Pepper Sagt: A Serious Game for Improving Memory and Physical Activity in Elderly People

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***Abstract*—The world is facing a phenomenon of population ageing, that is, the life expectancy is increasing and the birth rate decreasing. As a consequence, the number of people suffering from diseases related to age — such as dementia — is expected to increase; and the number of caregivers is expected to decrease. This paper presents a serious game with cognitive and physical exercises designed to help the elderly, slowing the symptoms related to dementia like cognitive decline. We used the humanoid robot Pepper as the platform. The game was presented in a nursing home, where it was tested by staff members to evaluate if it is safe to be use by elderly people. A questionnaire was used to evaluate the participant's interaction with the game. The results indicate a positive view towards the interaction and the use of the game.**

***Keywords*-elderly people; serious games; human-robot interaction;**

I. Introduction

The world is facing a phenomenon called population ageing due to the combination of declining birth rate and increasing life expectancy. World Health Organization's (WHO) reports of 2017 contain statistics indicating that there are 962 million elderly people (over 65 years of age) in the world. This number represents 13% of the global population. This age group is expected to double in size by 2050, reaching 2.1 billion people. Currently, developed countries are facing a advanced stage of population ageing, but this issue is growing faster in developing countries than it did in developed ones [1].

Brazil follows this trend. Reports published by the Brazilian Institute of Geography and Statistics (IBGE) indicate that the country had 30.2 million elderly people in 2017, 13% of the Brazilian population at that time. It is expected that Brazil will have the 5th oldest population in the world by 2030 [2]. This phenomenon will likely increase significantly the number of people who need long-term care and, at the same time, the number of people working as caregivers will decrease [3].

Elderly people suffer from diseases like dementia, which is commonly diagnosed in people over the age of 65. WHO and The Alzheimer's Disease International say that, by 2050, the number of people with dementia will increase three times [4]. Dementia is a progressive disease characterized by the declining of cognitive functions such as: memory, thinking, comprehension, language, etc. However, intensive cognitive training can be used to improve cognitive functions in early stages of dementia [5].

Socially Assistive Robotics (SAR) is a subfield in Human-Robot Interaction (HRI) that can help in the treatment of such diseases. SAR focuses on helping human users through social rather than physical interaction, aiding in their daily activities. This kind of robot has already been applied in several areas such as elderly care, rehabilitation therapy, and social disorders treatment [6], [7].

Another segment from academic research being applied to health care are Serious Games. A commonly used definition of this segment was firstly established by Clark C. Abt in his book, Serious Games (1975):

> "We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement." [8].

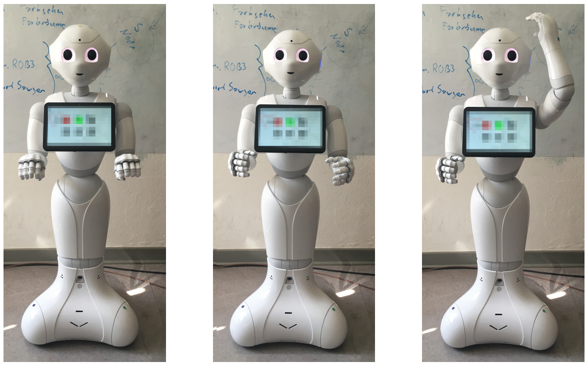
Some famous examples are games developed for Nintendo Wii (Wii Fit) and Microsoft Xbox (Kinect) where the player must perform some movements and the console acts like a trainer.

One method to evaluate HRI and serious games is using self-report questionnaires, where the participant reads the question and selects a response by themselves. This method is useful to collect opinions of the participants about some topic, and it is simple to be applied [9], [10].

This paper focuses on the development of a serious game, using a robot as a platform, to be used by elderly people. Moreover, it presents the evaluation of the game by the staff members of a nursing home.

II. Methods

The hardware used in the development of the game was the robot Pepper from Softbank Robotics, shown in Figure 1; and the software used was Choregraphe — a block-based visual programming language used to develop applications and interact with the robot. Pepper is a social humanoid robot designed to interact with people in a pleasant and



(a) (b) (c)

Figure 1. Robot poses during the game.

intuitive way. Pepper has 17 joints for body movements and three omnidirectional wheels which allow it to move in any direction. Pepper is 1.2 meters tall; and unlike some famous robots, Pepper's body has no sharp edges, which makes it more appealing and safer for humans during interactions. The robot has a tablet in its chest that can be used to display pictures, websites, and applications. Pepper's battery lasts 12 hours of uninterrupted activities.

A. *Pepper Sagt*

Pepper Sagt — "Pepper says" in German — is a game inspired by the classic electronic game Simon from Hasbro (in Brazil, produced by Estrela and known as Genius). In our version of the game, Pepper asks the player to touch a colored circle. Matching games like this can exercise cognitive functions such as attention, memory, motor skills, language, and visual and spatial processing [11].

Five colored circles are placed in different parts of the robot's body. The locations were selected based on Pepper's touch sensors. Table I shows the colors of the game, and where the player can find it.

Table I
COLORED CIRCLES LOCATIONS.

Color	Location
Yellow	Top of the head
Red	Back of the right hand
Blue	Back of the left hand
Purple	Right foot (bumper)
Green	Left foot (bumper)

Verbal communication is the main method used in the interaction between robot and player. Pepper has microphones and speakers that enable it to speak and listen. Choregraphe provides built-in methods to make the robot talk and recognize words in a reliable manner. Pepper is a polyglot robot; it is possible to choose between 21 languages.

The game starts with Pepper welcoming the player and explaining the rules of the game. We use body motions, in addition to the voice, to show the location of the colored circles. After presenting the rules, Pepper asks if the player wants to play. All the questions presented by Pepper are closed-ended, e.g., "yes" or "no", or Pepper suggest the answers. Once the player accepts to play the game, Pepper asks about the difficulty level of the game, i.e., "easy" or "hard". For this question the player can answer verbally or use the tablet to select the difficulty. After this, Pepper asks the player to say "ready" when he or she is ready. Then, the game starts.

Pepper has 3 poses during game-play, choosing one randomly before saying the name of a color. This feature was added to occlude the colors, and to force the player memorize the relation between the colors and body parts.

Immediate feedback was added to the game in such a manner that if the player touches the correct color, the robot will reproduce a "happy" sound and will nod in a positive manner. But, if the player touches the wrong color, the robot will reproduce a "sad" sound and will shake the head in disapproval. This kind of reward may encourage the player to stay motivated and contribute to learning.

The duration of the game is 2 minutes. After this time, Pepper will announce that the game is over and will show in the tablet screen the score achieved by the player. In each round, a score is calculated based on the time spent by the player to touch a circle, and if the circle was correct or not. This can be seen in Equation (1), where T_{game} represents the total duration of the game, and T_{answer} represent how long the player took to answer. In the end of the game, a final score is calculated from the sum of the rounds' scores as seen in Equation (2).

$$s_n = \begin{cases} (T_{game} - T_{answer}), & \text{if correct} \\ -(T_{game} - T_{answer}), & \text{if wrong} \end{cases} \tag{1}$$

$$score_{final} = \sum_{i=0}^{n} s_n \tag{2}$$

No matter the result of the game, Pepper will motivate the player to improve. After showing the score, Pepper tells the player some motivational phrases based on the number of correct and incorrect responses. Examples of the phrases used are: "Great job, you've got all answers right", "Well done! Let's try again to see if you get all answers right", "Nice job. Let's try again. I will present the rules again".

While Pepper is not playing, it tries to act as a curious robot. We used a basic awareness package from Softbank that makes Pepper aware of the surrounding environment. Pepper will pay attention, and stare at people talking; Pepper blinks randomly to emulate human behaviour. This behavior was implemented to improve Pepper's interaction with people.

B. Evaluation

The evaluation method used for this work was an anonymous self-reporting questionnaire containing questions about the participant's basic information such as age, education level, the participant's previous experience working with elderly people; and qualitative questions about the interaction with the robot.

Semantic differential scale questions were used to evaluate the appearance of the robot, feelings of the participant during the interaction, and about the difficulty of the game. This type of question measures the cognitive meaning of the topic by asking the participant to rate in a scale ranging between bipolar adjective pairs.

Likert scale questions asked the participant about what they think about the use of the robot in elderly care. Different from the other scale, in a Likert question the participant needs to evaluate a statement using a scale ranging from agreement to disagreement.

C. Experiment

Each participant plays with the robot individually. Firstly, the authors briefly present the robot and the game. Then, the participant is placed at a distance of 1.5 meters from the robot (inside of the social zone of 1.2 to 3.6 meters, distance used for conversation to non-friends [12]). At this time, one of the authors starts the game without the participant's knowledge. Pepper starts the game welcoming the player and explaining the rules of the game, as mentioned before.

When the player decides to stop playing, Pepper will thank him for the interaction and will say goodbye. After the interaction, the authors ask each participant to fill a questionnaire in a separated room.

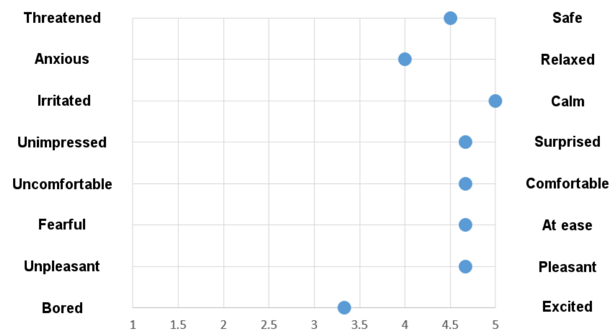
III. Results

The evaluation of the game was done in a nursing home with 7 non-elderly healthy participants. Inclusion criteria were established toward the users background of working with elderly people. This criteria was chosen because the experience of the participant with elderly care is important to evaluate the system for future use with the target population. One participant was removed from the analysis since he did not meet the inclusion criteria. Table II presents demographic data of the 6 participants. All of the participants had at least higher education and had already seen a robot in real life or on television, but had no experience with the topic.

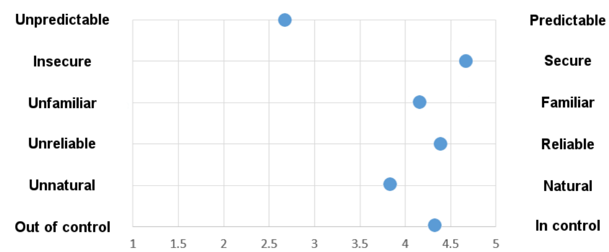
Table II
Characteristics of the participants.

Characteristic	Total (n=6)
Age (Mean (Standard Deviation))	40,8 (9,5)
Gender (n)	
Female	3
Male	3

(a) Question - "Please, rate your impressions about the game."



(b) Question - "Please, rate your feelings during the interaction with the robot".



(c) Question - "Please, rate your impressions about the robot."

Figure 2. Series of semantic differential items used to evaluate attitudes toward the robot and the game. Each graph presents the average of the participants' responses.

All the participants played the game once and described it as easy, as showed in Figure 2a. The graphs presented in Figure 2 show the participants' average response to the semantic differential questions. The impressions about the game were good, as presented in Table III. The players understood the rules presented by Pepper, and liked the game. But the game seems to be not so interesting.

The participants' reactions about the interaction with the robot were positive, as seen in Figure 2b. The difficulty of the game probably interfered here, as shown by the the excitement of the players.

The impressions about the robot were also positive. The novelty presented by the interaction with the robot could explain the ratings for the "Natural", and "Familiar" items. The item "Predictable" could be explained based on a failure presented by Pepper in the pose changing. Sometimes the robot took a long time to change the position, saying the color to the player before finishing the movement. Then, the player could interact with the robot during its movement.

The participants had positive thoughts about the future of robots working alongside the elderly, as seen in Table IV.

Figure 3 shows two interactions with Pepper. Figure 3a shows a caregiver playing the game. Figure 3b shows one of the authors (without disabilities) testing the game using

Table III
IMPRESSIONS ABOUT THE GAME.

About the game		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I understood the rules of the game	(%)	0	0	0	0	100.0
I liked to play the game	(%)	0	0	0	50.0	50.0
I found the game interesting	(%)	0	0	33.3	66.7	0
I would like to play the game again	(%)	0	0	50.0	50.0	0

Table IV
THOUGHTS ABOUT THE FUTURE.

About the future		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I think that the older people will interact with this robot	(%)	0	0	33.3	0	66.7
I can imagine myself working with this robot	(%)	0	0	0	33.3	66.7
I think that robots could be helpful in elderly care	(%)	0	0	0	0	100.0
I can imagine older people interacting with robots	(%)	0	0	0	16.7	83.3

a wheel chair.

(a) (b)

Figure 3. The picture on left (a) shows a staff member of the nursing home playing with Pepper. The picture on right (b) shows one of the authors (not a person with disabilities) testing the game using a wheel chair.

IV. CONCLUSION AND LIMITATIONS

This paper presented a serious game designed for elderly people, using a robot as the interface to interaction. We executed an experimentation with 6 staff members from a nursing home. Results showed a positive receptivity of our game by the participants. The participants expressed positive thoughts about the future of robots alongside elderly people.

The main limitation of this paper is related to the size of the population. Tests must be done in the future with more caregivers and with elderly people. Firstly, more test must address safety. Then, it is interesting to evaluate the effects of the robot in the context of elderly life.

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