizes the EboTalk tool to construct a customized narrative. This tool is designed to be user-friendly, requiring no specialized knowledge in robotics. The narrative comprises predefined dialogues that include key phrases, basic responses, and specific emotional expressions for the robot to display. These emotions are conveyed through a combination of movements and facial expressions exhibited on Ebo's screen.

Ebo utilizes a coordinated set of software components to accomplish its intended goals during the interaction. The current system version employs supervised therapy, employing the well-established *Wizard of Oz* (WzO) technique [31, 32]. This technique allows the system to simulate therapeutic interactions while being controlled by human operators behind the scenes.

Furthermore, to facilitate analysis and evaluation, the entire session is recorded for later review by the professional team. This recording captures the entirety of the interaction, providing valuable insights and data for further assessment and refinement of the system.

The following subsections provide a brief description of both the Ebo social-care robot and the EboTalk application. These two components play crucial roles in the overall system, ensuring an effective and comprehensive cognitive therapy experience for the older adults.

2.1 EBO: A Social-Care Robot

The EBO robot, created by the RoboLab research group at the University of Extremadura, is a social-care robot to assist needy individuals. This section presents a comprehensive overview of the EBO platform, highlighting its physical attributes and key hardware components. Figure 2 displays both a schematic diagram and a realistic image of the EBO robot, providing insights into its design and visual features.

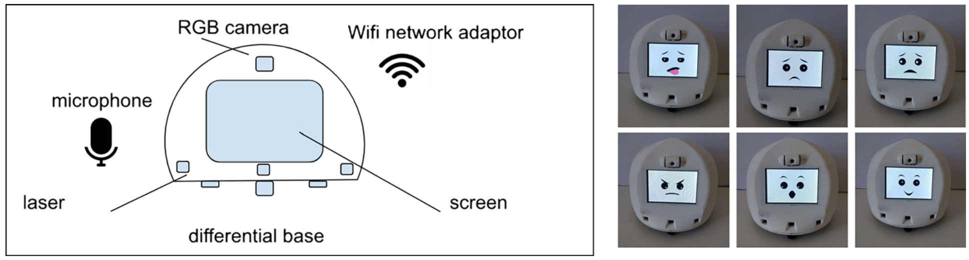

Fig. 2 The Ebo social-care robot. Device schematic and some of the facial expressions associated with basic emotions

2.1.1 Hardware Components

The EBO robot has been meticulously developed on a differential platform, integrating a diverse range of devices to enable environmental perception and expressive functionalities. These capabilities encompass not only emotional expression and image display on its screen but also encompass physical attributes such as its physical shape, tone and pitch of voice, and facial expressions. To ensure the suitability and acceptance of the robot among its target users, including older adults and healthcare professionals, their input was actively sought throughout the development process. Multiple collaborative meetings and working sessions were conducted to incorporate their valuable insights and preferences.

In line with maximizing user acceptance, the external structure of the EBO social-care robot was designed through a prototyping system. This iterative approach allowed for continuous refinement and consideration of user feedback. As a result, the EBO robot boasts a sleek and visually appealing aesthetic, which can be observed in Fig. 2, where its plastic housing is showcased. Measuring less than 15 cm in diameter and weighing less than one kilogram, the EBO robot exhibits a compact and lightweight form factor that enhances its portability and usability.

In its current version, specifically tailored for therapies involving older adults, the EBO robot encompasses a range of hardware components, which are summarized in Table 1. The table provides an overview of the key hardware components employed in the EBO robot, highlighting their respective functions and roles.

The hardware components listed in Table 1 play vital roles in enabling the functionalities and capabilities of the EBO robot. From the Raspberry Pi 3B+ that acts as the control center, to the various sensors, actuators, and multimedia devices, each component contributes to the robot's overall operation and interaction capabilities.

2.1.2 Software Components

The EBO robot's control software comprises various components that play integral roles in its functionality and interaction capabilities. These components encompass the control of physical devices, generation of emotional expressions, facilitation of human–robot interaction, and display of visual information on the robot's screen.

The *Navigation component* controls the robot's forward and rotational speeds. It receives specific commands corresponding to different emotions, allowing the robot to exhibit distinct movement patterns tailored to each emotion. This capability enhances the robot's expressiveness and enables it to adapt its behavior during therapy sessions.

The *Laser component* reads data from the laser sensors and detects potential collisions while the robot is in motion. By actively monitoring its surroundings, the robot can ensure safe and reliable navigation during basic movements, promoting a secure interaction environment.

The *RGB Camera component* controls the servomotor of the camera. It utilizes facial detection algorithms to track the player's face and capture facial expressions during therapy. This tracking capability enhances the robot's ability to respond to the player's emotional cues and adapt its behavior accordingly, fostering a more engaging and personalized experience.

The *Facial Expression* component is crucial in generating emotional expressions in the EBO robot. By leveraging various algorithms and models, this component allows the robot to exhibit basic emotions, enhancing its ability to express empathy and establish emotional connections with the player.

The *HRI (Human–Robot Interaction) component* facilitates communication between the EBO robot and the user. It utilizes Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) algorithms to enable speech-based interaction during different phases of the therapy session. This component enhances the robot's communication capabilities, providing appropriate audio responses.

When the EBO robot is activated, it establishes a local WiFi network that enables connectivity with other components involved in its interaction. While the EBO robot is designed to operate autonomously, it also offers the option for teleoperation through an intuitive and user-friendly interface. A predefined protocol is implemented using the EboTalk tool to ensure seamless and timely communication. However, it should be noted that the ability to modify the dialogue flow during game supervision is essential. Furthermore, the interface must incorporate features that allow the transmission of

Table 1 Hardware components of the EBO robot

Hardware component	Description
Raspberry Pi 3B+	Executes the host system responsible for controlling other hardware components. It serves as the central processing unit of the EBO robot
CSI-Connector Camera	Captures visual information, allowing the robot to perceive and analyze its surroundings through images and video
SG90 Servomotor Model	Provides precise movement control to position the camera at specific vertical angles, enabling versatile visual perception capabilities
Resistive Display (PiTFT 3.5")	Utilized for displaying images, including expressive emotions, providing visual communication and interaction with users
VL53L0X Laser Sensors (5 units)	Incorporates a set of five laser sensors to accurately measure the distances of objects in the robot's vicinity, facilitating obstacle avoidance and spatial awareness
PWM Pin Extender (Adafruit 16-Channel PWM)	Supplies a stable output for controlling the servo motor and allows configuration of the five lasers, ensuring precise control and synchronization of these components
Built-in Microphone and Speaker	Equipped with a microphone to capture audio input and a speaker to output audio information, facilitating voice interaction and audio feedback for users
DC 298:1 (73 RPM) Motors (2 units) in Differential Configuration	Enables agile and efficient movement of the robot's base, utilizing differential drive configuration to achieve smooth and precise navigation
Motor Controller (DRV8835)	Controls the speed and direction of the motors, ensuring the accurate and coordinated movement of the robot's base
Battery (7.4V)	Provides power supply to the robot, while the DC-DC voltage regulator (D24V50F5) reduces the voltage from 7.4 to 5 V, ensuring the appropriate power levels for the system's components

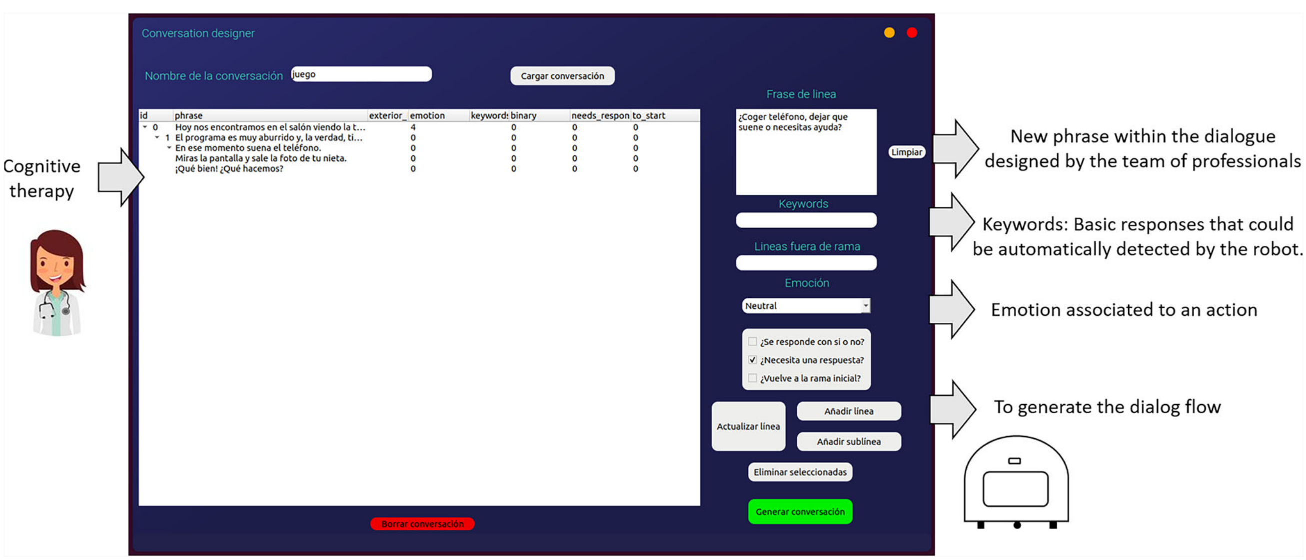

Fig. 3 The user interface of EboTalk, the interactive dialog and narration designer for the EBO robot (Spanish version)

emotions and subtle movements to the robot, enriching the dialogue with emotional elements.

2.2 EBOTalk: Facilitating Dialogues for Social-Care Robots

The EBOtalk tool facilitates the development of dialogues for the EBO robot, as depicted in Fig. 3. Implemented in Python, EBOtalk provides extensive functionalities for generating dialogue flows and keywords, representing the basic responses that EBO can automatically detect. The tool features a user-friendly interface, allowing individuals without prior knowledge of robotics, chatbots, or programming languages to utilize it effectively. EBOtalk generates dialogues in the.json format, which are then read by the underlying code of the robot, ensuring seamless integration of the dialogue within its operational framework. Along with managing the narrative flow, EBOtalk incorporates specific movements and emotional states into the robot's behavior, drawing from a predefined set of basic emotions. For the design of the dialogues used in the interaction sessions, different topics of conversation related to the users' areas of occupation were selected. A battery of questions was elaborated for each case following the structure of an informal conversation or chat between two people, giving the possibility to express their point of view and debate at all times. For each question, several answer options were generated, so that the interlocutor could easily and quickly choose the option most in line with the user's answer. The dialogues were designed by the health branch of the Robolab team, which is formed by occupational therapists, physiotherapists and nurses. At the same time that the robot interacts with the user in an auditory way, it produces a facial expression as visual reinforcement. In this way, and with the optimal pauses for users to process the information received and elaborate a response, we seek to make the conversation effective and pleasant for each user. Although a battery of pre-designed dialogues was available that facilitated the work of the operator behind the voice-over, the possibility of the interlocutor being able to elaborate 'in situ' questions and answers according to what the user was saying at that moment made the conversation as personalized and real as possible. The pre-designed dialogues aimed to achieve a natural and reciprocal conversation between the users and the robot, with closed questions (yes/no) and open questions to encourage the user to express their point of view on the topics covered. For the initial session, as a first contact, a dialogue was prepared to introduce the users to the robot. More personal questions were asked to get to know each user better and to foster user-robot trust. For the interaction sessions, the dialogue was structured as follows: greeting, reality orientation questions (location in time and space), questions related to the user's areas of occupation and farewell. In future interactions, we will work to ensure they can form part of occupational therapy for cognitive stimulation. Some examples of dialogue flow for cognitive stimulation through monitoring daily living activities are presented in Table 2.

Notably, a healthcare professional prepares the dialogue content following the established guidelines of cognitive therapy. This ensures that the dialogues align with the standard practices of cognitive therapy and are tailored to the specific needs of the individuals receiving therapy sessions with the EBO robot.

3 Method

3.1 Design

A descriptive observational pilot study was conducted in the RoboLab laboratories of the University of Extremadura and AZTIDE social and health center (Asociation of therapy with animals and therapies for people with disabilities, Cáceres, Extremadura, Spain) [33]. The trial was prospectively registered at ClinicalTrials.gov with the study identifier: NCT04896333. The Ethics Committee for Research with Medicines of Cáceres, of the Extremadura Health Service (Servicio Extremeño de Salud-SES) approved the study with registration no. 03/2020. All the ethical considerations and requirements mentioned in the Helsinki declaration [34] and the Spanish Data Protection Law were met [35]. The subjects included in the study signed the Informed Consent form to participate in the research. Written informed consent was signed by all the participants and the collaborating professionals of the AZTIDE center.

3.2 Participants

The population of interest were users of the AZTIDE social and health center in Cáceres, Extremadura (Spain), beneficiaries of the cognitive therapy provided in the occupational therapy service. The inclusion criteria were women and men over 65 years old with a Minimental State Examination (MMSE) equal or over 21 (mild to moderate cognitive impairment). Patients were excluded if they had severe cognitive or language impairments that prevented verbal communication.

3.3 Procedure

For each participant, the *robot–participant* interactions took place in two individual interventions, lasting 10–15 min each. Before this, a group interaction (for which the participants were randomly divided 3 by 3) with the robot lasted 12 min. The first *robot–participant* interaction occurred from the 17th to the 27th of May 2021 and the second, one month later, from the 21th to the 30th of June. The interactions were carried out when the user was in the center but not altering

Table 2 Dialogues for the EBO social-care robot: household hygiene/cleaning/care activity

Dialogue	EBO social-care robot	Participant (keywords)
Personal Hygiene, Frequency, and Time of Day	Hello, I am a robot and I am curious to know about personal hygiene. Do you usually shower?	Yes/No
	And do you shower in the mornings?	Yes/No
	Personal hygiene is essential. Do you practice personal hygiene every day of the week?	Yes/No
	I also practice personal hygiene daily	
	After washing, do you get dressed?	Yes/No
Household Cleaning, Task Frequency, and Execution	Are household chores usually done in the morning?	Yes/No
	Household chores take up a lot of time. Do you assist with these tasks?	Yes/No
	What would you choose if you had to choose one household task daily?	...
Self-Care: Physical Activity and Nutrition	Maintaining good health is essential. Do you try to take care of your health?	Yes/No
	Do you engage in any physical activity or exercise, such as walking?	Yes/No
	And do you pay attention to your diet?	Yes/No
	Do you eat fruits and vegetables?	Yes/No
	What is your favourite fruit?	...
	I like red fruits.	...
	Besides engaging in physical activities and eating healthily, following the recommendations provided to care for our health is important. Why do you do it daily?	...

the timetables of the therapies that the participants received at the AZTIDE center as the interactions were conducted in the center. The principle of non-maleficence was respected at all times in the research.

3.4 Wizard-of-Oz Methodology

The Wizard-of-Oz (WoZ) methodology is a widely used technique in human–robot interaction research for simulating real interaction between a robot and a human [31, 32]. Originally, this technique was used to create experimental prototypes in human-computer interactions. This methodology is based on the idea that a human operator, known as the *wizard*, controls the actions and responses of the robot while interacting with participants, creating the illusion that the robot is autonomous. In a typical WoZ setup, the wizard is positioned out of sight of the participant and uses a specialized user interface to control the robot. The wizard interprets the participant's actions and commands and responds accordingly through the robot. This carefully designed simulation allows researchers to collect valuable data on human–robot interaction without needing a fully autonomous robot [31]. It is a useful technique for extracting results on the usability of social robots or as a contact shot on the use of the robot, as is our experimental case study.

In this paper, we implemented a variant of the WoZ methodology. The wizard (*i.e.*, researcher) interacted with the participant using a user interface displayed on their terminal, leveraging the.json file generated by the EBOTalk tool. The EBO robot then executed the commands issued by the assistant. The participants entered the room and sat facing the robot, then the assistants stood far away at the end of the room, and before the end of each interaction, the assistants went outside. Fig. 4 provides an illustrative diagram depicting the experimental setup and an actual image captured during the study.

At the end of the study, following the ethical indications of this type of technique, the participants were informed that during the sessions, two assistants guided the conversation with the EBO robot.

3.5 Creation and Design of the Dialogues for the Study

Different topics of conversation related to the users' areas of occupation were selected to design the dialogues used in the interaction sessions. A battery of questions was elaborated for each topic following the structure of an informal conversation or chat between two people, giving the possibility to express their point of view and debate at all times.

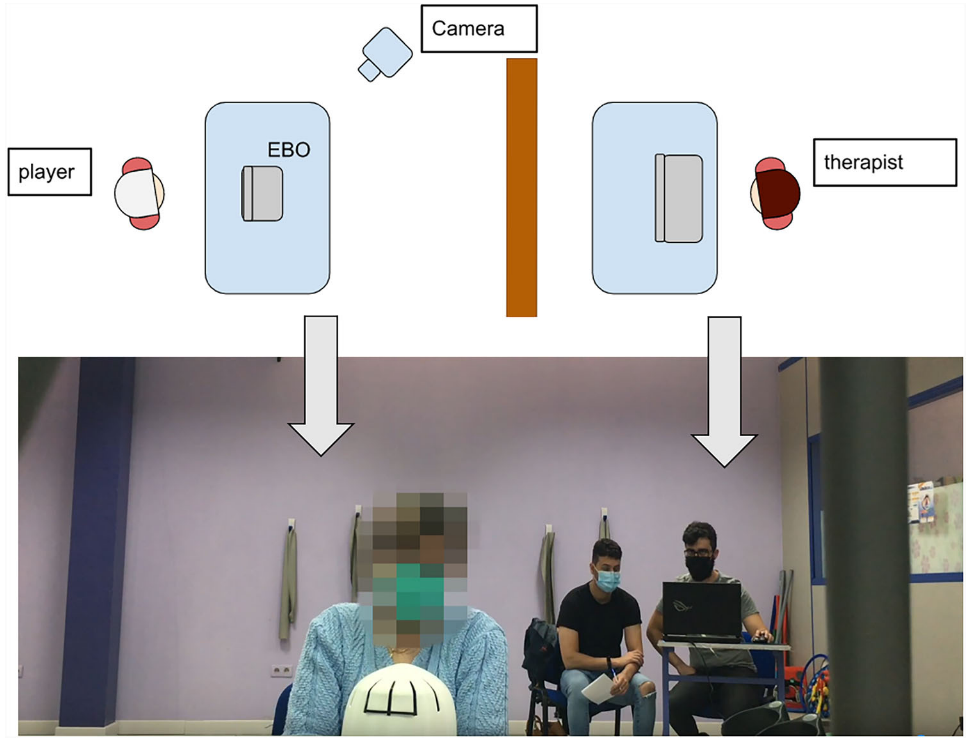

Fig. 4 Conceptual framework of the Wizard of Oz technique. Interaction tests between an older adult and the EBO robot in a daycare center in Cáceres, Spain

For each question, several answer options were generated so that the interlocutor could choose the option most aligned with the user's answer easily and quickly. The dialogues were designed by the RoboLab research group's health team, which comprises occupational therapists, physiotherapists and nurses.

At the same time that the robot interacts with the user in an auditory way, it produces a facial expression as a visual reinforcement. In this way, and with the optimal pauses for users to process the information received and elaborate a response, we seek to make the conversation effective and pleasant for each user. Although a battery of pre-designed dialogues was available that facilitated the work of the operator behind the voice-over, the possibility of the interlocutor being able to elaborate 'in situ' questions and answers according to what the user was saying at that moment made the conversation as personalized and natural as possible.

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3.6 Data Collected and Outcome Measures

A protocol was established to collect the data. The sociodemographic data collected included age, gender, residence and educational level. The data about the condition contained the diagnosis, the MMSE score and the ability to follow and participate in a conversation. The AZTIDE Center provided the data from the patient's records.

All participants attended two interactions that were recorded by video. A self-developed questionnaire was used to analyze the videos of the interactions (Appendix 1). The questionnaire had 17 questions with closed answers, items on a Likert scale (from 0 to 10), and a count of 'number of times that...'. The questionnaire for testing the viewing of the videos also has 3 questions for the viewer to evaluate the suitability of the proposed dialogues, taking into account whether the language used was appropriate for these users and whether the conversation and the structure of the talk presented by EBO are suitable/relevant for each patient. There was also one question related to the patient's emotional response during the interaction based on the video recordings. This questionnaire is based on previous studies that have tried to assess human–robot interaction; different aspects related to attention, attitude and action towards the robot were assessed [28, 36, 37]: (i) Level of attention or visual engagement: the degree to which the participant maintains the visual interac-

Table 3 Descriptive analysis

Gender	Age	Diagnosis	MMSE	Communication Difficulties	Verbal Fluency	Attention
Male	83	Parkinson	25/30	Sometimes speaks in a low tone	Generally good	Slightly affected
Male	73	Parkinson	29/30	Refers difficulty in communicating due to pronunciation problems	Good, with difficulties in expressing oneself	Good
Female	65	Sequelae of Polio	29/30	No problems reported	Good	Good
Female	75	Parkinson	26/30	No problems reported	Good	Good
Male	68	Intellectual disability	23/30	He expresses himself well, although he talks a lot and sometimes repeats what he has already said several times.	Generally good	Slightly affected
Male	69	Multiple sclerosis	30/30	No problems reported	Generally good	Good

tion with the robot, (ii) Fluent and natural action: the degree to which the participant reacts verbally to the robot, (iii) Meaningful: positive verbal engagement and maintenance of conversation; (iii) Remember: the participant asks about the robot, (iv) Attitude towards the robot: level of user comfort during the interaction.

The assessor was an occupational therapist permanently blinded to the research protocol. She was independent of the study and was not aware of the study's objective. She was independent of the AZTIDE center procedures and users and was not involved in the design of the conversations. To complete the study, the assessor was asked whether the questionnaire was suitable for assessing the acceptability of the robot by the users through video testing, as well as suggestions for improvement.

The adequacy of the proposed dialogues was assessed based on three items on a Likert scale ranging from 0 (not at all adequate, poorly structured) to 10 (totally adequate, perfectly structured), taking into account whether the language used is appropriate for these people, whether the conversation and the structure of the dialogue proposed by EBO are adequate/relevant for each participant.

3.7 Data Analysis

The data was analyzed using the statistical program IBM SPSS Statistics for Mac, Version 27.0. (Armonk, NY, U.S.A: IBM Corp). All responses were coded to ensure the anonymity of the participants and were analyzed by staff that were external and independent of the study. Due to the type of outcome measures, primarily qualitative, a descriptive analysis of the variables was carried out with the percentages and frequency distributions. In addition, the data obtained in the first and second interactions were compared.

4 Results

4.1 Descriptive of the Sample

A total of 6 participants who met the inclusion criteria and received cognitive therapy as part of occupational therapy interventions participated in the pilot study. All of them received various therapies at the AZTIDE social-health center. The results are presented concerning the data obtained from the test and the data obtained from the visualisation of the video recordings (Table 3).

4.2 Socio-Demographic and Condition-Related Data

Four men and two women voluntarily participated with an average age of 72.17 years, the youngest participant being 65 years old and the oldest 83 years old. The main diagnosis was Parkinson's disease (in different stages) in 50.0% of the participants, and one case for each of the following diagnoses: multiple sclerosis, polio sequelae, and mild cognitive disability. Regarding the level of studies, the descriptive analysis showed that 66.7% of the participants had basic level studies (paid professional occupation, hotel business, in one of the cases) and intermediate level studies (their professional occupations were ONCE kiosk worker, council official), one participant has university studies, (his professional occupation was director and company advisor); and another received special education, he does not refer to a professional occupation.

All patients attended occupational therapy to train cognitive functions, which were assessed using the MMSE [30]. The minimum value for MMSE in our study was 23 in one of the patients, and 50% of the sample had values of 27, so most of the participants had slight cognitive impairment, with the remaining participants having mild cognitive impairment.

4.3 Ability to Follow and Participate in a Conversation

The ability to pay attention during a conversation was considered fundamental as a precondition for our study of the acceptability of the EBO social robot. It was rated as “good" for 66.7% of the participants and “slightly affected" for 33.3%. The AZTIDE multidisciplinary team assessed in general terms whether or not the patients had difficulties in conversation. It was found that half of the participants in our study reported no problems in maintaining a conversation, and the other half had problems. These difficulties were related to pronunciation and/or speaking too low a tone and/or repeating what they wanted to say too many times. All the participants had previously been assessed as to whether they can have adequate verbal fluency during conversation regularly, and 50% of them do have the possibility of a fluent conversation. In contrast, 33.3% have minor difficulties, such as having to stop and think about what they wanted to say, or sometimes they could not express the word they were thinking about. One participant had aphasia of expression.

4.4 Data Collected from the Video Recording

These data were obtained through the systematic visualisation proposed in the data collection document ‘Questionnaire for the video recording analysis’ (Appendix 1).

Table 4 summarizes the main results after analysing the videos recorded in AZTIDE. In Table 4, we use the following variables:

- EYE CONTACT: Patient maintains eye contact with EBO;
- ATTENTION: Patient pays attention to the conversation with EBO.
- ANSWERS: Patient answers EBO questions.
- SPEAK: How the patient speaks with EBO.
- NATURALNESS: Natural conversation with elaborated vs Terse answers.
- MEANINGFULNESS: Keep the conversation on track. Maintain a well-spun conversation that makes sense.
- REMEMBER: Try to remember facts or places the robot asks participants about.
- COMFORTABLE: The participant feels Good, comfortable, and at ease.
- NERVOUS LEVEL: Completely calm and relaxed.

The results showed that the patient maintained eye contact with the robot in both the first and second interaction in 100% of the cases (EYE CONTACT variable in Table 4).

Concerning the attention paid by the patient to the robot in the conversation, 83.3% of the patients paid full attention (marked by the viewer as 10 on the Likert scale), and 16.7% did so with a score of 8 on the scale (ATTENTION variable in Table 4).

It was assessed whether the participants answered the questions asked by EBO during the conversation, and the results showed that 83.3% responded continuously and adequately in conversation to these questions. Only one participant sometimes did not respond to EBO in the interaction. (ANSWER variable in Table 4).

We also wanted to know whether the participants similarly talked to the robot as they would do with a person, especially because it was a robot or whether they did it in a clipped, awkward or embarrassed way (SPEAK variable in Table 4).

The naturalness and fluency of the conversation were assessed through the viewing of the videos and items 7 and 8 of the assessment of the “Viewing of the test videos". A Likert-type scale from 0 to 10 was used to assess the naturalness (item 7), taking into account whether the participant’s answers during the conversation mainly were developed or brief (“yes", “no"). We also wanted to know whether the participants maintained the conversation thread (item 8), with 0 being nothing and 10 being a full and well-spun conversation. The naturalness of the conversation was different for the participants so that for half of them, fluency values of 6 and 7 points could be seen, and for the other half, we found values of 8 and 10, both in the first and in the second interaction. Concerning Meaningful conversation, there was a slight increase in the scores, 66.7% of the participants showed scores of 9 and 10 in the first interaction, while in the second interaction, this score was maintained or improved in 83.3% of the cases except for one of the participants who lowered his score considerably to 3 (MEANINGFULNESS variable in Table 4).

Making an effort to remember facts or places about which the robot asks the participants were considered as it could be a sign of interest in the conversation, so an item (no. 9) was included in the video test related to trying to remember, where 0 was never trying to remember, and 10 was always trying to remember. In this assessment, the scores obtained coincide with fluency in conversation (REMEMBER variable) Table 4. We considered it important to assess whether participants felt comfortable or nervous in the interactions (items 9 and 10). The results showed that participants were highly comfortable with both interactions. In addition, regarding feeling nervous or uneasy, no participant showed any signs that could indicate uneasiness or nervousness during the interactions.

To measure the acceptance of the interactions, we grouped those whose values were measured on a Likert-type scale. These variables measured from 0-10 the following aspects: the attention that the participant paid to EBO in the interaction (ATTENTION), the naturalness of the conversation (NATURAL), if the participant tried to remember what EBO evoked or asked him/her, as another item of interest in the discussion, (REMEMBER), if a well-spun conversation was

Table 4 Results of the analysis of the videos

	First Interaction			Second Interaction		
Variable	Options	n	Frequency	Options	n	Frequency
Eye contact	100%	6	100%	100%	6	100%
Attention	10	5	83.30%	10	5	83.30%
	8	1	16.70%	8	1	16.70%
Answers	Continually/ Adequately	5	83.30%	Continually/ Adequately		83.30%
	Some Times	1	16.70%	Some Times		16.70%
Speak	Person-like	4	66.70%	Person-like	4	66.70%
	Speaks in a special way, because he is talking to a robot.	1	16.70%	Speaks specially, because he is talking to a robot.	2	33.30%
	Embarrassed to talk to a robot	1	16.70%	Embarrassed to talk to a robot	0	0%
Naturalness	10	2	33.30%	10	2	33.30%
	9	0	0%	9	0	0%
	8	1	16.70%	8	1	16.70%
	7	2	33.30%	7	2	33.30%
	6	1	16.70%	6-Mar	0	0%
	5-0	0	0%	2	1	16.70%
				1-0	0	0%
Meaningfulness	10	1	16.70%	10	3	50%
	9	3	50%	9	1	16.70%
	8	0	0%	8	1	16.70%
	7	2	33.30%	7-Apr	0	0%
	6-0	0	0%	3	1	16.70%
				2-0	0	0%
Remember	10	2	33.30%	10	2	33.30%
	9	3	50%	9	3	50%
	8	0	0%	8-Feb	0	0%
	7	1	16.70%	1	1	16.70%
	6-0	0	0%	0	0	0%
Comfortable	10	4	66.70%	10	2	33.30%
	9	2	33.30%	9	3	50%
	8-0	0	0%	8	1	16.70%
				7-0	0	0%
Nervous level	10	4	66.70%	10	4	66.70%
	9	2	33.30%	9	2	33.30%
	8-0	0	0%	8-0	0	0%

maintained, with complete sense (MEANINGFUL), if the participant felt comfortable (COMFORTABLE), or if they felt wholly calm or, on the contrary, if they got nervous in the interaction (NERVOUS). The results obtained showed that in both interactions, the only values obtained were the highest values for this interaction: 4 “GOOD" and 5 “EXCELENT (Table 5).

Table 5 Report on both interactions

Values: Interaction 1 and Interaction 2	Mean	N	Deviation
GOOD	4,5	2	0,707
EXCELENT	5	4	0
Total	4,83	6	0,408

5 Discussion

The ageing of the world's population, particularly that of our country Spain and our region Extremadura, is a problem of concern in all spheres, both from the perspective of health and social welfare, as well as the management of resources. Ageing is a severe challenge for our society, which implies changes in the models and quality of care for our older adults [38]. The population's longevity is increasing due to improved quality of life and better health conditions. Longevity is not the same as ageing [39]. We believe that enhancing environments and adding robotic solutions that intervene in care, rehabilitation and socialization can reduce costs and provide greater possibilities for participation and personal autonomy for the older adults y and those with functional and/or cognitive and/or mental diversity.

One of the aims of this study was to assess the acceptance shown by a group of older adults when interacting through a conversation with the EBO robot. Previous clinical trials point to positive results regarding using robotics in older adults with dementia, improving stimuli, communication and the patient's mood [40]. Among the advantages of using a robot to assist older adults with dementia is that the robot does not get tired, does not experience stress, can help with activities of daily living and cognitive and physical stimulation, and provides companionship, among others [22]. A robot is not a replacement for caregivers [41] or professionals in the intervention and rehabilitation of these patients. Still, it is another tool at the service of society to alleviate and/or facilitate the workload. Several studies assess the perception of Social Assistance Robotics as an effective tool in caring for older adults by their primary caregivers [40]. It is generally agreed that it is difficult to compare different studies on the use of social robots because different scales and elements are used for the assessment, which makes it impossible to extrapolate the data to the general population [40]. Among the studies available in the literature, we can highlight the one conducted by Petersen et al. [42] with a pet robot called PARO in older adults with dementia. The authors observed that the treatment with PARO reduced stress and anxiety in the experimental group concerning the control group and also found a reduction in the use of psychoactive drugs and analgesics. The PARO and NAO robots were compared in the study by Valentí Soler et al. [43] in patients in nursing homes. They showed statistically significant differences in the apathy scale scores for institutionalized older adults (APADEM-NH) in both the NAO and PARO groups. In addition, a decrease in the apathy item of the NPI (neuropsychiatric inventory) scale was found. However, an increase was observed in the MMSE scores and in the delirium item, which may derive from a progression of dementia, although the MMSE total score did not vary. In day center users, an increase in quality of life scores in late dementia was observed in the NAO group and a significant decrease in the NPI total score and irritability/lability item. Another study by Wang et al. [44] asked the opinion of older adults with Alzheimer's disease and their caregivers about robots providing graded prompts to assist in activities of daily living at home. This study also concluded towards positive consequences of robots in self-care activities, with decreased frustration and relationship tensions. It was seen to increase patients' social interaction with the robot, while on the other hand, the negative consequence is that it decreased interaction with caregivers. The designs of the studies consulted also include touch-screen technologies [45] that offer interventions to improve neuropsychiatric symptoms common to people with dementia and the needs of their caregivers at home. They found that this type of technology is easy to use and allows them to facilitate the daily life of caregivers by providing respite from their work. All these studies have found positive factors when including technological elements and robots and coincide with our results regarding the acceptability of its use.

The Wizard of OZ technique [31, 32] was used in our research. The conversations are not entirely created by artificial intelligence. In our case, we applied the work of an operator who, after inserting the dialogues created as the basis of the interaction into the EBOTalk tool, executed them individually for each participant and introduced phrases and conversation elements added to these already-created dialogues. In this way, more real and fluent conversations were achieved. In the proposed scenario, the participant only sees the robot and considers that the conversation is direct with the machine and does not suspect it is through an operator.

Other studies have also used this same technique, which is in continuous improvement as it brings undoubted benefits to human–robot interaction [46]. In the study by Kristoffersson et al. [47], they used telepresence to use their robot (Giraffe) to perform care tasks for older adults. In this case, the main caregiver was the "Wizard" behind the robot, unlike our study in which the operators were a computer scientist and an occupational therapist. In future studies, we consider that it would be appropriate for the operators to be the older adults care professionals themselves, as we believe that occupational therapists, physiotherapists, psychologists, nurses, etc., can add therapeutic value to the interactions of the older adults with our EBO robot.

AZTIDE [33] was the center where we experimented, with a total of 6 volunteer participants who met the selection criteria established, received cognitive stimulation therapy in the occupational therapy intervention and had an MMSE equal to or higher than 21. Two individual interactions were conducted, an initial and a final one. During these interactions, we tried to observe different aspects of the interaction between the participants and the robot, which are detailed below.

In order to assess the acceptability and level of interaction of the EBO social-assistance robot among the participants, we chose to use the systematic visualization proposed in this study as an assessment tool, which consists of a visualization test questionnaire (Appendix I). This allowed the occupational therapist who carried out this systematic visualization to assess all the participants with equal criteria in all the questions we wanted to study. The interactions lasted between 10-15 min. The therapist who carried out this test did not know the participants or the dialogues used in the experiment beforehand. In our opinion, this element gives more value to the tool and is a favourable element for its suitability for this task. Other aspects that favour its suitability are, in our opinion, the aspects that it assesses and that it makes it possible to do so quickly and reliably through the items of which it is composed.

In terms of the number of participants with mild cognitive impairment, our study coincides with that of Wu et al. [13]. In this study, the interaction was done with an assistive robot, and the results showed that the aspects related to the interaction with the robot were positive. Rouaix et al. [48] used the PANAS affectivity scale and concluded that in robot-assisted therapies, they were able to observe an improvement in the well-being of the participants and an improvement in their emotional state (increases in positive affect and decreases in negative affect). This suggests that this type of therapy is widely accepted and even presents higher satisfaction levels with the intervention in patients with dementia than traditional therapy. This fact is consistent with our results and encourages us to expand studies with interventions aimed at this group of patients.

Recently robots have been used to reinforce therapy and treatment adherence resulting in increased attention and fewer depressive symptoms in patients with mild cognitive impairment [49]. The humanoid features of EBO are similar to other experiments, such as facial gestures and expressions [50], which promote positive affect and attachment of the older adults to the robot.

The evaluation of the eye contact that the participants maintained with the robot and the attention paid during the conversation were 100% in the first and for both interactions, and the assessor considered on a Likert-type scale that was 10 points in 83.3% of the participants in both interactions. This shows that the participants considered the conversation real and joined this experience completely. To find out the level of interaction and its resemblance to a real conversation that is of sufficient interest to the participant, we wanted to know if the participants answered the questions that EBO asked them within the conversation. The results showed that 83.3% responded continuously and adequately in a conversation to these questions; in both interactions, only one participant sometimes did not respond to EBO. This was because he had difficulty in communicating due to pronunciation problems related to his underlying pathology, Parkinson's disease. However, she did make attempts to respond. These valued aspects, such as: eye contact with the interlocutor, attention paid, and setting in motion the response processes to the questions asked by EBO are all indicators considered necessary in a complete and adequate conversation, which requires feedback [51, 52].

Regarding the analysis of the way the participants talked to the robot, if they talked to the robot in a similar way as we do with a person or if they did it in a special way (under a feeling of embarrassment, in a cut-off, strange way) because it is a machine the results showed that one of the participants had a variation from the first interaction to the second one, changing from feeling embarrassed by talking to a robot, to talking in a special way for being a robot in the second interaction. We believe that this small evolution indicates that some people may need a few sessions to get used to the conversation with the robot. Another participant spoke in a special way because he was a robot in both interventions, and the rest of the subjects had a conversation with EBO in a similar way as they would do with a person in both interventions. With regard to the naturalness and fluency of the conversation, assessed by watching the videos, the objective was to know whether the participants could keep the conversation thread. The naturalness of the conversation was different for the participants so that for half of them, fluency values of 6 and 7 points could be appreciated, and for the other half, values of 8 and 10 were found, both in the first and in the second interaction.

Concerning Meaningful conversation, there was a slight increase in the scores, 66.7% of the participants showed scores of 9 and 10 in the first interaction, while in the second interaction, this score was maintained or improved in 83.3% of the participants. The reasons for this were that the second interaction with EBO and this participant occurred on a day when the participant was in a bad mood and had disagreements with different people. This leads us to believe that the relationship with EBO was in line with the participant's relationship with the other people in the center that morning. It is surprising that the interactions were generally similar to how we interact with people. We believe that this naturalness in the conversation with the robot could be a point in favour of the future use of these interactions for cognitive stimulation and assistance to the older adults. Other aspects that we have found in our experiment and that are in line with the fact that the participants maintain a conversation with our robot similar to that held with people, is the fact that they made a memory effort to remember facts or places that the robot asked about. In addition, in this assessment, the scores coincided with the fluency of the conversation. This seems very coherent to us, as both items align with the assessment of the naturalness with which the participants have approached the interactions. It coincided again that the same participant who had drastically decreased his score in the previous items also did so in a very striking way in this item, which may point to the fact that these items are suitable for studies of this type, as they can assess those participants who lose contact or fluency with the conversation.

When analysing whether or not the participants felt comfortable or nervous in the interactions, we could see that they were highly comfortable with both interactions. This also coincides with the fact that the participant who showed less natural interaction lowered his comfort score in the conversation from 9 to 8. Besides feeling nervous or uneasy, no participant showed any signs that could indicate uneasiness or nervousness during the interactions.

Therefore, we consider that the items used in the systematic evaluation through our questionnaire are coherent, as they all worked in a synchronized way, those that evaluate positive aspects (eye contact, interest in the conversation, full conversation, among others) and negative aspects (nerves, embarrassment, unnatural conversation, etc.), are reinforced as they never contradict each other in any of the cases. The assessment tool used has allowed us to systematically evaluate the most important aspects when analysing a “good conversation" and the acceptance of the participant having a conversation with the robot without requiring too much time for testing and data collection, with conversations that did not exceed 15 min (Appendix 1). Thanks to this pilot study, we have detected small changes that can improve and make the video testing questionnaire lighter and more efficient. This tool would allow us to assess a larger sample, representative of the population of older adults who receive services in day centers, and would provide us with very complete data for the acceptability assessment. We consider this research relevant as acceptability is fundamental as a first step for more ambitious uses at therapeutic and care levels.

Another of the objectives of this study was to analyse whether the dialogues proposed (its content and structure) were appropriate for the interactions between the participants and the robot. After the meticulous work of preparing the basic dialogues, we found that they have given an excellent result in all aspects in which they have been assessed: for the appropriateness/relevance of the conversation proposed by EBO for each of the users and for the structure of the conversation and in the assessment of whether the language used is appropriate/relevant. This is a fundamental task before the interaction and on which, in our opinion, both the success of the interaction and the success of future therapeutic and care uses will depend to a large extent.

Robotics is entering the lives of older adults to facilitate the specialized care that these persons require. Creating the appropriate dialogues so that Artificial Intelligence can make use of them in the future and create useful and appropriate human–robot interactions is a work in progress, in which close collaboration between technicians and health professionals is, in our opinion, essential. We believe that the benefits are many: economic, saving on care staff, decreasing the workload of the care staff, security for families and carers, and with the ultimate aim of allowing the older adults to remain in their homes for as long as possible.

5.1 Limitations of the Study

We consider that the main limitation of our study is the number of users. Due to the particularity of this research, the number of participants in the study was scarce and therefore this can be considered as a pilot study with the aim to expand in future research. Although this pilot study had six participants, it has allowed us to focus on future studies to expand the sample and allow us a more in-depth comparison with conventional therapies for mild cognitive impairment.

In the studies reviewed, we have not found unanimity in the aspects to be assessed or in the scales or instruments used, so comparison with other studies in several of the aspects that we have considered in this pilot study has not been possible to be performed in big depth.

The result of our study encourages us to continue the research with a larger sample and a greater number of interactions over time to assess if acceptability is maintained and to evaluate whether it is extrapolated to the population with dementia with moderate-mild cognitive impairment.

5.2 Clinical Implications

We consider the clinical implications of our study to be important. In this first approach, we have found good acceptance, which may allow us in the future to integrate EBO in the intervention therapies in Occupational Therapy.

6 Conclusions and Future Works

The results of the present pilot study showed high acceptability and interaction of the EBO social-care robot with the patients with mild to moderate cognitive impairment attending the day centre. Our results suggest that the systematic viewing of the videos proposed in this study provided enough data regarding the user-robot interaction for assessing the acceptability and interaction of the participants (day centre users) and the EBO robot of the Robolab laboratory. However, this pilot study has shown improvements to be made in the questionnaire that can facilitate the assessment.

These results provide a first insight into the acceptability of the EBO robot and encourage us to continue the study with larger samples and a greater number of interactions over time to evaluate if the acceptability is maintained and to assess whether it is extrapolated to the population with dementia with moderate-mild cognitive impairment.

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Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

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

Human participants The research involving human participants has undergone rigorous ethical review by the University of Extremadura Research Ethics Board. All modern ethical standards, including data privacy, procedures for obtaining informed consent, debriefing on deception, and the use of data and images with permission, were followed.

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