Using the Pepper Robot in Cognitive Stimulation Therapy for People with Mild Cognitive Impairment and Mild Dementia

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***Abstract*—Social Assistive Robotics (SAR) has successfully been used in healthcare interventions from the functional and socio-emotional points of view. In particular, they have been used in therapeutic interventions for elderly people affected by cognitive impairments. This paper reports of our research aiming at investigating the role of the social robot Pepper in aiding therapists during cognitive stimulation sessions for elders with Mild Cognitive Impairment (MCI) and Mild Dementia (MD). To this purpose, an experimental study was performed with a group of 8 participants in a 3-weeks cognitive stimulation program. To assess and monitor the results, each session was video recorded for further analyses. The collected videos were analyzed by three human raters, in order to evaluate them in terms of participation and engagement operationalized as eye gazes, number of correct answers and displayed emotions. Results show that Pepper has been positively accepted by the seniors, who were very attentive and involved in session tasks, during which the participants have rarely experienced negative emotions. Moreover, some correlations between the gathered data also emerged that emphasize the effectiveness of the proposed approach. In particular, seniors with lower impairment experienced less happiness; however, they were very engaged during the training with the robot.**

***Keywords*—Social Assistive Robots; Cognitive impairment; Cognitive Stimulation; Elderly people.**

I. INTRODUCTION

With the rapid growth of the older population worldwide, dementia and cognitive impairments are increasingly important issues in elderly care. Alzheimer's Disease International estimates that 24.4 million people worldwide suffer from dementia and that the number of patients will increase to 82 million by 2040. People suffering from dementia and cognitive impairments present problems with memory, thinking and behavior, and symptoms usually develop slowly and get worse over time [1] with devastating effects on the psychological well-being of the individuals.

MCI is an intermediate stage between the cognitive decline associated with typical aging and more severe serious forms of dementia. Individuals with MCI frequently show memory loss or forgetfulness and may have issues with other cognitive functions, such as language, attention or visuospatial abilities. MCI treatments aim to reduce existing clinical symptoms or to delay the progression of cognitive dysfunction and prevent dementia. The potential evolution of this disease makes it unavoidable to provide such people with increasing assistance over time. Therefore, it is especially relevant to offer them timely and engaging cognitive training to slow the progression of their decline, while significantly cutting down the associated socio-economic costs. The increasing attention for cognitive rehabilitation and neuropsychological interventions, in this case, is justified by the poor outcomes obtained with pharmacological treatments. Non-pharmacological treatments to these problems focus on physical, emotional and mental activation.

There is growing evidence that cognitive interventions may be associated with small cognitive benefits for patients with MCI and dementia. Based on recent trials, computer training program has particular positive effect on cognition and mood [2]. In particular, cognitive stimulation and rehabilitation therapy focus on protocols in which different types of tasks are used for recovering and/or maintaining cognitive abilities, such as memory, orientation and communication skills [3]. Also, motor activities are important to help individuals with dementia to rehabilitate damaged functions or maintain their current motor skills for preserving autonomy over time. According to some studies carried out on older subjects with MCI, several positive effects of physical exercise on cognition, executive function, attention and delayed recall are showed. This cognitive and physical training require a trained therapist that besides supporting the patient through their execution has to give feedback during the therapeutic session and keep track of the user's performance in order to monitor the progress over time [4]. In particular, humanoid robots seem promising since they can support more engaging interactions with users, and there have already been some work exploring the use of robots for aiding cognitive treatments [5].

Currently, there is a focus on humanoid robots and tablets to investigate how seniors with MCI relate with and perceive serious games accessed through humanoid robots, as part of a training program aimed to improve their cognitive abilities.Interestingly, few investigations exist currently that explore the impact of robots as tools to provide cognitive training for the elderly. Recently, Socially Assistive Robotics (SAR) is be-

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ing effectively used in dementia care and several commercially available robots have been employed with satisfactory results in cognitive stimulation and memory training [6]–[8].

Following these findings, in collaboration with a local association (”Alzheimer Bari” ONLUS), we set up an experimental study aiming at evaluating the effectiveness and acceptance of SAR technology in providing therapeutic interventions to people suffering from cognitive changes related to aging and dementia. In this paper, we focus on the results of this pilot study in which we used Pepper, a semi-humanoid robot developed by SoftBank Robotics, as support to psychotherapists in cognitive stimulation sessions. The experiment and its protocol have been co-designed with therapists, following the paradigm of cooperative and participatory design, in dedicated sessions in order to make how Pepper administered the tasks as similar as possible to the method adopted by the human therapists in their training sessions [9]. After this preliminary phase, the intervention protocol was defined and the robot was programmed to execute the planned exercises used during the training sessions. In total, we planned to run 4 sessions with Pepper as a tool to convey the planned therapeutic intervention. Unluckily, due to the COVID-19 emergency, we had to suspend the experiment one session earlier. Each session was video recorded, with the consent of participants and their legal representative, to be subsequently analyzed by three expert raters to evaluate them in terms of participation and engagement through eye gazes [10], the number of correct answers and expressed emotions. From the analysis of the obtained results, we can conclude that Pepper is a fairly good technology for cognitive stimulation because it expands the accessibility of control synthesis for social robots for people of all programming skill levels across many domains. In general, all the seniors participated actively in the experiment experiencing more positive than negative emotions during the intervention, and the correlation analysis showed that individuals with lower MCI expressed less happiness even if the eye gaze estimation showed that they were more engaged by the robot. These results encourage us to to continue the current work, also carrying out the comparison with a control group in which the same stimulation protocol will be executed without the use of social robots.

The paper is structured as follows. In Section II, motivations and background of the research are reported. Section III describes the study and reports its results. Finally, in Section IV, conclusions and possible future works are discussed.

II. Motivations and Background

Cognitive Stimulation Therapy (CST) is a short-term, evidence-based, group, or individual intervention program for people with mild to moderate dementia or Alzheimer’s disease. The goal of CST is to stimulate people with dementia through a series of themed activities designed to help them continue to learn and stay socially engaged. SAR describes a class of robots that is the intersection of assistive robotics (robots that aid a user) and socially interactive robotics (robots that communicate with a user through social and nonphysical interaction) [11].

One goal of an effective SAR system is to establish a relationship with the user that leads toward intended therapeutic goals. SAR has successfully been used in Human-Robot Interaction research (HRI) by including social robots in healthcare interventions by virtue of their ability to engage human users in both social and emotional dimensions [12].

The integration of robotics into both formal and informal MCI care opens up new possibilities for improving the lives of patients and alleviating the burden on caregivers and healthcare services. Early studies have shown that SAR has the advantage of improving mood, social relationships among patients and emotional expression of individual dementia sufferers [13]. Several investigations on the effects of robot therapy, using commercially available animal type robots has been investigated in [14] [15]. Other research aims instead at the creation of assistive humanoid robot therapists, using NAO robots [6].

Researchers [8] also investigate how patients with dementia relate to humanoid robots and perceive serious games accessed through it, as part of a training program aimed to improve their cognitive status. Here, it has been observed that elders became more engaged with Pepper along with sessions and there was a positive view towards the interaction with it.

In [3], NAO has been used to reproduce physical exercises to a group of seniors. NAO was also employed in individual and group therapy sessions [6] [16] to assist the therapist with speech, music, and movement. Indeed it has been argued that Pepper is easy to use by the patients with dementia, relatives, and caregivers, it brings patients with dementia in a more positive emotional state and in music sessions stimulating patients to recall memories and talking about their past [17].

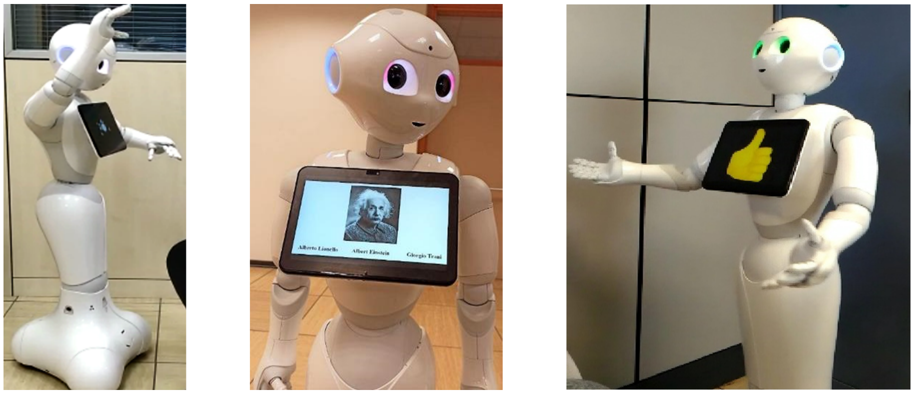
In the CST intervention reported here, we used Pepper as a social robot.

III. The Experimental Study

This section describes the study performed to investigate how seniors with MCI relate to and perceive the CST program performed with the aid of the social robot Pepper. The CST program during which the experiments were conducted lasted 3 weeks, with weekly meetings of about 35 minutes. Eight subjects were selected for the experimental study among the members of the Alzheimer Bari” ONLUS Association according to their MMSE score (Mini-Mental State Examination) and their willingness to take part in the study.

A. Material

1) The Robot Platform: The robot platform used in the current study is Pepper, a semi-humanoid robot developed by SoftBank Robotics (Figure 1). It is an omnidirectional wheeled humanoid robot 1.21 m tall, with 17 joints and 20 degrees of freedom. The interactivity is the key feature of Pepper. It has multimodal interfaces for interaction: touchscreen, speech, tactile head, bumper, and 20 degrees of freedom for motion in the whole body. The robot is equipped with several LEDs that can be programmed to change colors and intensity to



(a) (b) (c)

Fig. 1. (a) An example of physical exercises. (b) Memory training (c) Positive feedback.

signal and support communication. It is equipped with four directional microphones in its head that allow it to detect the origin of entries and thus to turn its face to whoever is talking. These microphones can eventually be used to analyze the voice tone and therefore interpret the emotional state of the interlocutor. Pepper can operate in complex environments thanks to its 3D video camera and the two HD cameras that allow it to identify movements and recognize the emotions on the faces of its interlocutors. The robot is equipped with 20 motors that allow it to move its head, back and arms. In addition, it has several sensors to provide information on the distance of objects placed up to 3 meters, in addition to its three cameras (two RGB and one 3D inserted in its head). Pepper has also tactile sensors on the head and hands, which are used for social interaction. The LEDs located in the eyes can take one of any RGB color: this feature is particularly useful when it is necessary to simulate emotions by changing the color of the eyes. Pepper has also a tablet to display videos, images and allowing the user to interact with it.

2) *Neuro-psychological Evaluation:* For the evaluation of the neuro-psychological state, the Mini Mental State Examination (MMSE) [18] was administered 1 week before starting the experimental phase to all the members of the association willing to participate in the study. The MMSE score was used to select seniors in order to have a group as homogeneous as possible.

3) *The Tasks:* The tasks to be performed during the CST program with Pepper were selected by the staff of specialized therapists of the center essentially from the volumes of "A gym for the mind" [19] and were adapted to Pepper communicative capabilities.

Three sets of cognitive stimulation tasks were created, all designed to be carried out in a group format. Each weekly session was planned to last between 30 and 40 minutes, according to the therapists' estimation of the duration of the patients' attention during the exercises. In Table I the exercises for each session are reported.

The opening and closing of each session with recreational activities were designed to make the therapy sessions less stressful for patients. The motor imitation task was chosen to open each session since it was evaluated as pleasant by all seniors in the group. In Figure 1a, Pepper is showing some movements to be imitated by seniors. For visual-verbal associative and word completion tasks, two levels of difficulty have been designed specifically to the type of exercise they have been associated with. During each session the levels of the activities to be carried out were performed one after the other, increasing the difficulty level. The tasks were based on vocal, visual, and touch-based interaction (through the tablet placed on Pepper's torso) in order to avoid some errors due to natural language understanding, such as: a) false positives: when the patient gives a wrong answer, but Pepper takes it as right, giving positive feedback and passing directly to the next question; b) false negatives: when the patient answers exactly, but the robot interprets it as wrong. For these reasons, the correctness of the answers to Pepper's questions was handled directly by the therapists by touching a different sensor on Pepper's head (for the correct answers it was decided to use the sensor closest to Pepper's face and for the wrong ones the last sensor behind the head and the central sensor was used to repeat the questions). In general, if the participant's answer was correct, Pepper reinforced it with positive feedback, showing a thumbs up on the tablet and body movements manifesting how happy it was with that response (Figure 1a). In the case of a wrong answer, Pepper encouraged the patient to try again without using negative words (e.g., bad, wrong).

TABLE I
DESCRIPTION OF THE EXERCISES FOR EACH SESSION.

Session 1	*Session 2*	*Session 3*
Motor imitation	Motor imitation	Motor imitation
Word completion	Memory of prose	Visual-verbal associative memory
Verbal associative memory	Verbal associative memory	Memory of prose
		Verbal associative memory

Further support was given by the LEDs positioned in Pepper's eyes and used to provide either positive (green eyes) or negative feedback (red eyes) basing on the answers provided. If the subject answered correctly, after complimenting the patients, the robot moves on to the next step of the task and, after a short pause, it moves on to the next question. After three wrong answers to the same question, before moving on to the next question, the robot communicates the correct answer.

Figure 1b shows an example of a Visual-Verbal Associative Memory Task in which Pepper shows on the tablet the image of a famous person and asks for his/her name. The interaction between the robot and the patients is vocal.

B. Context and Environment Settings

The study was carried out with the collaboration of the ”Alzheimer Bari” ONLUS Association in Bari, Italy. It was founded in 2002 and offers memory training and cognitive stimulation courses to subjects who have been diagnosed with mild or mild-moderate cognitive impairment (MCI), bringing together family members, doctors, psychologists, socio-health workers, and other figures all involved in various aspects of the management of Alzheimer’s Disease patients and their family members. They also offer physiotherapy cycles, music laboratory, artistic and laboratory activities. Furthermore, assistance is provided to the patients’ family members, who are also distinctly followed by neuro-psychologists and educators during the sessions dedicated to loved ones. Patients often follow multiple courses per week, in order to perform an intervention program as complete as possible, based on the stage of their illness.

The choice of the experiment room was important. We selected, according to the suggestion of the therapists, the room in which usually patients carried out musical sessions. In general, the seniors participated with joy in these exercises and then this environment for them represented a place where they had positive experiences. In addition, the chosen room is large enough to contain the two therapists, the patients and the robot, guaranteeing to the latter enough space to perform the movements, which, in the presence of obstacles, would not have been allowed by its safety sensors. The patients were seated in front of therapists and Pepper, and behind a wall, there was the technician in order to solve technical problems arising during the exercises with the robot.

Pepper was positioned about one meter away from each patient, respecting its range in which it manages to be engaged and perceive the people around it. Besides the Pepper’s internal video camera located inside its mouth (which allowed to better capture the faces of the patients), another video camera was positioned in the room in order to have a front view of patients’ faces and to be able to analyze the entire group behavior. Figure 2 shows the setting of the environment.

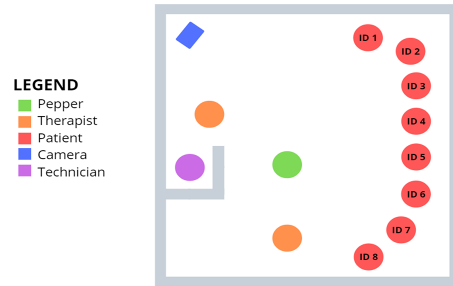


Fig. 2. The environment setting.

C. Participants and Procedure

The study involved 8 elderly people (see Table II for a description) enrolled among the population of members of the “Alzheimer Bari” ONLUS, considering as a condition of patient inclusion an MMSE score between 13 and 26.2, since patients with these scores can make progress with CST. The group included participants with MCI, MD and two with subjective cognitive impairment. Among the users of the Association, the subjects eligible for the experimental study were contacted to ask them to participate. A week before the experiment, the therapists carried out neuropsychological assessments on future participants in the experiments. Before running the CST with Pepper, participants and their relatives received detailed information about the study and subsequently signed a consent to be video recorded during the experiments. The consent was also signed by their legal representatives.

TABLE II
PARTICIPANTS’ MMSE

ID	*Gender*	*Age*	*MMSE*
1	F	89	23.4
2	F	77	26.2
3	M	82	24.1
4	M	89	21.1
5	M	82	13.0
6	F	79	13.2
7	F	69	20
8	F	72	17

In the same week, Pepper was presented to the Association for the first time to favor familiarization for the successive sessions. In the first five minutes of each session, the therapists put the elderly at ease, then Pepper was introduced already active, to avoid negative emotions and connected to the unanimated look of the robot. Once placed in the center of the room, Pepper greeted the elderly and conversed with them for a few minutes (directed by the technician who was sat on his hidden desk and exploited the Wizard of Oz technique). Subsequently, the set of exercises planned for that day was implemented. In the absence of answers, it encouraged patients to answer, asking the question again and helping them if necessary. Therapists intervened only to touch the sensor corrected on its head to direct the feedback provided by Pepper to each answer and to move on to the next question. At the end of each experimental session, the robot greeted the participants and was led out of the room to leave the patients with the therapists for a few minutes. The cognitive stimulation program lasted for 3 weeks, one day per week, performing a battery of tasks of about 30 minutes per day.

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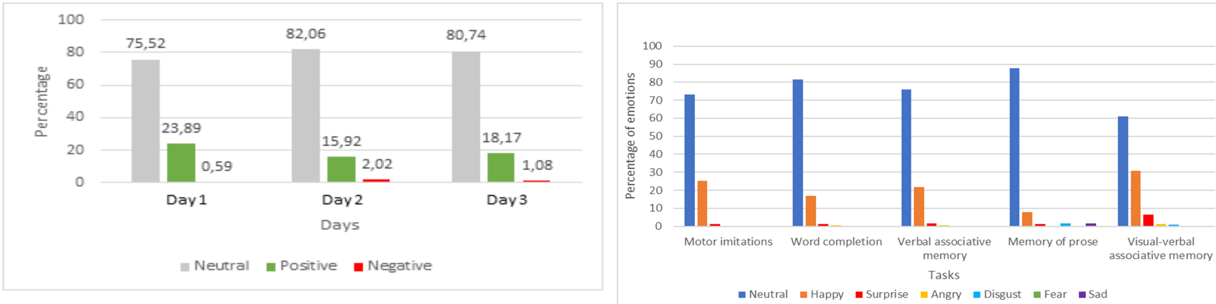

Fig. 3. (a) Valence of experienced emotions in each session. (b) Experienced emotions for each exercise.

D. Measurements

We collected the video-recording of the 3 sessions. Recordings were segmented in order to have one video for each exercise. In order to measure the number of correct answers, eye contact and emotions experienced by each participant during each session, three expert observers (two women and one man, of average age 37.67 y.o.) were selected. They had an almost perfect agreement index (0.83), calculated through the Fleiss' kappa [20].

To count the number of correct answers, they had the set of correct answers for each exercise. Subsequently, the total time each senior looked at Pepper during each exercise of the session was calculated. To annotate basic emotions (angry, disgust, fear, happy, sad, surprise, and neutral) expressed by the seniors the annotators were first trained on the Facial Action Coding System (FACS) [21].

E. Results

From the analyses of correct answers, we can say that the patients participated actively in the experiment. Overall, it has been noted that patients, in general, experienced problems with the prose memory exercise since the percentage of correct answers has been 0.2% in contrast to the average of the other exercises (55%), this type of task is inherently difficult and, in our opinion, the voice of the Pepper robot did not facilitate the story comprehension. Since this exercise was present only in the second session, we can ascribe to this the lower engagement in this day of the CST. As far as emotions are concerned, the level of negative emotions experienced by the seniors during the entire experiment is acceptable (0.59% for Session 1, 2.02% for Session 2 and 1.08% for Session 3). Considering the videos, it has been noticed that these emotions emerged when subjects disagreed with the statements made by the other participants and not towards Pepper. Besides the "neutral" state (on average 79.44% per day), seniors experienced more positive emotions (on average 19.33%) than negative ones. Figure 3a shows the valences of the emotions recognized in each session of the CTS. Analyzing the emotional experience for each task (see Figure 3b), during the visual-verbal associative memory one the maximum "happy" rate was achieved (30.75%), followed by the motor imitation task (25.32%). The observers also recorded the eye gaze of each participant's towards Pepper, by considering this a measure of engagement [22]. Figure 4a and Figure 4b show the engagement of seniors for each session and for each exercise, respectively. The session in which participants resulted most engaged in the interaction is the third one. In particular, during that session, they showed more engagement in the motor imitation task, in which they paid attention to Pepper for 76.53% of the exercise duration. The tasks on visual-verbal associative memory were also particularly successful (74% on average).

The Pearson coefficient was calculated to observe linear correlations between the results of the behavioral observations and the neuro-psychological evaluations' scores. In particular, seniors with a lower MCI tended to experience mostly neutral emotions (r=0.70) and were less happy (r=-0.80); this could be attributed to the need for separate sessions for them with tasks more stimulating. Positive correlations emerged between the eye gaze engagement estimation and the MMSE scores (r=0.42).

IV. Conclusions and Future Work

In this paper, we presented the results of an experimental study carried out in the context of rehabilitation interventions for reducing cognitive decline in the elderly people with MCI and mild dementia based on the use of the Social Robot Pepper. The reported study aimed at investigating how this technology can be used to support therapists in training programs for improving subjects' cognitive status. The evaluation and feedback from participants showed also that the system was appreciated and that the seniors involved in the study approached Pepper as a human and perceived it as a stimulus to go to the centre for the rehabilitation program. For example, participants talked to the robot as an entity having its own personality. Results obtained so far are encouraging but we must recognize some limitations. First of all we could not make a comparison with a control group as planned, due to the COVID-19 emergency. A second limitation concerns the sample size in that the research was implemented with only one group of people, which is not homogeneous for cognitive disease. Therefore, future work should involve a larger sample considering also a greater number of trials extended over more sessions. This will allow to make comparisons between people with different level of cognitive impairment and gender also

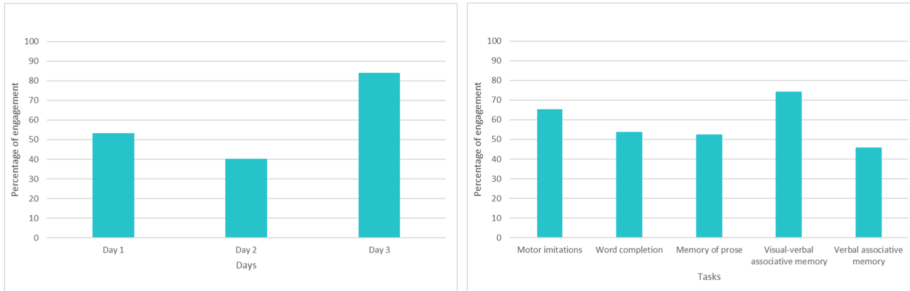

Fig. 4. (a) Percentage of Engagement in each session. (b) Percentage of Engagement in each exercise type.

exploring the effect of cognitive training on non cognitive functions, as mood and distress.

A further aspect that we plan to develop in the future, is the automatic analysis of engagement and emotions with the purpose of adapting the robots behaviour to the users for increasing their engagement in the rehabilitation program. It is desirable that robots applied to real world applications perform their activities in reactive but flexible manner. Thus, a robot architecture capable to adapt to human interaction is very suitable. Although the current paper concerns specific tasks, other abilities can be included. Besides, the investigation is a very common application of SAR, projected mainly for rehabilitation purposes.

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