Serious Games to Support Cognitive Exercise in Older Adults Using the Social Robot EVA

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Abstract

Socially Assistive Robots (SARs) are a new class of robots that are designed to engage in social interactions with humans. This paper proposes some Serious Games for the SAR called EVA, detailing how these games can be used in cognitive therapy for older adults. The applications developed for robots not only promote cognitive stimulation and mental health but also aim to improve the overall quality of life of older adults promoting greater independence and reducing feelings of loneliness. This study highlights the potential of SARs in transforming cognitive care and highlights the broader implications for the integration of robotics in older adult care.

Keywords

Socially Assistive Robots, Elderly Care, Serious Games, EVA robot, EvaML

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1 Introduction

According to the World Health Organization [14], the aging of the population is a global phenomenon that brings significant challenges, particularly regarding cognitive decline and the need for specialized care. Alzheimer's disease and other forms of dementia affect millions of people worldwide, demanding the adoption of new and effective approaches for the treatment and support of people living with these conditions.

Acoording to Shibata [17], assistive technologies have been widely used to improve people's quality of life and are becoming increasingly common. Feil-Seifer and Mataric [7] state that robots are becoming part of society as assistive devices, and human-robot interactions have proven to be an effective method to improve both physical and cognitive abilities in humans. These robots can assist with household tasks or support individuals with physical impairments.

With advances in the field of robotics, a new class of robots has emerged, combining characteristics of two distinct categories: Assistive Robots, which provide physical assistance, and Social Robots, which offer support through interactions that resemble human interaction. This new category is known as Socially Assistive Robots (SARs). According to Olazarán [13], SARs have been increasingly used in nonpharmacological therapies, including those for patients with dementia. The work of Cruz-Sandoval et al. [4] states that positive results were observed in therapeutic activities involving these robots.

Oie and Patterson's study [12] demonstrates a link between playing action games and improvements cognitive and perceptive functions. However, cognitive enhancement is not limited to action games; different types of games can improve different cognitive abilities. According to Sørensen and Meyer [18], serious games are defined as digital games and tools with an educational design agenda that goes beyond entertainment. As stated by Felicia [8], serious games aim to leverage new gaming technologies for educational or training purposes, exploring their educational, therapeutic and social impact. According to Gavelin et al. [9], for older adults, serious games can function as cognitive exercises, helping to preserve and enhance mental function in this population.

This study proposes four serious games using the social robot EVA as the main platform. The first game is based on the classic toy Genius [2, 10], known for stimulating memory and logical reasoning by challenging players to repeat sequences of lights and sounds. The game was originally created in the United States by the Milton Bradley Company, in 1978, and is known there as "Simon" [19]. In addition to Genius, three other serious games are proposed, inspired by the Montreal Cognitive Assessment (MoCA). These games involve letter repetition, word pair association, and mathematical calculations.

The remainder of this paper is organized as follows. Section 2 presents related work. Section 3 presents the tools used to develop the proposed serious games. Section 4 provides a detailed explanation of each game. Finally, Section 5 presents the conclusion and suggests directions for future work.

2 Related Work

With the advancement of technology and the growing interest in innovative methods for cognitive stimulation, the integration of serious games in the treatment of aging-related conditions has shown promising results. In this context, de Paula et al. [6] present a proposal for a serious game based on the Stroop test, a well-known cognitive psychology technique that involves reading color names printed in conflicting ink colors (e.g., the word red written in blue ink). The game requires the inhibition of automatic responses and the resolution of cognitive conflicts, being developed based on the classic Stroop task and adapted into an interactive digital format. This cognitive game, designed for older adults and developed using the Ginga-NCL middleware [1] for Brazilian digital TV, integrates light-based sensory effects to enhance user engagement and the effectiveness of cognitive stimulation.

Previous studies highlight the importance of virtual games in improving mental and cognitive health, particularly in the treatment of aging-related conditions. Tests conducted with older adults demonstrated high acceptance of the game, indicating that the sensory light effects positively influenced players' perception, making the experience more engaging.

The work of Rocha et al. [16] explores the use of serious games using a SAR for emotional regulation therapy for children with Autism Spectrum Disorder (ASD). The authors present the EVA robot, which is capable of speaking, listening and expressing emotions through facial expressions, and highlight improvements in the EVA's capabilities to recognize users' emotions through facial recognition and generate sensory light effects, making therapy sessions more attractive, especially for children. This advancement represents a significant step toward immersive therapy solutions for autistic children, integrating verbal and non-verbal communication along with social interaction.

Both studies emphasize the relevance of sensory effects in technological interventions for different age groups, whether for cognitive stimulation in older adults or for emotional regulation in children with ASD. The use of lights and other sensory stimuli has proven to be an effective strategy to increase engagement in serious games and related activities, reinforcing the potential of assistive technologies in the healthcare field. This work follows a similar approach, proposing new serious games using the SAR called EVA, that was specifically designed for older adults.

3 EvaML Language and EvaSIM Simulator

EvaML [15] is an XML-based programming language designed to simplify the development of interaction scripts for the EVA robot. It provides abstractions that facilitate the script creation process, allowing developers to write them using a simple text editor. Since it is based on XML, EvaML is more readable for non-programmers.

EvaML includes elements that enable voice interaction, control of a smart bulb, execution of audio files, and manipulation of the robot's head and arm movements. Additionally, it provides features for variable creation and manipulation as well as control flow management within the script, among others.

To assist in the development and testing of scripts for the EVA robot, Rocha et al. [5, 11] proposed the EvaSIM simulator. This application simulates the behavior of the physical robot through graphical elements in its interface. In its current version, EvaSIM features enhanced multimodal interaction capabilities, including facial expression recognition, gesture recognition, and QR code scanning using a webcam. Additionally, it supports voice interaction through a microphone.

All the serious games proposed in this study were developed and tested using EvaML and EvaSIM, ensuring proper functionality before deployment on the EVA robot.

4 Proposed Serious Games

All the applications developed are interactive serious games that utilize the EVA robot as a platform. The games were designed to engage users through a series of dynamic and multimodal interactions.

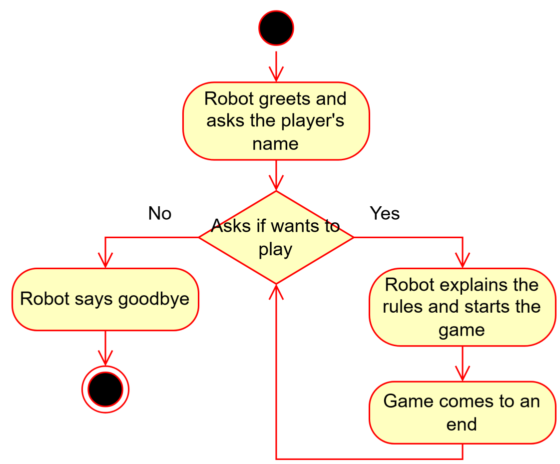

Figure 1: Flowchart of the general functioning of the games

At the beginning of each game, the EVA robot welcomes the user and invites them to participate. Using light effects and emotional expressions, the robot creates an immersive and engaging environment. Next, the robot asks for the user's name, personalizing the interaction accordingly. Figure 1 illustrates the main workflow of the applications.

4.1 Genius Game

This serious game is inspired by the Genius toy, a version released in Brazil of the original game called "Simon" that was created in the United States in 1978.

Similar to the original game, this serious game aims to stimulate memory using colors and sounds. The objective is to repeat a sequence of colors, which is displayed via a smart bulb. Each color is associated with a musical note, which the robot plays to reinforce cognitive processing. As the player correctly repeats the sequence,

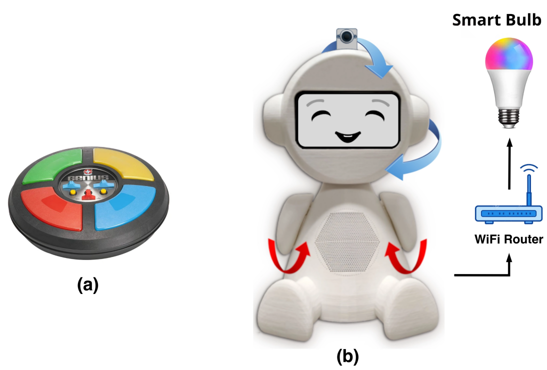

Figure 2: (a) Electronic toy Genius. (b) EVA robot.

a new color is added in each round. The red curved arrows in Figure 2(b) represent the robot's arm movements during interactions, while the blue curved arrows indicate its head movements. Figure 2 shows both the original Genius game and the EVA robot connected to a smart bulb via Wi-Fi.

At the start of the game, EVA introduces itself and asks for the player's name. It then asks if the player wants to participate. If the user refuses, the robot says goodbye and ends the interaction. If the user accepts, the robot explains the rules and introduces the four possible colors: yellow, green, blue, and red. Along with the visual presentation, EVA also plays the corresponding musical note for each color. Once the explanation is complete, the game begins.

The game starts with a randomly selected predefined sequence. The application offers seven different sequences, each containing up to five colors. If the player successfully repeats the sequence five times in a row, EVA expresses happiness and congratulates the player for winning. Additionally, EVA provides motivational phrases praising the user's memory skills. If the player makes a mistake at any point, EVA expresses sadness and informs the player of the error.

After each round, whether the player wins or loses, EVA asks if they want to play again. If the player agrees, EVA happily restarts the game with a new randomly generated sequence. If the player declines, EVA expresses sadness, thanks the player for participating, and ends the game. The detailed logical workflow of the Genius game is presented in Figure 3.

A demonstration video of the Genius serious game using the EVA robot can be accessed via this link[1].

4.2 Games Inspired by the MoCA Test

Cognitive difficulties are common among older adults, and early intervention can help slow the progression of conditions like dementia. One of the tools used for cognitive impairment diagnosis is the Montreal Cognitive Assessment (MoCA) test. Cecato et al [3] highlight the MoCA test's effectiveness in diagnosing Mild Cognitive Impairment (MCI).

This section presents three serious games inspired by the MoCA test, developed using the EVA social robotics platform. Each game

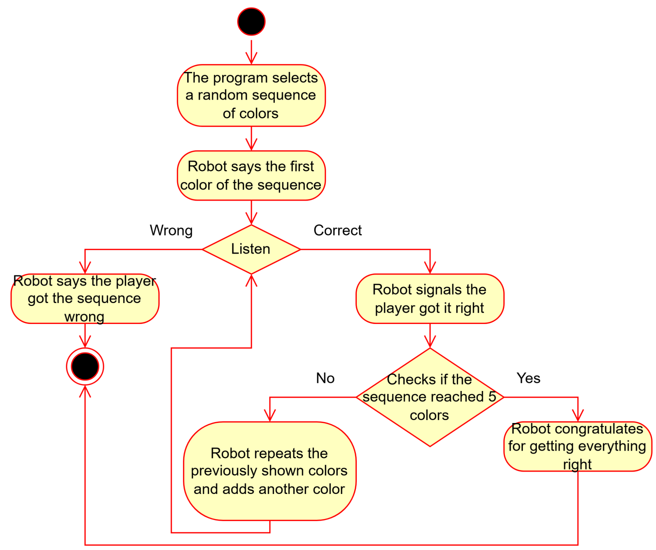

Figure 3: Flowchart of the logical functioning of the Genius game

is designed to evaluate different cognitive abilities. The following subsections describe each game in detail.

4.2.1 Word Pair Association Game. This game evaluates the user's abstract thinking and analogy skills.

In this application, the EVA robot presents two words and asks the user to identify what they have in common. For example, if EVA says "apple" and "orange", the expected answer would be "fruit". This exercise helps assess the user's ability to recognize categories and identify relationships between concepts. Figure 4 illustrates the game's workflow from start to finish.

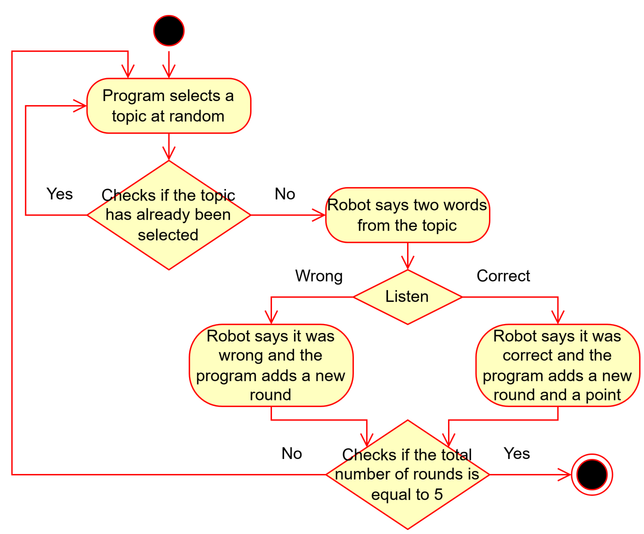

Figure 4: Logical flowchart of the Word Pairs game

[1]https://youtu.be/1fVstVthDHs

A demonstration video of the Word Pair Association game running in the EVA robot simulator can be accessed via this link[2].

4.2.2 Letter Repetition Game. In this game, the player must count how many times the letter 'X' appears in a sequence spoken by the robot.

At the beginning, EVA explains the rules and then presents the sequence. The game can present different sequences of letters and check the correct number of occurrences of the letter "X". The robot listens to the player's answer, provides feedback based on accuracy, and expresses emotions of happiness or sadness depending on whether the answer is correct or incorrect. At the end of the game, EVA asks if the player wants to play again and either restarts or ends the game accordingly. The game's interactive experience includes voice, audio, and light effects to enhance engagement.

A demonstration video of the Letter Repetition Game in the EVA robot simulator can be viewed via this link[3].

4.2.3 Calculation Game. This calculation and attention exercise is another MoCA-based game that involves subtracting 7 repeatedly.

In this test, EVA asks the player to start with a randomly generated number (between 35 and 100) and subtract 7 continuously five times. For example, if the starting number is 100, the expected sequence would be 100, 93, 86, etc. This task assesses mental calculation skills and the user's ability to maintain focus throughout the process.

A demonstration video of the Calculation Game in the EVA robot simulator can be accessed via this link[4].

5 Final Considerations

This study introduced a new field of robotics, Socially Assistive Robots (SARs). These robots can interact with humans with interactions that resemble human interactions. The potential of assistive robotics was demonstrated by creating applications for the EVA robot, using the EvaML language. Four serious games were presented with the aim of stimulating memory (Genius Game), using colors and sounds, and serving as a tool for assessing some cognitive abilities (games inspired by the MoCA test). These applications aim to promote interactive and educational experiences focused on cognitive improvement in the elderly, demonstrating how technology can engage users in tasks that stimulate memory, attention and other cognitive functions.

The integration of sensory elements, such as lights, sounds, and emotional expressions, enriches the robot's interaction with users. This work contributes to the use of socially assistive robots in therapeutic contexts, promoting mental health and well-being among the elderly, while also offering new possibilities for care and social inclusion of vulnerable populations.

For future work, new applications will be developed to take full advantage of the robot's recent capabilities, including features such as QR code reading and facial expression recognition. These new capabilities will allow the robot to interpret a wider range of human signals, resulting in more natural interactions. In addition, an important future step involves conducting tests with older adults in geriatric settings to collect critical data on the acceptance and emotional impact of these technologies in aging populations. A project with this focus has already been submitted to the Research Ethics Committee, which will enable these evaluations to be carried out in the near future.

[2]https://www.youtube.com/watch?v=V6aMChU50PE
[3]https://youtu.be/IdELAmW3RhY
[4]https://www.youtube.com/watch?v=aqNjOxdWwMQ

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