Socially Assistive Robots for Individuals Suffering from Dementia

Adriana Tapus, Juan Fasola and Maja J Mataric'
Interaction Lab
University of Southern California
Los Angeles, USA

adriana.tapus@ieee.org; fasola@usc.edu; mataric@usc.edu

ABSTRACT

This paper presents a hypothesis-testing pilot study of *socially assistive robotics technology [1]* aimed at providing affordable personalized cognitive assistance, motivation, and companionship to users suffering from cognitive changes related to aging and/or Alzheimer's disease. This is work-in-progress.

Keywords

socially assistive robotics; therapeutic robotics; human-robot interaction

1. INTRODUCTION

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 and that number is increasing every day [2]. The rapidly increasing number of people suffering from Alzheimer's disease could cripple 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 it will rise to 100 million by 2050 — 1 in 85 of the total population. More than 40% of those cases will be in late-stage Alzheimer's, requiring a high level of attention equivalent to nursing home care. 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.

In our society of longer lifetime, the probability of suffering from dementia increases with advancing age. Dementia appears in the second half of life, usually after the age of 65. The frequency of dementia increases with age, therefore from 2% at 65-69-year-olds to more than 20% at 85-89-year-olds. Thus, individuals suffering from moderate or severe dementia are restricted in their daily activities and in most cases need for 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 also mental activation. Engagement in activities is one of the key elements of good dementia care. Activities (e.g., music therapy, arts and crafts) help individuals with dementia and cognitive impairment maintain their functional abilities and can enhance quality of life. Also cognitive rehabilitation therapies that focus on recovering and/or maintaining cognitive abilities such as memory, orientation, and communication skills are other specific therapeutic protocols designed for individuals with dementia. Finally, physical rehabilitation therapies that focus on motor activities help individuals with dementia rehabilitate damaged functions or maintain their current motor abilities so as to keep the greater possible extent of autonomy.

This paper focuses on studying the social, interactive, and cognitive aspects of robot behavior in an assistive context designed for the elderly and/or individuals suffering from dementia. 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.

2. GOALS AND APPROACH

Our work is focused on the interaction modalities, and on the motivational and cognitive strategies for elderly users suffering from cognitive changes related to aging and/or Alzheimer's disease. The main advantages of the proposed approach are that it provides time-extended personalized cognitive and social interaction and "exercise" in a robot-supervised fashion, facilitating ongoing monitoring and companionship. We focus on contact-free strategies, wherein there is no physical contact between the robot and the user, and where social interaction, motivation, and engagement play key roles instead [3, 4]. This is an entirely novel area of research in assistive and rehabilitation robotics and it opens up a broad avenue for future discovery and development.

The specific aims of the proposed study are as follows:

- Validate that a robotic system can safely and effectively interact with elderly users suffering from cognitive changes related to aging and/or Alzheimer's disease.
- Validate that a robotic system can establish a productive interaction with the user that can serve to motivate and remind the user about specific tasks/cognitive exercises.

The paper briefly describes the following areas: experimental design, software and hardware development, and preliminary results. Each area is described below.

3. EXPERIMENTAL DESIGN

This section briefly summarizes the hypotheses and the experimental scenarios that we have developed based on the insights gained through the focus group process.

3.1 Hypotheses

1. Individuals with dementia and/or cognitive impairments will verbalize more while interacting with the social robot than when the robot is absent.

2. The child-like physical appearance of the robot and its playful interaction will be socially engaging to individuals with dementia and/or cognitive impairments.

3. The social robot will successfully encourage individuals with dementia and/or cognitive impairments to perform their fitness programs and/or physical or occupational therapy.

3.2 Experimental Scenarios

Two basic experimental scenarios will be used:

1) One-on-one interaction between the robot and the user, either in a separate room or in public areas of the facility.

2) Group interaction between the robot and multiple users, with the robot forming a social focus for the group.

Three types of roles for the robot will be evaluated:

- **Social aid**: the robot will provide social cues (pointing, prompting, asking, playing music, reciting/reading books and newspapers, etc.) for the user while proactively attempting to engage the user in a companionable social interaction.
- **Cognitive games**: the robot will monitor the user while the user is performing a cognitive task, such as a trivial game, and will provide help, motivation, and encouragement. The game will be custom-designed to employ simple yes/no questions and to be appropriate to the user's cognitive abilities, background, and areas of interest. The robot itself will also serve as a discovery tool for a cognitive challenge for the user; the user will be able to control the robot's movements with its own.
- **Encouraging physical activity**: the robot will encourage the user to perform mild exercise, providing examples of simple movements and encouraging imitation. Imitation will be used as means of capturing and holding the user's attention. The robot will map the observed behavior of the user to its own behavior repertoire and perform the best possible imitation. The ability to imitate will be used to induce the user to mimic the robot in return. The user will also be able to use arm gestures to command the robot to move about the room (e.g., by raising the left arm the robot would move to the left). All physical activity will be based on exercise activities already employed at the facility (e.g., bending and touching toes while sitting, arm exercises while sitting, Tai Chi), and will be performed in the familiar setting, slowly, safely, and while the robot is providing verbal encouragement.

4. TEST-BED

4.1 Robotic Platform

To address the role of the robot's physical embodiment, we will use a biomimetic anthropomorphic robotic platform that involves a humanoid torso, mounted on an ActivMedia Pioneer 2DX mobile base (equipped with a speaker, and a SICK LMS200 eye-safe laser range finder), 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 (see Figure 1). All actuators are servos allowing for gradual control of the physical and facial expressions.

Figure 1: Humanoid torso mounted on a mobile base (Bandit II - the hands-off therapist robot designed at the USC Interaction Lab)

4.2 Hardware Development

In order to quantitatively measure patient response, we designed and developed two types of user-appropriate input devices. The first device is intended for use during question and answer sessions (A), and the second during exercise sessions (B):

(A) During the question and answer sessions, 'yes' or 'no' questions are posed to the participants. An accurate method of measuring each participant's response is needed. For this purpose, we obtained table-mounted off-the-shelf push buttons (the Staples large and visually pleasing "Easy" buttons), which we then slightly modified for our experimental purposes. Each time the button is pushed, the analog voltage level of the output changes, allowing us to log participant responses.

(B) During the exercise sessions, the participants raise and lower their legs while seated. This is based on a standard exercise already used in the facility, which we hope to integrate into a social interaction with the robot. To interface this exercise with the robot, we need a means of counting the number of times the participant raises and lowers his/her legs. For this purpose, we designed and developed a 'foot sensor.' The sensor consists of a metal plate and four strain gauges. A strain gauge is an electrical element used to measure deflection. The advantage of our design is that the flat plate used in the sensor is no more than a quarter of an inch above the ground, providing an accurate account of the user's activity, but presenting no hazard to the physical stability of the user.

The developed sensors and components used are non-emitting electrical devices, and are safe for use with our participant population.

5. PRELIMINARY RESULTS

In order to test participant preference between the speech and button interfaces with the robot in the context of the question and answer scenario (see Section 3.2 – cognitive games), the feasibility of our experimental design, and the acceptance of our hardware devices by the Silverado Senior Living residents, we performed a preliminary experimental test.

Six residents suffering of mild cognitive impairment and one therapist volunteered to participate in the preliminary study. The therapist was charged with asking the participants 20 questions with ‘yes’ or ‘no’ answers. The participants were asked to answer these questions either by pressing the button, or by speaking, or by using both the button and speech. Two members of our team were recording their verbal answers and observing their preferences between speech, the button, and the speech and button options. The audio records of the interaction were intended to be used in the software development, for developing a small learning corpus for the robot’s speech recognition module, aiming to enable the robot to automatically understand the participant’s answers.

We observed that 4 participants preferred the combination of the speech and button interface, 1 participant preferred the button, and 1 participant preferred speech over pressing the button. This preliminary experiment involving no robot helped us to understand the challenges in working with users with dementia and to refine our experimental design. More experiments with the robot will be performed once the IRB Proposal is approved.

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