

# The Role of Physical Embodiment of a Therapist Robot for Individuals with Cognitive Impairments

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**Abstract**—This research focuses on studying the possible role of a socially interactive robot as a tool for monitoring and encouraging cognitive activities of the elderly and/or individuals suffering from dementia. One of the aims of this work is to show the benefits of the robot’s physical embodiment in human-robot social interactions. The social therapist robot tries to provide customized cognitive stimulation by playing a music game with the user. The results of the 8-month pilot study depict a more efficient, natural, and preferred interaction with the robot rather than with the simulated robot.

## I. INTRODUCTION

In the recent years, there has been a growth of interest in rehabilitation and assistive technologies featuring flexible and customizable robotic systems. The main goal of such robots is to support elderly individuals and/or individuals with disabilities in their home environments, and therefore to improve their quality of life. Moreover, most advanced countries world-side are becoming aging societies, and the special needs populations are on the rise.

The American Alzheimer’s Association reported that more than one million residents in assisted living residences and nursing homes have some form of dementia or cognitive impairment [2]. The rapidly increasing number of people suffering from Alzheimer’s disease could have a disastrous effect on the healthcare services in the next few decades. The latest estimate is that 26.6 million people were suffering from Alzheimer’s disease worldwide in 2006, and that the number will increase to 100 million by 2050, constituting 1 in 85 of the total world population. More than 40% of those cases will be late-stage Alzheimer’s, requiring a high level of attention equivalent to nursing home care.

Alzheimer’s disease is a form of dementia, a disorder that progressively affects the brain. People with dementia may not be able to communicate verbally or perform normal activities, such as getting dressed, eating, and toiletry. They usually lose their ability to solve problems or control their emotions. Their personalities and typical behavior patterns change, and memory loss is common. Dementia appears in the second half of life, usually after the age of 65. The frequency of dementia increases with age, from 2% in 65-69-year-olds to more than 20% in 85-89-year-olds.

This work was supported by the National Academies Keck Futures Initiative (NAKFI) program.

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Therefore, most affected individuals need some kind of assistance. While there is no cure for dementia, medication and special therapy may improve symptoms or slow down the progression of the disease. Non-pharmacological treatments focus on physical, emotional, and mental activities. Engagement in such activities is one of the key elements of good dementia care. Activities (e.g., music therapy [1], arts and crafts) help individuals with dementia and other types of cognitive impairment to maintain their functional abilities and can enhance their quality of life. Other cognitive rehabilitation therapies and protocols focus on recovering and/or maintaining cognitive abilities such as memory, orientation, and communication skills. Finally, physical rehabilitation therapies that focus on motor activities help individuals with dementia rehabilitate damaged motor functions or maintain their current motor abilities so as to maintain the greatest possible autonomy.

Even if nursing homes and other care facilities can provide assistance, space and staff shortages are already becoming an issue. As the elder population continues to grow, a great deal of attention and research will be dedicated to assistive systems that allow the elderly to live independently in their own homes. The first efforts towards having socially assistive robotic systems for the elderly have been focused towards constructing robot-pet companions aimed at reducing stress and depression. However, little long-term research has been done in the area of therapeutic robots for individuals suffering from dementia and other types of cognitive impairment. In their research [7], Libin, and Cohen-Mansfield described a preliminary study that compared the benefits of a robotic cat and a plush toy cat as interventions for elderly persons with dementia. Furthermore, Kidd, Taggart, and Turkle [5] used Paro, a seal robot, to explore the role of the robot in the improvement of conversation and interaction in a group. Marti, Giusti, and Bacigalupo [8] justified a non-pharmacological therapeutic approach to the treatment of dementia that focused on social context, motivation, and engagement by encouraging and facilitating non-verbal communication during the therapeutic intervention.

Our methodology focused on using socially assistive robotics (SAR) [3], [9], [10], [12] technology aimed at providing affordable personalized cognitive assistance, motivation, and companionship to users suffering from cognitive changes related to aging, dementia and/or Alzheimer’s disease. The work described in this paper aimed to validate that a robotic system can establish a productive interaction with the user, and can serve to motivate and remind the user about specific tasks or cognitive exercises. Our robot

is used as unique individualized/customized complement to humans/nurses/therpists.

Embodiment is increasingly viewed as one of the key issues and open challenges in AI and robotics. The fundamental tenet of socially assistive robotics is that the robot’s physical presence and shared physical context with the user create engagement between the robot and the user, a relationship that is inherently different from other types of human-machine interactions that do not involve physical embodiment. Research has only begun to explore the differences in user perception and engagement between embodied robot and computer interfaces and has not yet focused on elderly users. Our own past work addressed a direct comparison [15], [14] but with college-aged participants. A study in the weight loss domain performed by [4] also performed a direct comparison between a robot head and a computer interface, but across the age spectrum.

The presented work is based on the testable hypothesis that the robot’s physical and social embodiment play a key role in its assistive effectiveness. Hence, embodiment constitutes a key means of establishing human-robot interaction and user engagement in SAR. The work presented in this paper thus tests the embodiment aspect of the interaction, in addition to the effectiveness of the adaptable social, interactive, and cognitive aspects of robot behavior in an assistive context designed for the elderly and/or individuals suffering from dementia.

## II. ROBOTIC TEST-BED PLATFORM

To address the role of the robot’s physical embodiment and to remove platform-specific artifacts, we compared two experimental testbeds: (1) a custom-designed humanoid torso mounted on a Pioneer mobile platform (Figure 1(a)); and (2) a simulation of the same humanoid robot (Figure 1(b)) displayed on a large computer screen. The physical robot consists of an ActivMedia Pioneer 2DX equipped with a speaker, a Sony Pan-Tilt-Zoom (PTZ) color camera, and a SICK LMS200 eye-safe laser range finder. The humanoid torso is mounted on the base (Figure 1(a)) and consisting of 22 controllable degrees of freedom, which include: 6 DOF arms (x2), 1 DOF gripping hands (x2), 2 DOF pan/tilt neck, 2 DOF pan/tilt waist, 1 DOF expressive eyebrows, and a 3 DOF expressive mouth. All actuators are servos allowing for gradual control of the physical and facial expressions. The simulated was rendered using Gazebo (Figure 1(b)), which creates a 3-D rendering of its worlds with simulated dynamics, using an approximate physical model of the robot and its sensors to establish parity with the physical robot [6].

## III. EXPERIMENTAL DESIGN

We designed a hypothesis-testing experiment that took place over repeated sessions with human participants, conducted over 8 months. The users interacted with the robot/computer in the context of a music cognitive game. The first session served as the orientation, in which the robot was brought into the room with the participant, but not powered on. During this introduction period, the experimenter or

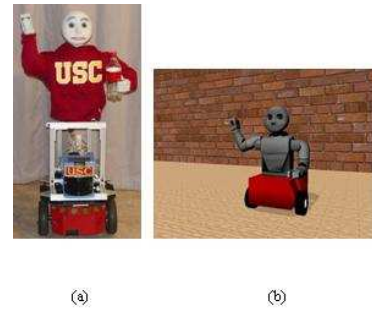


Fig. 1: Test-bed: (a) Human-like torso mounted on the mobile base; (b) Computer interface showing the simulation of the robot platform

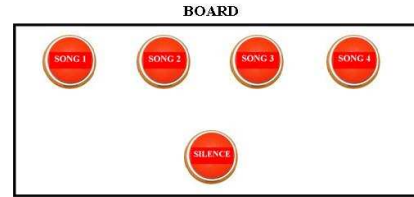


Fig. 2: Cognitive Game: Name That Tune

the participant’s nurse/physical/music therapist explained the robot’s/computer’s behavior, the overall goals and plans of the study, and what to expect in future sessions. The participant was also asked about his/her favorite songs from a variety popular tunes from the appropriate time period; those songs were later used in the subsequent sessions. At the end of the introduction session, the Standardized Mini-Mental State Examination (SMMSE) cognitive test [13] was administered to determine the participant’s level of cognitive impairment and the stage of dementia. The scores of the SMMSE test are typically interpreted as follows: (1) score in between 30 and 26 = could be normal; (2) score in between 25 and 20 = mild; (3) score in between 19 and 10 = moderate; (4) score in between 9 and 0 = severe. This test provided information about the cognitive (e.g., memory recall) level of impairment of the participant for use in initializing the challenge level of the game. The SMMSE was also administered at the end of the study, for comparison. The criteria for participation in the experiment (in addition to the Alzheimer’s or dementia diagnosis) also included the ability to read large print and to press a button.

The experiment was designed to attempt to improve the user’s level of attention through a cognitive stimulation game called Song Discovery or, more informally, Name That Tune. In the game, the user is asked to find and press the button that corresponds to the song being played, and, in some cases to say the name of the song, and sing along. In the experimental scenario, the participant sat in front of an experimental board equipped with 5 large buttons (e.g., the Staples EASY buttons - see Figure 2). Four of the buttons correspond to the different song excerpts (chosen as a function of the user’s preference) and the fifth button corresponds to SILENCE/no

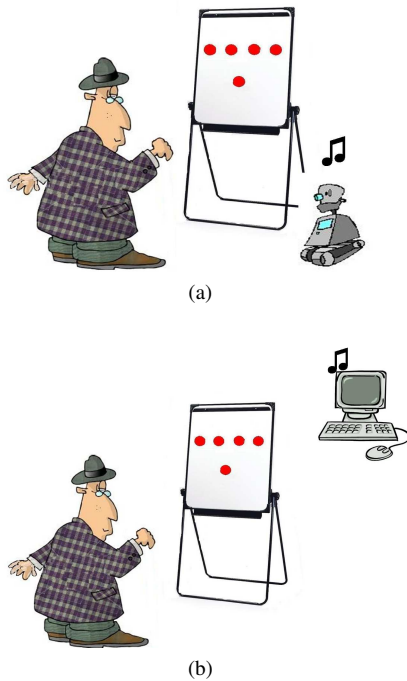


Fig. 3: The two conditions that are tested: (a) The image represents the human-robot interaction and (b) The image illustrates the human-computer interaction (the participant will see on the computer the simulated robot)

song excerpt condition. Under each button, a label indicated the name of the song it corresponded to (or SILENCE).

The robot/computer described to each participant the goal of the game before each session, based on the following transcript: “We will play a new music game. In it, we will play a music collection of 4 songs. The songs are separated by silence. You will have to listen to the music and push the button corresponding to the name of the song being played. Press the button marked “SILENCE” during the silence period between the songs. The robot will encourage you to find the correct song.” (see Figure 3).

After the orientation session, two conditions where a robot is present will be presented in a random order to the subject. In the first condition, the individual will interact with a computer simulation projected on a 2D screen (Figure 1(b)) and in the second condition, the individual will interact with a physically embodied biomimetic robot (Figure 1(a)). In an attempt to rule out the potential novelty effects, we presented the same two conditions in a randomized fashion.

Each participant was first asked by the music therapist or the robot/computer to read aloud the titles of the songs and to press a button. Some additional directions were given. The participant was also directed to press the SILENCE button when there was no music playing. After a review of the directions, the participant was asked by the robot/computer to begin the music game. The music compilation was composed of a random set of song excerpts out of the four different songs that formed the selection and the SILENCE condition. The entire music compilation lasted between 10 and 20

minutes, and was based on the user’s level of cognitive impairment: the larger the impairment, the shorter the session. A song excerpt could be vocal, instrumental, or both. The order of song excerpts was random.

The objective measure used in the study was the button pushing reaction time for both song and silence detection. The main goal was to minimize the reaction time and maximize the number of correct answers, signifying improvement of cognitive attention. The reaction time was calculated from the start of the song until the button was pressed. The maximum time was set to the duration of the song (in our case 60 seconds for the songs and 30 seconds for the silence). The robot/computer attempted to achieve this by modeling the following interaction parameters:

- Level of game challenge presented by the robot/computer:
  - No hint (difficult level);
  - At the start of the excerpt, say “push the button” but do not indicate which button to push (medium level);
  - At the start of the excerpt, say which button to push (easy level).

The robot/computer used arm movements to encourage the user in response to correct answers. The game level, i.e. the amount of hints provided, was initialized based on the participant’s level of impairment and adapted based on the participant’s task performance (i.e., reaction time and number of correct). The robot and computer used the same pre-recorded human voice for all interactions with the participants. The vocabulary used by the system was positive and encouraging, regardless of the participant’s performance. The volume of the music and the robot’s/computer’s voice were set at a high yet comfortable level as determined by the participants’ nurse and music therapist.

Our robot is therefore used as an unique individualized/customized complement to humans/nurses/therapists.

#### IV. HYPOTHESES

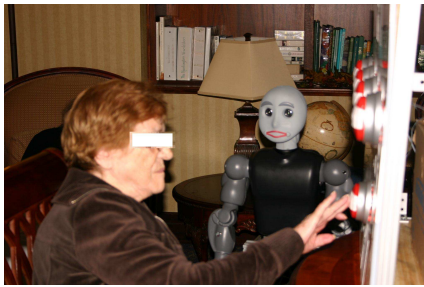
This work aimed at validating the following main hypotheses:

H1: Individuals with dementia and/or cognitive impairments will not show a negative response to a humanoid robot and will engage with such a robot designed to monitor and encourage cognitive and/or physical activities.

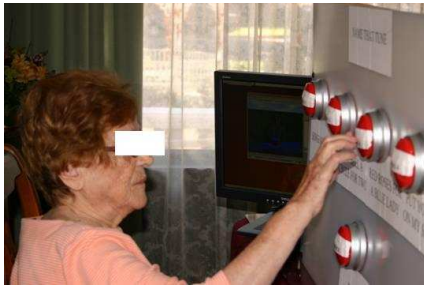
H2: Individuals with dementia and/or cognitive impairments will prefer the physical robot to the computer. The more physically engaging the technology is, the better received it is by the participant and the more effective it is in encouraging therapeutic activities, whether they be cognitive and/or physical. A computer is the less engaging than a humanoid robot.

The study also addressed a third hypothesis, which is not the main focus of this paper and is reported on elsewhere:

H3: Individuals with dementia and/or cognitive impairments engaged in a cognitive/stimulation/recall game with a socially assistive robot can sustain or even improve their performance on the game.



(a)



(b)

Fig. 4: The two experimental conditions: (a) the human-robot interaction setup; and (b) the human-computer interaction setup

## V. PILOT STUDY RESULTS

The initial pilot experimental group consisted of 9 participants (4 male, 5 female) from the Silverado Senior Living care facility. All the participants were seniors over 70 years old suffering from cognitive impairment and/or Alzheimer's disease. Their cognitive SMMSE scores were the following: 1 mild, 1 moderate, and 7 severe. Due to the total unresponsiveness of 6 of the 7 severe participants, only 1 severe participant was retained for the rest of the experiments, resulting in the final group composed of 3 participants (all female). Figure 4 shows the interaction of user # 3 with both the robot and the computer.

The system evaluation was performed based on user introspection (oral questionnaires). After the experiments, the participants were orally asked to evaluate their impression of the interaction with the robot/computer on a 5-point Likert scale.

Hypothesis H1 was addressed by all of the individuals involved in the experiments. We found no adverse responses to the robot. The participants enjoyed interacting with the robot (see Figure 5) and expressed anticipation of future sessions. At the end of the experiment, the three participants demonstrated attachment to the robot and the music game by referring to it as part of their weekly schedule and something they looked forward to. When the robot was absent for one week, one of the participants asked the facility staff when the robot will be back because she was enjoying playing the game with it. From the interviews with the families and staff, we can conclude that the robot had a positive effect on the users because they discussed it and described their interactions with it to both their families and other residents



Fig. 5: Participant interacting with the robot

in the facility. Based on those discussions, we received inquiries from two other residents about participating in the music game with the robot. While it was not possible to include them in the study due to the lack of permission from their families, their interest was encouraging.

Hypothesis H2 was addressed to a limited degree due to the small sample size. The results obtained with the three participants suggest that the elderly users with Alzheimer's Disease consistently preferred the robot to the computer. The computer interface with the simulated robot was perceived much like a TV, and did not receive as much attention as the physical robot; two out of the three participants paid no attention to it at all. When the participants were asked "How did you like the interaction with the robot on the computer screen?", participants #1 and #3 responded "I haven't even noticed it. I don't like watching TV!!". Moreover, when the same question was asked relative to the interaction with the physical robot, "How did you like the interaction with the robot?", all of the participants responded that they liked the interaction. For example, participants #1 responded "I like him. He's my friend and he's helping me with the game." No further quantitative data are available regarding H2 at this time.

Finally, as part of evaluating H3, we also found that the social interaction and the task performance were improved while interacting with the robot compared to the computer condition. More details on this hypothesis and the associated results can be found in [11]

The post-experiment SMMSE tests, administered after 8 months of interaction with the system, showed a slight improvement in scores: the mild participant progressed and moved in the normal window (from the pre-experiment score of 24, improved to the post-experiment of 26), and the moderate and severe participants improved (from the pre-experiment score of 16, improved to the post-experiment of 17) and maintained (from the pre-experiment score of 9, stayed at the same post-experiment score of 9) their scores, respectively. These results are not conclusive because of the small number of participants used in the study, but are promising for the future directions of this work.

## VI. CONCLUSIONS

The described research aims to develop methods toward socially assistive therapist robots for individuals suffering from dementia and/or other cognitive impairments. Our

approach involved the use of a SAR system in the context of a music-based cognitive game. The pilot study results demonstrated the users' preference for an embodied SAR system over the computer interface, and the overall effect of sustaining or improving user performance on the memory task through the assistance of the SAR system.

## VII. ACKNOWLEDGMENTS

This work was supported in part by the National Academies Keck Futures Initiative (NAKFI), by the USC Alzheimer's Disease Research Center (ADRC), and by the NSF IS-0713697 grant. The infrastructure for this research was supported by the NSF Computing Research Infrastructure grant CNS-0709296. We are also grateful to our partner: Silverado Senior Living - The Huntington, Alhambra, CA, USA. Many thanks to Vida Gwinn (Facility Administrator), Cheryl Stollman (Activities Program Director), Jessi Nunez and Zena Buccola (Activities Assistants), Rudy Medina (Plant Operations Supervisor), Tamara Mitchel (Administrator Assistant), and all the personnel for all their help and support.

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