Socially Assistive Robotic Music Therapist for Maintaining Attention of Older Adults with Cognitive Impairments

Adriana Tapus and Maja J Matarić

Interaction Lab, Department of Computer Science
University of Southern California
Los Angeles, USA
tapus@usc.edu; mataric@usc.edu

Abstract

This paper presents a hypothesis-testing preliminary study that aims to develop affordable customized socially assistive robotics (SAR) tools that can help to provide cognitive care to users suffering from cognitive changes related to aging and/or Alzheimer's disease.

Introduction

Dementia is a progressive brain dysfunction that affects the global functioning of the individual progressively impairing cognition (e.g., impaired memory and orientation, limitations of concentration, speech and hearing disorders), and changing personality and behavior. Individuals suffering from moderate or severe dementia are restricted in their daily activities and in most cases require special care. As with numerous other diseases, there is no cure for dementia but medication and special therapy can improve disease symptoms. Non-pharmacological treatments focus on physical, emotional, and mental activity (Halpern and O'Connor 2000). Engagement in activities is one of the key elements of good dementia care. Activities (e.g., music therapy (Carruth 1997, Clair and Ebberts 1997), arts and crafts) help individuals with dementia and cognitive impairment maintain their functional abilities and can enhance quality of life. Other cognitive rehabilitation therapies and protocols focus on recovering and/or maintaining cognitive abilities such as memory, orientation, and communication skills.

Very few researches have been done in the area of therapeutic robots for individuals suffering from dementia and cognitive impairment. Libin and Cohen-Mansfield (Libin and Cohen-Mansfield 2004) describe a preliminary study which compares the benefits of a robotic cat and a plush toy cat as interventions for elderly persons with dementia. Furthermore, Kidd, Taggart, and Turkle (Kidd et al. 2006) use Paro seal robot to explore the role of the robot in the improvement of conversation and interaction in a group. Finally, Marti, Giusti, and Bacigalupo (Marti et al. 2007) justify a non-pharmacological therapeutic approach to the treatment of dementia that focuses on social context, motivation, and engagement by encouraging and facilitating non-verbal communication during the therapeutic intervention.

Our methodology uses *socially assistive robotics technology* (Feil-Seifer and Matarić 2005) 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 aims 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/cognitive exercises.

This paper focuses on the study of the social, interactive, and cognitive aspects of robot behavior in an assistive context designed for the elderly and/or individuals suffering from dementia. The robot will serve as a music therapist and will try through active listening to practice extra-music objectives such as recall, memory, social interaction, alertness, and sensory stimulation. In addition to serving as a social and cognitive tool, the robot will also be capable of providing detailed reports of patient progress to caretakers, physicians, and therapists.

Hypotheses

This research work is designed to test two main hypotheses. Hypothesis 1 addresses the role of the robot's adaptive and encouraging behavior in active listening for attention and cognitive maintenance. Hypothesis 2 addresses the role of physical embodiment of the robot.

Hypothesis 1

The robot's encouraging behavior can help elderly people with cognitive impairments to maintain active listening capabilities (see cognitive game – Name That Tune). Active listening provides a potential method for engaging cognitive skills for people with Alzheimer's and/or dementia.

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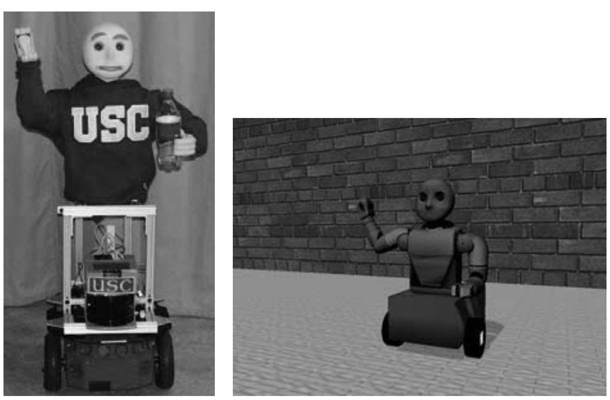
Hypothesis 2

The more physically engaging the interaction technology is, the better received it is by the participant and the more effective it is in encouraging therapeutic game. A computer is less engaging than a human-like robot.

Experimental Test-Bed

To address the role of the robot's physical embodiment and to remove platform-specific artifacts, we will compare two experimental testbeds: (1) a humanoid torso mounted on a Pioneer mobile platform (Figure 1(a)); and (2) a simulation of the humnoid robot (Figure 1(b)). The robot base used is 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 biomimetic anthropomorphic version of the setup involves a humanoid torso, mounted on the same mobile 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 agent will be rendered using Gazebo (Koenig and Howard 2004) (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.

We are particularly interested in utilizing the humanoid's anthropomorphic but not highly realistic appearance as a means of establishing user engagement, and comparing its impact to our prior work with non-biomimetic robot test-beds (Matarić et al. 2007, Feil-Seifer and Matarić 2005, Tapus et al. 2008).



(a) (b)

Figure 1. (a) Human-like torso mounted on the mobile base; (b) Simulation of the robot platform

Experiment Explanation for the Participant

The robot and simulation use the following transcript: "We will play a new music game. In it, we will play a music collection of 1, 2, 3 or 4 songs (depending on the user's level of cognitive impairment). 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/computer will encourage you to find the correct song." (See Figures 2 and 3.)

The first session is the orientation session. In it, the participant is 'introduced' to the robot. The humanoid robot is brought into the room with the participant, but is not be powered on. During this introduction period, the nurse/physical/music therapist will explain the robot behavior, the overall goals and plans of the study, and generally inform the participant of what to expect in future sessions.

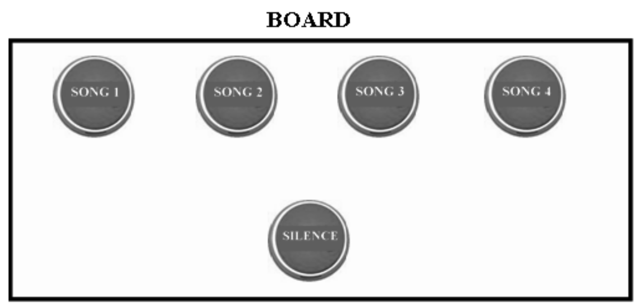


Figure 2. Cognitive Game: Name That Tune – Experimental Setup

Finally, at the end of the first session, cognitive tests, FAST (Functional Assessment Staging Test) and FIM (The Functional Independence Measure), are performed so as to determine the participant's level of cognitive impairment and the stage of dementia. These tests provide information about the cognitive (e.g., memory recall) and locomotion level of impairment of the participant for use in the interactions with the robot.

The primary purpose of the first session is to determine the participant's initial, no-robot condition motor task functionality, mental state, and level of cognitive impairment. The nurse/physical/music therapist and the experiment designers will analyze the mental state and level of cognitive impairment.

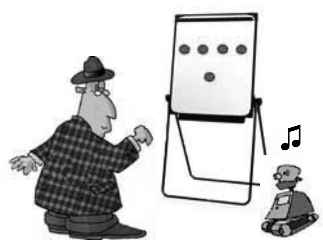
Experimental Design

This experiment is designed to improve the participant's attention and consists of a cognitive game called Song Discovery or Name That Tune (i.e., find the right button for the song, press it, and say the name of the song). The criteria for participation (in addition to the Alzheimer's or dementia diagnosis) in this experiment include the ability to read large print and to press a button. The participant stands or sits in front of the experimental board fixed on a wall. On the board are mounted 2, 3, 4, or 5 large buttons (e.g., the Staples EASY buttons). The number of buttons (NB_BUTTONS) is determined as a function of the level of cognitive impairment. The NB_BUTTONS-1 buttons correspond to the different song excerpts (chosen as a function of user's preference) and the last button corresponds to the SILENCE or no song excerpt condition. Under each button, a label with the name of the song (or SILENCE) is printed.

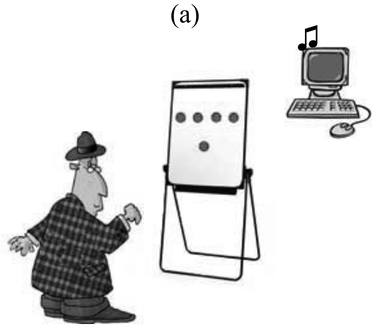
The participants are first asked by the music therapist or the robot to read aloud the titles of the songs and to press a button. Some additional directions are given. They are also directed to press the SILENCE button when there is no music playing. After a review of the directions, the music collection is played.

In order to test the role of the physical embodiment of our robot and to see if the robot is making any difference, two main conditions will be tested with the participant (see Figure 3):

1. human-robot interaction
2. human-computer interaction



(a)



(b)

Figure 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)

In the first condition, the participant interacts with a human-like robot and in the second condition a computer will be used for interaction. The participant is asked by the robot/computer to begin the music game. Music selection is based either on music recognition and preference data about elderly listeners or on the participant's music specific preference (if available).

A piece of music compilation contains the different chosen song excerpts and the silence condition. The duration of the music compilation lasts 10 minutes. A song excerpt can be vocal, instrumental, or both. The order of song excerpts can be random.

The objective measure used in the study is the reaction time for both song detection and silence detection verbally and with buttons. The main goal is to minimize the reaction time and maximize verbalization, which signifies improvement of cognitive attention. The reaction time is calculated as the difference between the start of the song began and the time the button is pressed. The vocalization is quantified either as the number of utterances pronounced or the time the utterances were spoken. The robot attempts to achieve this goal by modeling the following interaction parameters using Policy Gradient Reinforcement Learning (PGRL) (Tapus et al. 2008): amount and speed of movement and robotic help style (3 conditions: A. no hint (difficult level); B. when the song excerpt starts say "push the button" but do not indicate which button to push (medium level); C. say which button to push (easy level)). The robot also uses its body and arms to point towards the board and the correct button. The robot help style starts in a policy initialized based on the participant's level of impairment, and is then adapted as a function of the participant's task performance (i.e., reaction time and/or verbalization). All experimental conditions use the same pre-recorded human speech. The verbal content of the interaction is held constant in all conditions in order to assess the impact of the embodiment only. The vocabulary used by the robot/computer is positive and encouraging, regardless of the participant's performance. The volume of music and the robot's voice will be set at a high, yet comfortable level as determined by the nurses and the music therapist.

The experiment is repeated twice per week for a period of at least 3 months (minimum 12 weeks). This is intended as a longitudinal study to verify any lasting effects of the robot therapist. A comparison will be conducted between a group of elderly participating in the Robot Music Cognitive Game (called RMCG group) and a control group of elderly who will not participate in the RMCG (non-RMCG group). Another comparison will be done between subjects in order to track any improvement over multiple sessions.

Evaluation

We will do a pre- and post- assessment without the robot/computer – the music compilation will be played and the songs recognized and the reaction times quantified. The participant's performance during the game will be assessed (e.g., the reaction time for both song detection and silence detection and the amount of verbalization) using both data obtained from the interaction with the robot and button recordings, and data obtained from video recordings. Music therapist feedback will be gauged through a questionnaire completed at the end of the experiment. Outcomes will be quantified by evaluating task performance and time on task. Caregivers will also be asked about the improvements and the possibility of transfer of knowledge (interactive format with the patients, family members, and the robot).

Experimental Results

Two focus groups were conducted at our partners' sites: Silverado Senior Living and The Jewish Home Los Angeles. The preliminary focus groups and early studies already show promise for our approach. More experimental results validating our hypotheses will be available by the time of the workshop, as this paper reports on ongoing work in progress.

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