RoboTherapy with Alzheimer patients

Francisco Martín, Carlos Agüero, José M. Cañas, Gonzalo Abella, Raul Benitez, Sergio Rivero, Pablo Martínez and Meritxell Valenti

***Abstract*—Humanoids have became a increasing focus of attention in robotics research in last years, specially in service and personal assistance robotics. This paper presents the application developed for humanoid robots in therapy of Alzheimer patients, as a cognitive stimulation tool. The behavior of the robot along the therapy sessions is visually programmed in a session script that allows music playing, physical movements (dancing, exercises...), speech snyhesis and interaction with the human monitor. The application includes the control software onboard the robot and some tools like the visual script generator, a monitor to supervise the robot behavior along the sessions. Their impact on the patient's health has been estudied. Experiments with real patients have been performed in collaboration with a neurological health medical center. Initial results show a light improvement in neuropsychiatric symptoms over other traditional therapy methods.**

***Index Terms*—Social Robotics, Humanoid robot, Robot Therapy**

I. Introduction

ONE field of growing interest in robotics are humanoids. Prototypes such as the Honda Asimo or the Fujitsu HOAP-3 are the basis for many research efforts, some of them designed to replicate human intelligence and maneuverability. Their appearance similar to people facilitates their acceptance and natural interaction with humans as a personal assistant in the field of service robotics, for instance. As a representative sample, the functionality achieved in the Asimo humanoid has progressed significantly in recent years, allowing running, climbing stairs, pushing carts, serve drinks, etc..

On other hand, neurodegenerative dementia is a disease that progressively deteriorates brain functionality. One of the most common symptoms of dementia is memory loss. Also, usually, patients lose the ability to solve problems or control their emotions and present changes in personality and normal behavior. Over time, people with dementia are unable to properly perform the basic activities of daily living such as maintaining personal hygiene or food. Estimates point that in 2016 there will be 26.6 million people worldwide with Alzheimer's disease, and this figure will be three times bigger by 2050. On that date, the Alzheimer will affect 1 in 85 people of the total world population. And 40% of them will be in an advanced state of disease, requiring a level of care that involves high consumption of resources [1].

While there is no causal cure for the disease, palliative medication and nonpharmacological therapy are the only ways patients can improve symptoms and slow down its progression.

Nonpharmacological therapy focuses on strengthening the activities mentally, physically and emotionally. Such actions seek to maintain the functional capacity of the person, while ensuring her levels of quality of life and autonomy. Animal therapy has also shown good results, especially with elderly that live alone. However, it is not always possible. Sometimes the entrance of animals in elder residences it is not allowed due to health and safety reasons. Other times it is the cost of maintaining these animals and the care they need which precludes their presence in the residence. Another issue to consider is that the therapeutic interaction at the cognitive level needed in older people with dementia is not resolved with the presence of animals in the environment of the patient [2].

In this paper we describe the use of a humanoid robot as a cognitive stimulation tool in therapy of Alzheimer patients. Several software modules have been programmed and three types of robotherapy sessions have been developed: physiotherapy, music and logic-language sessions. They have been used with real patients.

The remainder of this paper is organized as follows. Second section presents some works with social robots and their use in dementia therapies. Third section explains all the software developed for this humanoid application, including some tools designed to visually program the robot behavior in the robotherapy sessions. The fourth section describes the experiment performed with real patients to measure the impact of this robotic tool on their health. Finally some conclusions are summarized.

II. Related works

The interest in social robots is growing, as one of upcoming application fields of the next generation robots. For instance as game platforms [3], personal assistants, nursing robots [4] or assistive tools in rehabilitation [5].

In the past 5 years, several projects have been initiated with the therapeutic use of social robots [6] as reasonable substitutes for animal therapy in people with dementia. Robots do not involve the responsibility or the need for an animal facility and their sensors can respond to environmental changes (movements, sounds ...) simulating an interaction with the patient [7]. At the same time, they provide the opportunity to monitor patients and perform cognitive therapy, unlike animal therapy [8]. Other potential benefits of therapy with robots are that it has no secondary effects (like drug therapy) and does

Francisco Martín, Carlos Agüero, José M. Cañas, Gonzalo Abella, Raul Benitez and Sergio Rivero are with Rey Juan Carlos University .

E-mail: {fmartin, caguero, jmplaza}@gsyc.es, {abellagonzalo, raulbenitezmejias, serginho.river}@gmail.com

Pablo Martínez and Meritxell Valenti are with Centro Investigación Enfermedades Neurológicas.

E-mail: {pmartinez, mvalenti}@fundacioncien.es

not require specially trained personnel (as opposed to the other therapies such as music therapy, pet therapy, etc..).

The Paro robot with seal shape has been used in dementia therapies [9] with positive results.

Broekens et al published in 2009 [10] a systematic review analyzing the literature on the effects of social robots in the health care of the elderly, especially in the role of the company to the patient. It is noteworthy that all studies are after 2000, which indicates the novelty of this research area. Most studies have been conducted in Japan, Southeast Asia and the U.S. [11]. The main results of analysis of these studies are:

- Most of the elderly like robots.
- The shape and material of the robot influence the acceptance and the effect of the robots.
- Improving health by lowering stress levels (measuring stress hormones in urine) (Kyoko et al, 2002) and increased immune system response [12].
- Improvement of humor (through surveys and the evaluation of facial expressions)
- Decreased sense of loneliness (using scales measuring loneliness)
- Increased communication (measured by the frequency of contact with robots and family).
- Remember the past (especially with a robot as a baby).
- Some studies indicate an improvement in the scales of severity of dementia.

III. Robot software for robotherapy

We have developed several software pieces for the use of humanoids in therapy. The robot behaviors in therapy sessions are described mostly as a sequence of basic movement, music or text playing and light turning on-off operations. A file format syntax has been developed to store these behavior descriptions, they are called *session scripts*. A programming framework, named BICA, was created to develop autonomous robot applications and it has been used for robotherapy. Some specific components inside BICA have been developed, like one that runs session scripts or other that provides access to robot lights from application software. In addition, some tools have also been created: a session script generator that allows an easy and visual "programming" of robot behavior in therapy sessions, and the session monitor tool that helps the human therapist to control the session progress. They are all described in this section.

A. BICA architecture

The software of our humanoid robot is organized with a behavior-based architecture. It is implemented in a component oriented software architecture, named Behavior-based Iterative Component Architecture (BICA) [13], programmed in C++ language. Components are independent computation units which periodically execute at a pre-configured frequency. Every component has an interface to modulate its execution and retrieve the result of the computation. Behaviors in BICA are defined by the activation of perception components and actuation components. Actuation components take movement decisions, send commands to the robot motors, or locomotion system, or activate other actuation components. They run iteratively to periodically update their outputs. Perception components take data from robot sensors or other perception components and extract information. They basically provide information to the actuation components. The output of a perception component is refreshed periodically and can be read from many other components in the system.

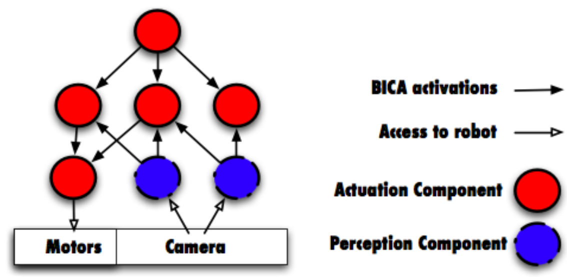

Fig. 1. Behavior in BICA composed by actuation and perception components

Not all the perception capabilities of the robot must be active at the same time, consuming computing resources. Even more, the whole set of behaviors that the robot is able to eventually perform is not suitable to deal with the current situation. Only a subset of behaviors and perception units are relevant to the current situation. In BICA each component is activable and deactivable at will, so it remains inactive until the situation demands it, when another component activates it. Typically an actuation component activates the perception components it requires and the child actuation components (if any) that implement its control decisions. This activation chain creates a dynamic component tree to cope with the robot's current situation. Figure 1 shows an component activation tree with both perception and actuation components.

Beyond being a framework to integrate perceptive and actuation capabilities for autonomous behaviors, the BICA architecture also includes components that provide access to the basic sensors and actuators of the robot, a Hardware Abstraction Layer (HAL) for robot applications. BICA is built on top of Naoqi, the manufacturer middleware, and offers this HAL as a set of object method invocations. For instance, the `Body` component provides access to the motion capabilities, both the legged locomotion and the arm movements. The `Perception` component provides access to the camera images. The `LED` component provides access to several lights on the robot head and chest, which can be turned on and off from the application software. The `Head` component provides access to the neck of the humanoid, allowing to rotate the head horizontally or vertically. The `Music` component provides the capability of playing sound files. It has been specifically developed for the robotherapy application. The stories, questions, songs involved in therapy sessions are stored as sound files and played back using this BICA component.

The behavior based organization of the software of the robot in BICA allows a modular development of robot functionalities, with new components to accomplish new robot tasks or to perceive new stimuli associated. Beyond the humanoid behavior in the RoboTheraphy application, this architecture is also used for humanoid behavior programming in other scenarios like the RoboCup competition, where we developed several perceptive and actuation components for the SPL soccer player. Some actuation components were programmed as PID reactive controllers, and others as Finite State Machines, depending on the complexity of the behavior.

B. *Session script generator*

The robot behavior set required for robotherapy application is smaller than for other fully autonomous applications like the robotic soccer in RoboCup. In essence, the robot behaviors in therapy sessions are described mostly as a sequence of basic movement, music or text playing and light turning on-off operations. They are usually launched together as the robot may be playing a song and dancing at the same time, for example.

A file format syntax has been developed to store these behavior descriptions, they are called *session scripts*. It includes three basic instructions: `move`, `music` and `light`. Two or three basic operations of different type can be grouped together, in group instructions, to be executed simultanously. The robot behavior is a sequence of these basic or group instructions. In the script some synchronization points can be included to wait for the termination of all the basic intructions inside a group. In addition, the `wait` instruction causes the robot to stop execution until the human therapist provides the continue order, striking one button in the robot body or using any monitor tool. This allows the human therapist to control the session progress.

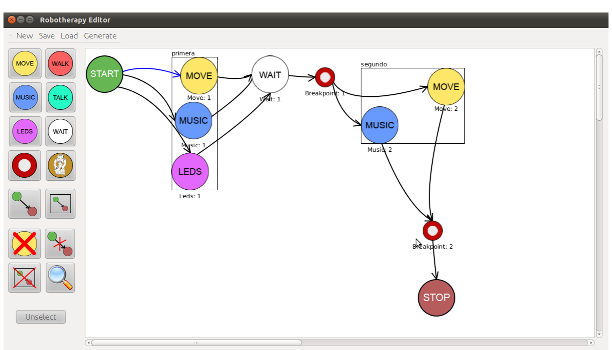

Fig. 2. Session script generator

The scripts are generated and stored in text files. Their contents are designed by medical doctors and health assistants, attending to the desired stimulation in the Alzheimer patients. At the beginning they were created directly editing text files. We have developed a graphical tool, the session script generator (Figure 2), that allows a fast a visual creation of these scripts.

C. *Movie component*

One specific component has been developed inside BICA for the robotherapy application, the `Movie` component. It accepts session scripts as input and runs the corresponding orders to robot motors and actuators, at the proper timing, unfolding the specified robot behavior. It uses several HAL components available in BICA, like the `Body`, `LED`, `Music` and `Head` components, as shown in Figure 3.

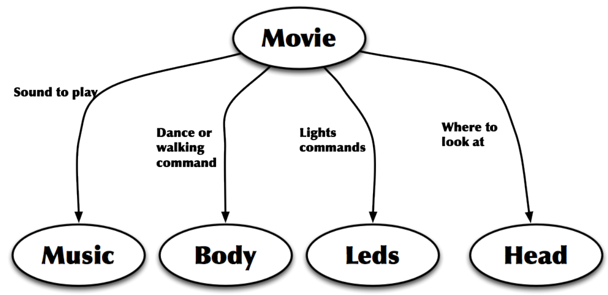

Fig. 3. Movie component in BICA runs session scripts on board the robot

For dancing the robot has previous descriptions of its movements. They are stored as single files following a given syntax, and can be referenced in the scripts run by the `Movie` component. Those movement files include the position of all robot joints and the right time for each one. For singing or a story telling the corresponding song and text are stored as sound files, and they can also be referenced in the session script.

D. *Session monitor*

The human therapist needs a way to communicate with the robot, start a robotherapy session, stop its execution while the patients answer one of the robot questions, repeat any script step, etc.. The basic interface with the real robot was the set of buttons on its feet and chest. At the beginning these buttons were used, but we developed two session monitor applications to allow an easier way to control the robot.

The first branch is an application running on a regular computer. It offers a Graphical User Interface with sliders, selectors, visual buttons, etc. as shown in Figure 4. It allows the teleoperation of the robot body and head, in order to approach the robot towards the patients at the beginning of the sessions, for instance. It can be operated from an external computer, or used in conjuntion with a *wiimote*. This is more convenient than the regular display, keyboard and mouse configuration. In this case the session monitor reads the therapist orders from the *wiimote* buttons and accelerometers using bluetooth.

In order to improve the tool usability, a second branch has been created that runs mobile devices like Android tablet or smartphone (Figure 5). Using it no extra computer, nor wiimote is required, just the robot and a tablet. With it, the human therapist has full control of the progress of the therapeutic session.

Interaction between different BICA components is performed as method invocation of other component objects. An specific module has been developed for communication between BICA and software outside the robot, for instance the communication between these session monitor tools and the `Movie` component onboard the robot. This module and the session monitor use ICE as communication middleware.

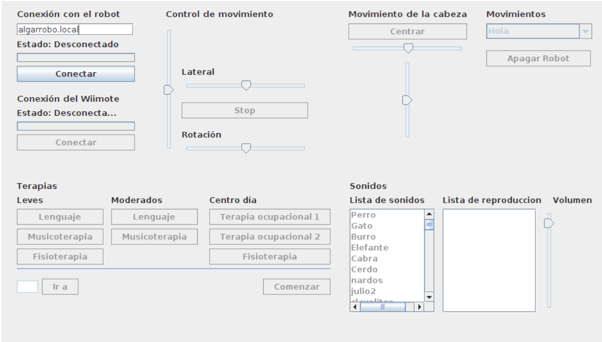

Fig. 4. Session monitor GUI

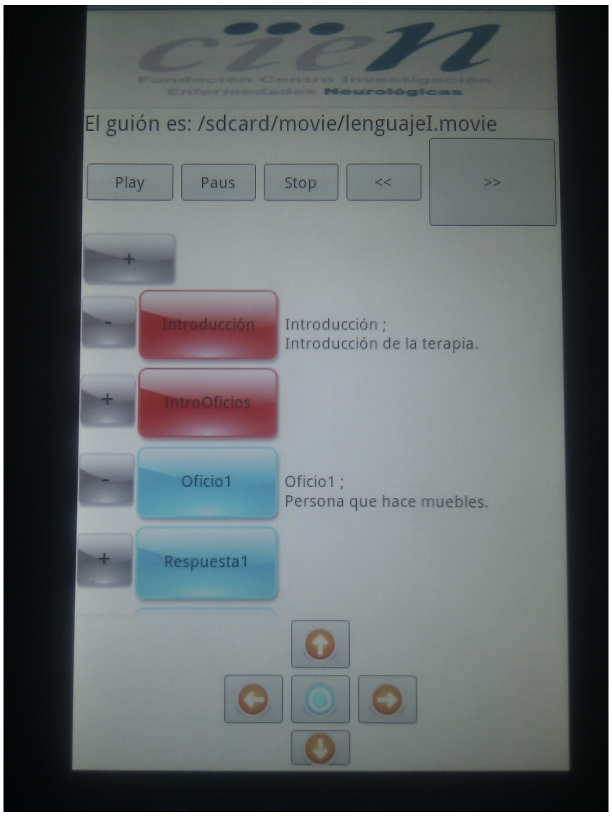

Fig. 5. Session monitor at a tablet

IV. Experiments

The platform available for this project were initially the robot seal Paro, Aibo robot dog robot and humanoid Nao. The mobility robot seal Paro is mainly confined to his head (it moves the eyes) and produce sounds that simulate those of a baby seal. In the opinion of the psiconeurlogos invloucrados in this evaluation, this robot is not effective in diseases of dementia, but in patients with diseases related to autism.

The robot dog Aibo and humanoid robot Nao offer much more functionality: they are both nice to look, walk, move his head, have lights and make sounds. In principle, psychologists conclude that cognitive activation is similar in both robots, but the larger size of humanoid makes it more visible than the robot dog. In addition, the humanoid robot is most useful in physical therapy. It can perform the same exercises that patients, and the ability to mimic the movements of the robot by patients is a key factor.

From a technical point of view, the development of software for the robot seal Paro is complicated because it is a closed platform. Our group has extensive experience in the programming of the other two platforms in the RoboCup environment, and in both cases we could develop the work described in this paper. The difference on behalf of humanoid robot Nao was due to availability. Although we have several robots Aibo, and was a best-selling commercial robot currently its manufacturing has been discontinued since 2008. Currently our group is participating in the Robocup Nao humanoid robot with, and the architecture developed to control the robot in this environment, is also general enough to be suitable in the application of therapies. Before the session phase, the robot was presented to a group of 20 patients with differing severity of the disease. The robot was accepted by most of them: 80% showed a very positive attitude, 15% did not react and 5% (one person) showed aggression towards the robot (and also to therapists and psychologists). Most patients identified him as a child, and tried to talk to him.

A. *Therapy sessions*

The therapy sessions have been designed by therapists specialized in diseases of dementia. Our work focuses on developing the software so these sessions can be carried out with maximum fidelity to how they were conceived. We have developed all software components, sounds and movements that they have required, and we have proposed new tools they have evaluated.

Fig. 6. Real sessions with Alzheimer patients

We conducted two experimental phases. The first lasted 6 months and was performed in a single group (Figure 6) with involvement of the moderate-severe disease (Figure 7). Each week there was a session. Each session takes between 30 and 45 minutes and was recorded by three cameras. These recordings were later analyzed by experts to observe the reaction of patients. We designed four types of sessions: language, music therapy, storyteller and physiotherapy. In the language sessions, the robot asked about numbers, days of the week, riddles and questions specializing in cognitive activation. In the music therapy session the robot combines basic questions related to popular songs. Physiotherapy session consisted in a set of exercises that the robot explained and then performed: movements of arms, head, torso and walking exercises. Storytelling session had no interaction with patients; the robot told a story, using movements and lights at a time.

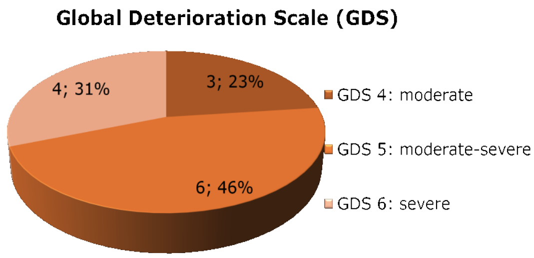

Fig. 7. Global deterioration Scale of the group involved the first phase

The conclusions of this first phase was that patients accepted well the robot and participate as actively in therapy sessions with robot as in the regular sessions. Clinical study using robots for cognitive therapy in dementia institutionalized patients was classified feasible. The second phase experiments depended on the success of the first and last took place during 1 year and the composition of the groups was different (Figure 8). There were three groups, each one with patients with different degrees of severity of the disease: mild, moderate and severe. The methodology was similar: 30-45 minutes each session and they were recorded and analyzed. Storytelling session was discarded to be clear that without interaction, all patients quickly lost attention.

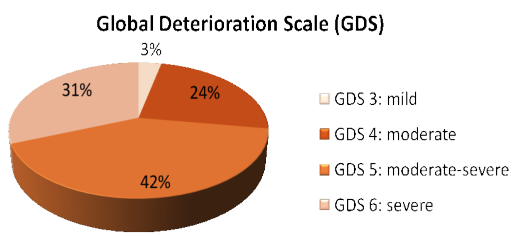

Fig. 8. Global deterioration Scale of the group involved the second phase

The medical results, showed in Figure 9, were promising. Neuropsychiatric symptoms and apathy tended to improve after robotherapy in patients with moderate dementia. The sessions for seriously ill patients can not be structured in sessions because they are unable to maintain attention long enough to be effective. For them we designed a set of activities to be carried the robot: Walking to a patient, ”look” at the face of a patient, making sounds of animals ... These actions significantly improved the apathy of critically ill patients. Moreover, some of these activities (walking towards a patient and ”look at him” to the face) were also applied during the sessions in the rest of the group, clearly improving the response. To carry out these activities, we improved tools to be easily used by the therapist. In wiimote and tablet have been developed to see, during the experiments, the autonomy needs of therapists.

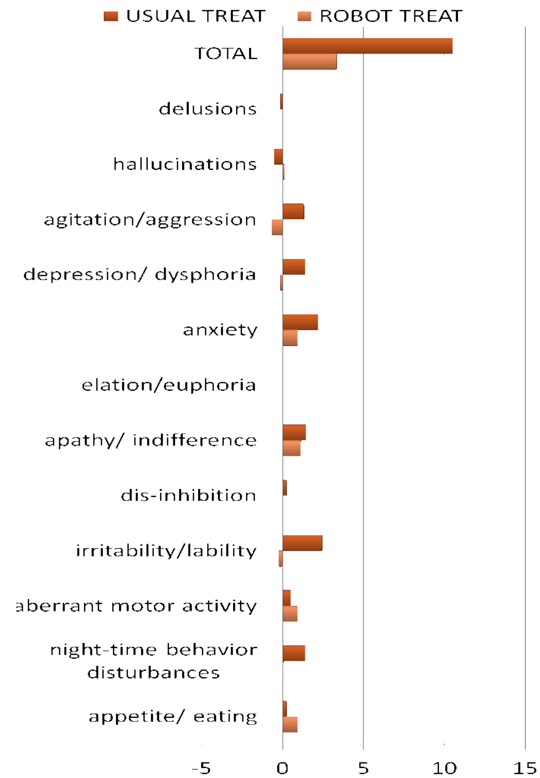

Fig. 9. Graphical results of the second phase

V. Conclusions

In this paper we have presented a cutting edge application of humanoid robots in therapy of Alzheimer patients, as a new cognitive stimulation tool. They help to slow down the increasing impairment typical of this kind of dementia.

We have developed some software pieces to support this application. First, a software architecture (named BICA) to integrate all robot perceptive and actuation capabilities. Second, a software module helps to visually generate “session scripts”. These session scripts are simple descriptions of robot behavior sequence along the therapeutic sessions, they involve the music playing, movement and light generation capabilities onboard the humanoid. They have been created with the knowledge and support of medical experts and are stored in single files. Third, a software module inside BICA runs the session scripts on the real robot. Fourth, a monitor module allows the human therapist to control the script execution, proceeding with the next behavior, repeating, etc. and so modulating the session development. Two different monitors have been develped, one running on a regular PC and another one running on an Android tablet. The use of a wiimote has also been explored.

Three kind of sessions have been prepared and performed: music therapy, physiotherapy and logic-language therapy. In music sessions the robot plays some songs from the years when the patients were young, trying to touch their affective and feeling stimulation. In physiotherapy sessions the robot performs several physical exercises with the intention of being repeated by the human patients. Logic-language therapy is based on several simple questions to cognitive stimulate the patient responses.

The preliminar results on real patients with moderate dementia are promising. Their neurophyschiatric symptoms have improved over those of patients following classic therapy methods. Surprisingly the robots capture elder attention due to its human shape, their movement and music capabilities.

We are working on extending the direct interaction between the patients and the humanoid. For instance, the real patient showing colored cards to answer to questions done by the humanoid. Also we are programming the robot with more autonomous behaviors like face tracking or people following.

Acknowledgment

This work was supported by the project S2009/DPI-1559, RoboCity2030-II, from the Comunidad de Madrid, by the project PI10/02567 from the Spanish Ministry of Science and Innovation and project 231/2011 from IMSERSO.

References

[1] A. Tapus, C. Tapus, and M. Mataric, “The use of socially assistive robots in the design of intelligent cognitive therapies for people with dementia,” in *Proceedings of the International Conference on Rehabilitation Robotics (ICORR)*, Kyoto, Japan, jun 2009.

[2] G. Anerdi, A. Greco, L. Odetti, and G. Rodriguez, “An animaloid robot as a cognitive stimulator to support elders with cognitive impairments: preliminary requirements,” in *HCP-2008-Third International Conference on human centered processes*, 2008, pp. 81–91.

[3] V. Gonzalez, A. Ramey, F. Alonso, A. Castro-Gonzlez, and M. Salichs, “Maggie: A social robot as a gaming platform,” pp. 371–381, 2011.

[4] J. Pineau, M. Montemerlo, N. Roy, S. Thrun, and M. Pollack, “Towards robotic assistants in nursing homes: challenges and results,” pp. 271–281, 2003.

[5] A. Jardn, J. Vctores, S. Martnez, A. Gimnez, and C. Balaguer, “Personal autonomy rehabilitation in home environments by a portable assistive robot,” pp. 1–10, 2011.

[6] K. Wada, T. Shibata, T. Musha, and S. Kimura, “Robot therapy for elders affected by dementia: using personal robots for pleasure and relaxation,” pp. 53–60, july 2008.

[7] T. T. et al., “Is an entertainment robot useful in the care of elderly people with severe dementia?” pp. 83–85, 2004.

[8] S. Lauriks, A. Reinersmann, H. Van der Roest, F. Meiland, R. Davies, F. Moelaert, M. Mulvenna, C. Nugent, and R. Dres, “Review of ict-based services for identified unmet needs in people with dementia,” pp. 223–246, 2007.

[9] K. Wada, T. Shibata, T. Musha, and S. Kimura, “Effects of robot therapy for demented patients evaluated by eeg,” in *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS-2005)*, 2005, pp. 1552–1557.

[10] J. Broekens, M. Heerink, and H. Rosendal, “Assistive social robots in elderly care: a review,” pp. 94–103, 2009.

[11] T. Shibata, K. Wada, Y. Ikeda, and S. Sabanovic, “Cross-cultural studies on subjective evaluation of a seal robot,” pp. 443–458, 2009.

[12] K. Wada and T. Shibata, “Social effects of robot therapy in a care house -change of social network of the residents for one year,” 2009.

[13] F. Martín, C. Agüero, J. M. Canas, and E. Perdices, “Humanoid soccer player design,” in *Robot Soccer*, V. Papic, Ed. INTECH, 2010, pp. 67–100.

[14] J. Gorostiza and M. Salichs, “End-user programming of a social robot by dialog,” pp. 1102–1114, 2011.

[15] E. Williams and R. Jenkins, “Dog visitation therapy in dementia care: a literature review,” pp. 31–5, 2008.

[16] S. Filan and R. Llewellyn-Jones, “Animal-assisted therapy for dementia: a review of the literature,” pp. 597–611, 2006.

[17] A. Libin and J. Cohen-Mansfield, “Therapeutic robocat for nursing home residents with dementia: preliminary inquiry,” pp. 111–116, 2004.

[18] N. Richeson, “Effects of animal-assisted therapy on agitated behaviors and social interactions of older adults with dementia,” pp. 353–358, 2003.

[19] B. McCabe, M. Baun, D. Speich, and S. Agrawal, “Resident dog in the alzheimer’s special care unit,” pp. 684–696, 2002.

[20] S. Kyoko, S. Miki, Y. Hiroe, N. Shinobu, and M. Chieko, “Change in the concentration of salivary iga by contact of elderly subjects with a pet robot,” pp. 251–254, 2002.

[21] K. L. Greer, K. A. Pustay, T. C. Zaun, and P. Coppens, “A comparison of the effects of toys versus live animals on the communication of patients with dementia of the alzheimers type,” pp. 157–182, 2001.

[22] M. Kanamori, M. Suzuki, K. Yamamoto, M. Kanda, Y. Matsui, E. Kojima, H. Fukawa, T. Sugita, and H. Oshiro, “A day care program and evaluation of animal-assisted therapy (aat) for the elderly with senile dementia,” pp. 234–239, 2001.

[23] M. Churchill, J. Safaoui, B. McCabe, and M. Baun, “Using a therapy dog to alleviate the agitation and desocialization of people with alzheimer’s disease,” pp. 16–22, 1999.