Pepper-based serious games for older adults: initial experiences in real-world settings*

Giulio Canapa[1], Benedetta Catricalà[1], Marco Manca[1], Fabio Paternò[1], Carmen Santoro[1,*] and Eleonora Zedda[1]

CNR-ISTI, HIIS Laboratory, Via Moruzzi 1, 56124 Pisa, Italy

Abstract

Social robotics for supporting cognitive stimulation of older adults has been investigated in recent years but it has not been adopted in the real world. To better understand how it can be deployed in such settings, we have carried out a trial in a healthcare residence. A set of games able to automatically personalise their interactions according to user memories has been designed and implemented in a Pepper robot. The games aim to stimulate cognitive resources such as memory and attention. In this paper, we introduce the approach proposed, how it has been proposed in a residential health care facility for older adults, and discuss the initial feedback received.

Keywords

Social robotics, older adults, real world

1. Introduction

Nowadays, especially developed countries are confronted with a rapidly ageing society, leading to a growing need for effectively coping with the cognitive decline of ageing people, which, in severe forms, could even hinder their ability to maintain independence and perform activities of daily living. Non-pharmacological interventions, such as cognitive training, physical training, and social stimulation activities, have traditionally been used to mitigate cognitive decline, by maintaining or improving mental abilities, and increasing the social well-being and quality of life of older adults ([1], [2], [3]).

Cognitive training is a rehabilitation technique aiming to exercise the areas of cognition that pose greater difficulties to an individual. It typically involves repetitively practicing tasks aimed at improving single or multiple cognitive abilities (e.g. memory, attention, executive functions) [4]. Usually, it is delivered by a therapist via paper-and-pen-based tasks, although computer-based support is increasingly exploited. Also, it is typically administered in group settings, whereas individual interventions occur infrequently due to the caregivers' increased time commitment and effort required. These latter aspects could place an undue burden on formal caregivers, who not only are already grappled with numerous responsibilities, but are also in increasing shortage due to their rising demand consequent to the risen life expectancy. Considering this, and the increasingly high societal healthcare costs associated with ageing, there is an urgent need for innovative approaches more sustainably and effectively supporting older adults suffering from cognitive decline.

Assistive technologies can provide useful support to address this problem, as they can help older adults maintain their independence during daily routines, and they also represent an important instrument for elderly's cognitive rehabilitation ([5]). However, one issue associated with cognitive training is the fact that, to be effective, it requires significant levels of engagement

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[1*]Corresponding author.

giulio.canapa@isti.cnr.it (G. Canapa); benedetta.catricala@isti.cnr.it (B. Catricalà); marco.manca@isti.cnr.it (M. Manca); fabio.paterno@isti.cnr.it (F. Paternò); carmen.santoro@isti.cnr.it (C. Santoro); Eleonora.zedda@isti.cnr.it (E. Zedda)

0009-0002-4478-3636 (G. Canapa); 0009-0004-9042-978X (B. Catricalà); 0000-0003-1029-9934 (M. Manca); 0000-0001-8355-6909 (F. Paternò); 0000-0002-0556-7538 (C. Santoro); 0000-0002-6541-5667 (E. Zedda)

over an extended period. Unfortunately, several factors and barriers ([6]) could hinder elderly's adherence to cognitive training over an extended time. Among them, a recurrent problem is the dropout rate from the proposed programs because they are found repetitive by involved subjects. From this perspective, advancements in humanoid robots that exhibit human-like characteristics and behavior represent a promising and more sustainable direction to engage users, potentially enhancing the effectiveness of the supported interventions while mitigating the problem of the burden on caregivers.

Including interactive serious games within the cognitive training delivered by humanoid robots seems a promising approach to further engage users in training on key cognitive functions (such as e.g. memory, attention, and problem-solving), as it has the potential to synergistically leverage the engaging qualities of both. However, this approach may not be sufficient to address the diverse and evolving needs of this population, which is heterogeneous in terms of preferences, interests, and abilities. Thus, it is important to propose serious games that can be relevant to them, to increase their motivation and interest in training. To solve this issue, we propose games which have been personalised using information derived from facts, events and memories taken from older adults' own lives. While this approach has been used in past work [7] using mobile apps, here we consider humanoid robots as its supporting platform, which brings specific advantages in terms of engagement thanks to their embodied interaction.

The research question of this study is to investigate whether and how a personalized game-based cognitive training provided by a humanoid robot and based on elderly's life memories can promote the engagement and user experience of older adults with varying cognitive levels, in a real-world setting.

To this aim, we designed and implemented a set of robot games able to exploit information associated with older adults' biographies and used them in a cognitive training program for older adults, in the wild. The games are of different types (Music, Events, Games, Places, Affects and Hobbies) to deliver a varied experience to elderly, also exploiting various difficulty levels, to ensure that users remain motivated and feel a sense of accomplishment/progression over the game. One of the developed games also leverages recent developments in generative AI (LLMs), as it creates a story based on a life memory of an elderly and then asks the elderly some questions about it.

The games have been exploited in a trial conducted within the premises of an Italian residential aged care facility and involved both a number of older adults living in the nursing home of that facility, and another group of other adults attending a day centre (located in the same facility), where they participate in a variety of activities promoting mental stimulation, socialization, etc.

In the paper, after discussing related work, we present our approach to personalised serious games for cognitive training, by describing the prototype platform we designed and implemented to support such games, and the app used for collecting and organising older adults' memories. We then report how we have organised and conducted a trial in the real world, involving twelve older adults having varied cognitive profiles, and who played the developed games over 4 sessions (for each user). Lastly, we report some preliminary information we derived from the trial experience, discuss it, and provide indications for future work.

2. Related Work

Social robots have recently started to be considered for supporting stimulation activities for older adults, especially those with cognitive decline, because the flexibility provided by their design can make them more engaging, interactive, and autonomous, while also potentially alleviating the need for human facilitation [8]. The increased flexibility associated with social robots has roots in robots' physical appearance itself, as well as their multi-modal interaction and perception capabilities. Indeed, some work supported the importance of physical embodiment [9] in increasing participants' engagement [10]. Furthermore, Lopez-Samaniego et al. [11] pointed out that cognitive games presented on a robotic interface have been found to be more effective than those on a non-robotic interface.

However, an issue typically associated with cognitive training is that participants tend to lose interest and motivation after a while, with potential negative effects on its outcomes, since cognitive stimulation should last over a relatively long time to reach some therapeutic effect. Personalization is a common strategy employed to enhance engagement and adherence to training, by increasing motivation, by using content that is more relevant and appealing to users.

Among the aspects that can be considered for personalising robot behaviour when providing cognitive training, we focused on leveraging personal memories and past events associated with older adults' lives. Some previous work somehow already considered life-based content for personalising training. For instance, in [12], robots were used to facilitate reminiscence therapy to improve the mood and communication of people with Alzheimer's disease. Also, Kasap and Magnenat-Thalmann [13], and Sanchez et al. [14] exploited autobiographical information for enhancing engagement in long-term interactions with a human-like robot. Edirisinghe et al. [15] explored the possibility of acquiring knowledge about users through friendly conversations, to recall such info during the next interactions, to improve long-term human-robot social interactions. However, in all such cases, the memories are mainly used for provoking emotion-related bonding with users in long-term relations, by exploiting the recollection of past important events, to improve the relevance of user-robot conversations. Differently from these pieces of work, we exploit the content associated with biographical memories drawn from users' past lives to personalise the training content for older adults, a topic that has not been considered much in previous work. The benefits of choosing to focus on information related to the past life of elderly is also highlighted by a recent study of Zhang et al. [16], which recommend, when designing games for the elderly, to meet psychological elements that e.g. evoke nostalgia on users, to the goal of enhancing motivation and positive effects of playing with them.

In a very recent paper [17] information from the past is exploited for enhancing training content to cognitively engage older adults hospitalized in a geriatric care unit: a semi-immersive musical game called "A Life in Songs" allows patients to immerse themselves (the users wear VR glasses to explore the environment) in a past era through visuals and songs from that period. While that study has some similarities with our work in that it is an in-the-wild study and tries to provide game content more relevant to subjects, to better engage them, the level of customization provided seems very limited. For instance, it is not based on information connected with each individual and social robots were not considered.

Still in regard to the aim of improving elderly motivation in playing with cognitive serious games more frequently, recent studies have started to integrate generative AI techniques in serious games (see e.g. [18], [19], [20]), as it is believed that AI can provide several benefits in the realm of game adaptation. Indeed, AI enables the games to be more comprehensive, since it provides access to a vast amount of information which can be used to vary the game content as well as to enhance game personalization. In this regard, one approach used in past work is to dynamically adapt the difficulty levels of the games. For instance, in Zuo et al. [20] an AI LLM was integrated into a VR jigsaw game to dynamically balance game difficulty, based on user's errors and vocal inputs. The game collects active metrics such as operation time and accuracy, as well as passive data like eye-tracking and controller tremors, and regularly sends them to the LLM for analysis. The system enables dynamic difficulty adjustments within eight different difficulty levels, considering factors such as player's reaction time, concentration, and motor coordination, to ensure an experience tailored to the user's performance and abilities. However, differently from this previous work, our study was carried out in a real setting, also including an AI-based serious game delivered by a humanoid robot to provide cognitive training to elderly.

The most relevant paper for our work is by Xu et al. [7], where the authors present a serious game app and a method to create and integrate personalised game content based on lifelog visual analytics: they extract personalised content from visual lifelogs, integrate it into a mobile game app consisting of eight puzzle games, and evaluate the effect of personalisation on user experience. However, in that case, a mobile app was exploited, and older adults without any cognitive

impairment were involved in the experiment, whereas in our study we aim to investigate on the potential of embodied humanoid robots in cognitively stimulating elderly with varying levels of cognitive decline.

3. The Approach

We have designed and developed a prototype platform able to collect personal memories from older adults' lives and then deliver serious games exploiting such personally relevant information using a humanoid robot. The games are based on information related to the participants' biographies, making the interactions potentially more meaningful and engaging while also providing cognitive stimulation. The platform includes a memory collection app and a set of games that utilize these memories through the humanoid robot.
The selection and design of the game types were based on a semi-structured interview conducted in September 2024 with two psychologists from the care center. The goal of the interview was to understand the specific needs and preferences of the nursing home residents, to ensure that the games were relevant to the target group, providing cognitive stimulation while remaining interesting.

Psychologists recommended designing games that are closely related to usual, concrete elderly tasks/activities, and which are not too complex, to ensure that they would engage all older adults. Thus, this discussion inspired the idea of focusing on familiar tasks for the games, which thereby included activities connected to listening to music (which led to the Music game, see next section for a description of the games), organizing daily routines (Reorder Activity game), playing memory games with visible photos (Memory), storytelling games (Memory Story quiz) and completing proverbs (Complete proverb). In addition, to provide a varied game experience to elderly, able to continuously challenge them in a way suitable to each user, we decided introducing an adaptive difficulty mechanism where the complexity and challenge of the tasks increase proportionately with the player's progression, to ensures that the difficulty level remains appropriately challenging and engaging as the user's skills improve.

3.1. The Prototype

We have designed and developed a prototype application aimed at providing serious games that utilize personally meaningful information from older adults' lives, presented through a humanoid robot. To simplify the collection of memories, we utilized Remind [21], a responsive web application aimed at supporting the collection and saving of personal memories into six different categories, depending on their content: Music, Events, Games, Places, Affects and Hobbies. Then, considering the literature and the suggestions of the caregivers who assisted the older adults, we designed and implemented 5 serious games having three different difficulty levels (easy, medium, and hard), and exploiting the content contained in memories.

- **Complete the proverb**: In this game, the robot presents a proverb with a missing word and the user must complete it by choosing from three options. Approximately thirty Italian proverbs were selected and categorized into three difficulty levels based on their everyday usage: in the easy level, very common proverbs are used, while in the medium and hard levels, the proverbs become increasingly uncommon and less frequently used in everyday language.
- **Reorder activities**: This involves arranging a set of actions in the correct order to complete an elderly's daily task or one of the user's hobbies. For the easy level, three actions were included, four for the medium and five for the hard. During the memory collection phase, each user was asked to indicate at least four hobbies they used to practice.

- **Music Quiz**: The user listens to a meaningful short clip of a song and is challenged to identify the title for the easy level, the artist for the medium, or part of the lyrics for the hard level, choosing from three options. In this game, the song played is related to the year of a memory.
- **Memory**: The user is presented with a set of 6 or 8 images (depending on the difficulty level) that they must match to complete the game. For this game, we used the photos shared by the users during the memory collection phase.
- **Memory Story Quiz**: This game uses ChatGPT-4o to create a personalized story based on a user's memory. Once the story is generated, the user must answer a set of questions related to the story and tailored to the difficulty level: the most difficult game levels ask questions involving story details introduced by ChatGPT, whereas the easy game levels ask questions related to the elderly's memories.

The game session begins when users interact with the humanoid robot. Once the session starts, the robot downloads the user's memory data from the backend and use it to personalise the exercises according to their content. After logging in, the users access the game menu, where they can select a game either through voice or by interacting with the tablet's touch screen placed on the chest of the robot Pepper. During the interaction with the user, the robot provides various vocal feedback and animations to generate a more natural human-robot interaction. At the end of the session, the application presents a detailed report about the exercises performed in the latest session, allowing users to monitor their progress.

4. The Trial

We are conducting a user study to analyze the user experience of older adults interacting with robot-based games personalized with their personal memories. The study was carried out in collaboration with PAIM, a social cooperative providing various services to elderly people in Pisa. In particular, the trial involved users of a care facility (managed by PAIM) providing various types of support to its users. Indeed, that facility houses, for a period ranging from a few weeks to indefinite time, non-self-sufficient persons who cannot be cared for at home and who require specific medical care from multiple specialists, and/or articulated health-related support (residential care). Beyond these users, the center also provides support to people with cognitive-behavioral disorders via its daycare center, and to people in need of rehabilitative treatments, who thereby need just temporary hospitalization (semi-residential care).

Users from both types of care areas were involved in our trial. Before starting the experiment, a familiarization phase was conducted to introduce the robot to them (see Figure 1). This phase was essential to help participants become familiar with the robot and feel comfortable when engaging with it. Prior to the start of the trial, all participants also provided a written consent, which included a detailed explanation of the study's objectives, procedures, timeline, and the data management protocols in compliance with the General Data Protection Regulation. This consent was signed by each elderly participant involved in the trial.

Figure 1: Familiarization phase with the robot involving older adults from the daycare center and residents at PAIM.

4.1. Description

We are conducting a user study to evaluate the user experience of older adults engaging with robot-based games tailored to their personal memories, involving users of a care home located in Pisa and managed by PAIM.

The trial started in October 2024 and is scheduled to be completed by the end of January 2025. It involves a group of 12 older adults with various cognitive levels (8 males and 4 females, average age = 77 years, standard deviation=9.33) with an MMSE score ranging from 18 to 30. 4 out of 12 are semi-residential patients, meaning they attend the healthcare residence only in the mornings and on specific days of the week, while the remaining 8 live full-time in the nursing home.

The trial was structured in three phases. In the first phase, the research group introduced the robot to all the residents in the nursing home for familiarization purposes: within it, the robot was presented, and users who wished to interact with it tried some games with the robot, while all the other users watched the interaction (see Figure 1). In the second phase, two researchers met the participants and the caregivers to describe the project's objectives. The following weeks, the researchers conducted one-on-one interviews to collect the participants' memories using the Remind web application. The third phase focused on game sessions with the Pepper robot: each participant is scheduled to complete four game sessions, each lasting approximately 20 minutes. However, as the experiment is still ongoing, not all participants have completed all four sessions yet. At the end of each session, the users express their preferences for each game played with the robot. At the end of the fourth session, participants are asked to complete a questionnaire to evaluate their overall experience and provide feedback on the games.

The final questionnaire asks sociodemographic information, as well as questions to evaluate users' familiarity with digital devices. Then, to evaluate the human-robot interactions, the Godspeed Questionnaire's questions [22] related to the anthropomorphism, animacy, and perceived intelligence categories are submitted to users, as well as some other specific questions to assess the overall user experience.

At the time of writing, the analysis is still ongoing, as the user testing sessions have not yet been fully completed. So far, participants have expressed positive feedback regarding the robot's voice and appearance, with many of them highlighting its engaging and friendly behavior as key factors contributing to their overall experience. Additionally, the games have been described as fun, varied, and cognitive stimulating, with various users indicating that the experience was both entertaining and rewarding. Hearing their stories through activities with a humanoid robot evoked amazement and amusement in all participants: one user remarked, "It's amazing to hear a story

with my own memories!". They particularly appreciated the novelty and the opportunity to train their memory in an enjoyable and engaging way. Additionally, some users appreciated the variety and creativity of the activities, with one stating, "All the games are interesting, and there are even some tricks." The music game was particularly well-received, as highlighted by the comment, "I like the music game because I like music". Overall, the evoked stories were connected to positive memories, and the robot's behavior and interaction style were well-received, creating a relaxed and engaging atmosphere, with some participants noting they would recommend it to others if they knew someone who could benefit.

5. Conclusion and Future Work

This paper introduces how an approach to personalised serious games for cognitive training, exploiting personal memories of older adults through a humanoid robot has been proposed in a residential health assistance center for older adults. A prototype platform was developed to collect and organise individual memories, which were then used to create engaging and meaningful games tailored to participants' biographies. The study involved 12 older adults with varied cognitive profiles who participated in game sessions over four sessions. The study was conducted in a real environment, to better understand the ecological validity of its possibilities. Preliminary results indicate that the platform's personalised and interactive nature enhances engagement and enjoyment, providing valuable insights for future development in this field.

Furthermore, the analysis of the associated data, when completed, could provide insights and recommendations for future studies conducted with ageing people in real care environments.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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