Interactive games with robotic and augmented reality technology in cognitive and motor rehabilitation

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ABSTRACT

Over the years, robotic has become a technological service tool in different application domains. This chapter presents a direct application of games and robotics as therapeutic tools in the health care of patients.

These strategies are used in ACROSS project, involving more than 100 researchers from 13 Spanish entities. The main objective of this project will be to modify the current perspective of the therapies, taking advantage of the game properties that will be implemented in social robots which are blocked in providing predefined services. These new systems are able to self-reconfigure and adapt autonomously. In

order to provide an open framework for collaboration between universities, research centres and the Administration, ACROSS will develop Open Source Services available to everybody.

This chapter aims to contribute a new overview of treatment therapies with elderly and paediatric patients that present cognitive and motor impairments as well as present the methodology of evaluation to determine the effect of games and social robots as a means to carry out a therapy.

INTRODUCTION

Games have been widely proven to contribute to integral development and learning in humans and their socialization. Piaget considers 'play' as a mean to develop thought and to learn about the world. Vygotski emphasizes that games contribute to social development because the socio-cultural framework will be trained in 'play'. Bruner adds that games help to resolve conflict, acquire and recover language. This is applicable in the cognitive rehabilitation of people with cognitive loss or dementia, because it permits to stimulate residual functions and, in some cases, acquire compensatory cognitive strategies. Dementia is a clinical syndrome characterized by an overall cognitive impairment, usually chronic and progressive, that represents decreasing functional activities and social relations. Sometimes, it is associated with a behavioural disorder, which affects the patient, his relatives and friends. (Moyles, 1990; Dorado, 2008)

Games can also be used as a tool for rehabilitation of motor functions in paediatric patients with upper-limb impairments, cerebral palsy and obstetrical brachial paralysis. Cerebral palsy is a neurological disorder of the brain that can be accompanied with other possible clinical signs such as muscle tone disorders, movement and posture disorders, mental disability, and so on. Obstetrical brachial paralysis is a mechanical lesion of the brachial plexus.
Innovative treatments of cognitive and motor rehabilitation, such as the introduction of robot caregivers, multi-sensory systems, augmented reality, and so on, have not been implemented in Spain due to difficulties in the segregation of service network resources. The discontinuity of care and the lack of rigorous research and knowledge affect the development of non-pharmacological strategies. In this project, we aim to break down such barriers and demonstrate with our experience, the benefits of using these technologies in rehabilitation programs (Woods, 2003; Svansdottir et al, 2006).

The Spanish national project called ACROSS (Auto-Configurable Robots for Social Services) proposes cognitive and motor rehabilitation through games. ACROSS has been funded by the Ministry of Industry, Tourism and Trade belonging to Plan Avanza2. The consortium of the ACROSS project is composed of thirteen organizations. Broadly, the project is part of the development of intelligent environments, in which, through sensor network tools, communication and computation enable a new paradigm in social robotic platforms.

The project aims to analyse current technology to specify basic requirements of future social robots and their environments. For this purpose, we have defined objects with digitally augmented environments that allow robots to know the context and adapt to it. In addition, the project has developed new forms of rehabilitative therapy through the use of interactive games.

Non-pharmacological interventions in which they train different skills and abilities through the use of robotic platforms and augmented reality are being developed in two use cases of our study. These technologies (robotics and augmented reality) linked to the development of interactive games allow specialists to perform cognitive and physical training customized for each patient. In the area of dementia, the main objective is to stimulate the cognitive ability and socialization to compensate for cognitive and functional loss in senior citizens. In the motor area the objective is to stimulate diminished motor capability and improve adherence to rehabilitation and increase the motivation of the paediatric patients through play and leisure activities. This encourages proactive learning in the patient, because the games represent a significant activity for the person, and not just a leisure activity.

We hope that the results obtained will improve if we compare it with other conventional techniques due to the attractive feature of the games. The use of these techniques contributes to increased patient motivation and adherence to treatment, to promote personal and interpersonal development, social inclusion and their right to self-determination. These facts translate into a higher satisfaction not only for patients, but also for relatives, caregivers and practitioners.

BACKGROUND

Although games may be considered an end in itself, a number of disciplines have approached it as an instrumental tool or a means of achieving a certain goal. Both conceptions of play are not contradictory but rather complementary and synergic.

Games aren't only an activity. They're a learning tool, a need. Therefore, games are a self-and-others relation tool. Games are sources of fun and satisfaction that allow people to motivate themselves in order to do tasks learn, and so on, and it's essential to their development as a person.

A person might play with the objective of learning, socializing, whiling the time away, etc. or just out of pleasure, without any other goal than fun and entertainment; i.e. enjoyment comes in first place, and other things come by itself (Fulleda, 1999).

"The essential characteristic of a recreational action – its utter definition – is being a symbolic inner representation of reality, enjoyable and voluntarily undertaken, which promotes the processes of assimilation and accommodation" (Fulleda, 1999) described by Piaget (Piaget, 1975). Playing is mainly an anthropologic function, because the symbolism in the play of non-human adult individuals (which is not a subject of this study) is not associated to the high human degree of abstraction and symbolic representation of the environment, or to artistic creativity (Fulleda, 1999). Symbolic processes in adult play are thus, an essential characteristic of human beings.

Games and its basic manifestations should be considered one of the most genuine human activities, which are present throughout life (Lavega, 1996). Engaged under different circumstances and approached in different ways during the different stages of life, play acquires its typical socio-cultural elements from the beginning. Thus, play is determined by culture, while generating culture at the same time. We postulate that playing and participating in recreational activities, discovering and satisfying curiosity are among the basic needs of human beings. Therefore, using games as the basis for different rehabilitation treatments – cognitive, functional, therapeutic, etc. – through recreational actions should not present any problem. In the pilot experiences we applied robotics to rehabilitation treatments: for rehabilitation, on one hand, in elderly people with dementia and, on the other hand in children with motor and cognitive disorders. This experience aims to introduce social robots capable of intelligent interaction, adaptable to the specific needs of the different patients, specifically the need to play.

Social robotic emerged in the mid-forties as a discipline of robotics that refers to those robots that are able to interact with humans following the social patterns of behaviour. Although their preferred morphology is said to be humanoid, it is not a necessary requirement to achieve a proper communication with humans. The difficulty lies in the social environment where the robot must develop their functions, since this is not a laboratory, which is considered a controlled environment, but a real environment such as an office, home or hospital, among many other examples. The combinations of situations where the robot can be involved are countless and the robot must be able to resolve satisfactorily without causing accidents or situations of risk to humans. In order to achieve successful integration of robots in our lives it is important that, the robot be designed with provision to respond appropriately to changes occurring in an everyday environment. The surprise factor and dynamic nature of the environment, together with the capacity to recognize, learn and respond well to human interaction, make the design of both the physical appearance and programming of social robots complex.

Services where social robots can be introduced are health, entertainment, education, and in institutions such as hospitals, senior centres, schools and homes. The applicability of service robots ranges from running as an assistant, taking care of household chores, and used with patients undergoing motor rehabilitation and cognitive therapy.

Many researchers are working on new lines of research with the aim of enabling patients to perform rehabilitation therapies with the help of social robots. In the bibliography we find some contrasted references. Concretely, in Cook et al (2005) researchers studied robot use in paediatric patients with upper-limb impairment and cognitive and language disorders. That study was carried out in a hospital-school in fifteen sessions for four weeks. The teacher's interviews showed that the children had made progress in expressive language and they had developed more interest in activities done with robots. After this experience, teachers explained the main features that the robot needed to catch the children's attention. Those features are based mainly on colour, contrast, character, as well as sounds and music production.

Another experience is explained by Frascarelli et al (2009), who presented a study carried out in the Paediatric Rehabilitation Department of a Children's Hospital where the effect of robots in therapy was evaluated with twelve paediatric patients with acquired or congenital upper extremity movement impairment aged 5 to 15 years. The children were in therapeutic session for an hour, three times a week. To measure the children's impairment, The Melbourne Scale (MS) and the upper-extremity subsection of the Fugl-Meyer Assessment (FMA) were used. Secondary measurements were evaluated using the Modified Ashworth Scale (MAS). The variables were smoothness, position, velocity, and applied forces. The results obtained showed an improvement in all variables established. Therefore, also resulted in an improvement in upper limb posture and the benefits in the rehabilitation of children with congenital and acquired hemiparesis were demonstrated.

On the other hand, we can't forget the elderly population. According to OECD Health data (Organization for Economic Co-operation and Development, www.oecd.org), the number of elderly people is increasing and this high number will require prolonged medical care and assistance, it is estimated that this data will increase in the following years to be doubled before the year 2030. For this reason, one of the goals is to improve care through the inclusion of new technologies such as robotics. In the literature, we can find other references about the use of robotic technologies in the care and assistance of elderly people. An example was a sociable robot system that was designed in order to assist people who have recently lost weight in maintaining their target weight. The system will help in automating some of the current treatment methods in order to improve patients' ability to track their own progress and behaviour while sharing information with their doctor. That robot will create a relationship with the person that will allow them to become more engaged in their own long-term progress acting as a "mirror" of the patient's behaviour (Kidd, Breazeal, 2005).

Another interesting project is the SKOTEE (Sister Kenny hOme ThErapy systEm) prototype. People with chronic health conditions are known for their difficulty adhering to medical recommendations, and a sociable robot is a proven way to modify their behaviour. The system has influence on physical, emotional, functional and social aspects of the patient's life. Some of its numerous functions include: help to negotiate obstacles, remind the patient about events and appointments, motivate and provide instructions to follow certain protocols, record audio and video and allow the clinician to communicate and configure the system (Oddsson et al, 2009).

The experiment conducted by the USC shows us the union between social robots and other interesting technology like motion capture. In it, the robot (either physical or virtual) receives data from arm sensors placed in post-stroke patient and motivates them properly. The patient's adherence to this method was high, but perhaps because of the technological innovation itself (Mataric et al, 2007).

Another large group of people we must cope with is that of patients with dementia. One of the most curious initiatives in this field was conducted in Japan, introducing robotic pets in a nursing home. Pet therapy has proven to be effective (physiological, psychological and social) but has its risks, so the robot-pet is the perfect solution. A study of six patients with dementia showed promising results in areas such as memorization, emotion control or sociability (Hamada et al, 2008). With these antecedents, we propose this project.

If we combine robotic with augmented reality, it could be a landmark improvement in the concept of social robots. Augmented reality is a term used to define a direct or indirect vision of an environment of the physical world, which combines its elements with virtual elements to create a real-time mixed reality. Using computer systems virtual reality is superimposed on the captured image of the physical world. In general, augmented reality seeks to increase our own vision and understanding of the world that is surrounding us.

Augmented reality could be used in educational applications, emergency services, navigation systems and advertisements, among many other things. But this chapter pretends to highlight the importance of the implementation of augmented reality game development not just for entertainment but also for therapeutic purposes.

The combination of social robotics and augmented reality for therapeutic purposes may allow the improvement of techniques used in rehabilitation and, in consequence, an improvement of the quality of patients' life.

MAIN FOCUS OF THE CHAPTER

In this section, the ACROSS project is exposed in depth. First, the general methodology is presented, concreting the different sub-projects that are included in ACROSS. Below the technical solution is exposed, technical design and finally, the pilot design, where the case uses are presented according to the design.

METHODOLOGY

A balanced multidisciplinary team collaborate from technical, clinical and social disciplines. Concretely the team is composed of six enterprises, three universities, two research centres and two hospitals. Due to the magnitude of the project, it is divided into different sub-projects which are composed internally in different work packages with different tasks. The following figure (fig. 1) shows these sub-projects and the relationship between them:

Fig.1 [Project Methodology]

Sub-project SP1. Requirements: the requirements are defined by levels: functional, (demanded by application domains), technical (technical considerations prior to implementation) and security (at the technical level in the treatment of confidential information and functional level in the interaction with people).

Sub-project SP2. Robot Middleware: after doing a study of existing technology, a robotic middleware support will be designed and implemented. An object-based architecture will be carried out. The scope of this subproject will standardize access to computers and the creation of an open source middleware and functionality of a self-configurable robot (to apply to social services). The importance of this subproject will be used as integration software for other stages providing mechanisms of visibility and effective communication.

Sub-project SP3. Cognitive Computing: do a study of psycho-affective behaviour in three general scenarios of work, with multimodal interaction through voice and image, and analysis of the interaction devices that make up the basis of this subproject. Different platforms will be analysed according to the degree of interaction required: simple (personal monitoring, appliances), medium (technological support, personal support) or advanced (entertainment, pet).

Sub-project SP4. Context awareness: The context will be semantically modelled by defining ontology to collect concepts and partnerships to shape it, implicit knowledge will be interpreted and generated from explicit knowledge. It will be the point of view of end-user programming, determining the current goals or intentions of the user.

Sub-project SP5. Autonomic Computing: Platforms will be equipped with robotic capabilities "Autonomic Computing", intelligent software architecture services for tasks such as self-maintenance (monitoring, self-diagnosis, "self-repair", management of energy independence), self-configuration (dynamic composition of services, updating of middleware / software, so "self defences"), self-learning (machine-learning, behavioural patterns) or swarm robotics ("robot collaborative", compute distributed to achieve a common goal). The scope is to obtain a basic and generic Autonomic Computing for robotic platforms extended to other systems, consumables via services, pug & play & forget artificial intelligence and soft-computing.

Sub-project SP6. Integration and applications: analysis of user needs, design and implementation of software modules for different scenarios and services in each application domain.

Sub-project SP7. Dissemination, exploration and business models: The goal is the dissemination, transparency, operation and internationalization of the project results. The following figure shows the public Web project (http://www.acrosspse.com) (fig. 2) and a Technologic Observatory which aim is analyse and monitor relevant technologies in Social Robotics (fig. 3).

Figure2. [ACROSS Web]. (© [2011], [Treelogic]. Used with permission.).

Figure 3. [Observatory of Technology]. (© [2011], [Polytechnic University of Cataluña]. Used with permission.).

TECHNICAL SOLUTION

One of the most important tasks of any robotic system is the analysis of the environment and their subsequent action or operation. So, it is necessary to equip the robotic system with sensors that able the robot to perceive the environment as close to reality as possible since the response will be based on that perception. Thus, the importance of choosing the right sensors to sense the environment and thus recognize the reality is vital to set an appropriate response to that perceived reality, especially if the robotic system is a social robot involved in cognitive and motor rehabilitation where it is in contact with patients and medical staff.
For the correct choice of the sensors, the physical property that is wanted to be read must take into account: pressure, position, distance, speed, temperature, light, etc., and the operation to be carried out by the robot, so that intelligent vision systems or speech recognition can be needed.

The sensors which are mostly used in robotics are ultrasonic sensors, lasers, accelerometers, encoders and intelligent vision systems.

Ultrasonic sensors are devices that using acoustic signals are capable of measuring distances, which are generally used to detect obstacles. Laser sensors measure distance also, but the difference is that ultrasonic sensors first use light instead of acoustic signals for such measurement. Moreover, usually this type of sensors is capable of making measurements in polar form with a wide angular range at high speed.

Other sensors widely used are encoders, to determine the position of a motor or speed. For this reason it is used for odometer calculations implemented in the autonomous navigation software.

In this sense, we must also take into consideration the accelerometers, since they are capable of detecting accelerations. They are helpful and usually complementary to the encoders to give more precision to the odometer calculations.

Finally, we cannot forget the intelligent vision systems or artificial vision; used to perceive more directly the environment in which the robot is. Basically it is composed of a camera and a processing system. The camera used can be conventional, stereo or flight time, among others.

Given the above, it follows that the same sensors cannot be used in all social robots. The choice of these sensors depends on the type of task to be developed. Thus, in a robot designed for motor rehabilitation therapies, it is important the perception of the limb position while the patient is executing the assigned exercises and games. A robot designed to be used in the patients' cognitive rehabilitation exercises should interpret the patients' voice signals and their emotional state.

In this first case, the therapies will be based on augmented reality systems and intelligent vision to interpret the position of those limbs, completed with a pressure sensor or position (encoder or accelerometer) as a function of the game. In the second case, the robot must base their perception systems focusing on intelligent vision such as facial and voice recognition systems to provide adequate feedback depending on the game developed.

In the ACROSS project, two robots incorporating the above mentioned features will be used: *Roinbot®* in the first use case, and *Ursus* in the second and third use case. In the following section both robots are described in detail.

TECHNICAL DESIGN

Roinbot® is an autonomous social robot developed by m-BOT Solutions SL, a company that arose from the Robotics and Intelligent Vision Research group of Rovira i Virgili University. *Roinbot*® was first developed to move autonomously and securely to attendant the public at events, while it gives and receives information from the user. Basically, the interaction is achieved through a touch screen and the ability of the robot to speak. In collaboration with the Geriatric Day Hospital of the Consorci Sanitari del Garraf, this robot has been used for games to improve memory in elderly people with Alzheimer's. Play sessions with the robot consisted in Robot-patient interaction, where the robot showed photos and videos related to childhood toys.

The robot used in the Virgen del Rocío University Hospital pilot is called ***Ursus***, it is an assistive robot developed in the Laboratory of Robotics and Artificial Vision at the University of Extremadura. It is designed to propose games to children with cerebral palsy and children with Obstetrical brachial paralysis in order to improve their recovery. It will also be used as a tool for their therapists because it monitors patient's evolution and registers predefined variables. In order to make it visually pleasant for children, it has a friendly height and it looks like a teddy bear. Patients can get feedback of the status of their exercise in real-time by looking at the image the robot projects on the wall. This information encourages children to auto-correct themselves.

Benefits provided by the robotic approach

Increase in Attention

There are many reasons to use robots for therapy. In order to stimulate patients' memory pictures, videos and smells are used that they can remember easily. The use of new technologies (computer) can facilitate the reproduction of images, videos or songs to the patients, but elderly people see the computer as something strange and therefore are not willing to play. The use of a social robot allows closer interaction with the user. Older people do not perceive the robot as a computer, but as something more attractive; it generates curiosity, so their motivation increases and they are more ready to play.

The most important reason that led to the development of *Ursus* is that children get easily bored. This is a handicap in comparison with therapy in adults. Making a game of the therapy, lessens the problem. It makes it easier to grab their attention and also to maintain the focus for longer periods of time, which is of key importance depending on the children or the specific therapy.

Quantitative information

Moreover, besides the qualitative information that therapists were already able to gather, *Ursus* also provides objective quantitative information, which is very difficult to gather by humans. This kind of information can be used to adapt the exercises to the peculiarities of each patient such as performance, limitations or personality. Depending on the performance, the proposed exercises must be easier or harder. The personality of the patient is also an important issue, the robot must adapt its own personality to the child (i.e. some children will get nervous with pressure, others will find it fun). Depending on the limitations of each child the exercises must have different limits (i.e. limitations in the time or in the mobility of the patient's limbs).

Discrimination

Dealing with this kind of conditions entails different unrelated problems. Therapy is an expensive activity. It requires the supervision of qualified staff. Since hospitals do not have unlimited resources, the amount of therapy might be reduced to the hours the hospitals can afford. Only families with a high purchasing power can pay for private therapy. The use of robots could also help in this area, using multiple robots per therapist, who would supervise the activity and tune the exercises depending on the progress of the patients, robots collect data and track patient outcomes, which facilitates the work of the therapist.

Potential Drawbacks

Security

Introducing a robot into a clinic environment introduces the risk of harming the patients. Thus, this must be taken very seriously. In *Ursus*, this problem has been approached from two different points of view. Firstly, the arms of the robot have only the necessary power to lift its arms. This way it would be very difficult to cause any harm. Secondly, the robot does not do any hands-on interaction. Despite that it has been considered to make the robot move in the future; currently the robot is not capable to move its platform. Since patients have serious mobility problems, as long as the therapist places the robot more than two meters away, the risk of collision is very low. Even if there were, the robot is unable to cause any harm. As a last resource, if the patient moves from the location where the exercises take place, the arms turn off.

Patient Rejection

Roinbot® was not designed initially to interact with older people with mobility problems (many of those found in a day care centre have such problems.) It’s difficult for therapists to work with patients with dementia. One day they are doing well and recognizing the therapists, and the next they aren’t. The same thing occurs when using the robot. Therefore, the patient may not accept the robot.

Although unexpected, it is possible that some patients would reject to work with the robot. Some might reject the robot because they are afraid of it, because they might prefer to have therapy only with a human, if the robot has a size similar to a person that has the ability to move by itself they might be more receptive. As previously introduced, the develop team made the robot as friendly as possible. They gave *Ursus* the appearance of a robotic teddy bear and adjusted its height to avoid making the robot look threatening. Its voice is a female synthesized voice whose emphasis can be altered with special marks. Finally, in order to avoid being to forward, the robot adapts its personality to the one of the child: if a child is playful, the robot will be more active and would talk and interact more; in the opposite case, it would say each message only one time. Last but not least, since the results of the exercises are projected on the walls, most children take is as a game, thus, by making it fun, rejection probability is also reduced.

Therapist Rejection

Therapists might feel threatened by the performance of the robot. In that case the evaluation of the benefits of the robot might be biased. Due to therapists possibly seeing the robot as a threat in the course of their work, it is important to make clear that the robot is not a therapist substitute; it is a tool to make therapists able to perform more therapy and thus, improve the results.

Technological description

Hardware

The current version of *Roinbot*® is a mobile robot platform equipped with 2 motors that allow the robot move at a maximum of 4 kilometres per hour, but in general it moves at a slower velocity. It uses 4 ultrasonic sensors and a laser to measure distances between the robot and the possible obstacles in its surroundings, with the aim of avoiding harming the users. It has been designed to be a secure system one of the most important requirements. The robot is 140 centimetres high and its round base has a radius of 55 centimetres. Its weight is approximately 80 kilograms. *Roinbot®* can carry out its functions during 5 hours, but can be increased to 8 hours if motor performance is limited. The current version of *Roinbot®* includes a 15 inches touch screen.

The developers are actually working on incorporating a robot's head in order to give it a friendly appearance and in turn to increase the sensors that allow more interaction with the user. The addition of new cameras allows facial recognition to identify the user that is interacting. The robot also incorporates special cameras that allow it to have a three-dimensional representation of the environment to observe people in front of the robot and to recognize their movements.

On the other hand, the current version of *Ursus* is a static robot platform equipped with two 3 degree of freedom arms. Articulations are motorized with medium sized servos, so they can move the arms but not to cause any serious harm. The audio system is empowered by an on-board speaker with the necessary power to be heard clearly in a regular room. The input of the system is a regular web camera. The height of the robot is 140 centimetres, but the height of the camera is just 120 centimetres.

Vision

In *Ursus*, in order to perform the exercise, the vision system monitors the position of the arm of the children. This is done by using special markers. To begin the exercise the robot asks the child to lower and lift the arm in order to know the arms limits (this might be done with the help of the therapist). Once the scenario is calibrated, the robot tracks the movements, so it knows in every moment the position of the patient's arms. The last stage is the exercises in the interactive games that are achieved by projecting on the wall where the child should put the marker. If the exercise is successfully completed the robot proposes a new target position until the exercises are finished.

Speech

Both robots provide speech feedback in real time to the users. In order to cheer the patients up, the robot provides audio feedback using synthesized audio sentences.

PILOT DESIGN

To reach the therapeutic goals it's advisable to use an active and dynamic methodology, and play is a suitable tool to motivate the patient to do the exercises more than with traditional methods that are more boring where the patient isn't going to be actively involved.

In this project three use cases are piloted. The first use case is centred in elderly patients with dementia. In this use case, the robotic platform *Roinbot®* is applied for elder people.

Older people have different physical needs, such as mobility, hearing or vision needs, cognitive, and the need to remind them to take medication and perform other activities, or even the need for social support.

Due to the characteristics of the robotic platforms that are being developed in this project (robot assistant to provide information, which interacts with users through voice / screen and has no arms) we consider that the robot could offer support in the Daily Living Activities as:

- Robots to remind of events such as appointments, taking medication, important dates (birthdays, anniversaries, etc.), visits and so on.
- Robots as social support to facilitate communication with significant others such as family or

friends.

Introducing elderly people to the use of new technologies, particularly social robots, is not an easy task. Many obstacles hinder this process, from functional issues that impair the use of robot platforms (impaired mobility, sensory deterioration, etc.) to psychological and social issues (self-perception of inability or usefulness, fear, lack of motivation, etc.). There are a number of ways to raise elders' awareness and motivation in the use of new technologies. We chose to follow a most recreational enjoyable approach, likeable by everyone i.e. play.

A preliminary test was done in order to know the reaction of some elderly people that have to interact with a social robot platform. The goal of this was to see what improvements were considered necessary to obtain the best possible benefits in elderly people.

Symbolism in play refers to "Pretending that...." which is the base of childhood symbolic games (Fulleda, 1999). We worked on "Pretending that...." with patients, who participated in a pilot session with the platform[i].

For more than one hour, a group of nineteen adult participants interacted with (played with) a social robot. They pretended that the robot talked to them and looked at them and finally, they fantasized that the robot could understand them. During that time, they had a "conversation" with the robot; they sang along with it, gave answers to it and asked it for information. Eventually, they recreated their childhood, which was the goal of the session. Some participants expressed, in their own words: "evidently, it was a robot, but I found it easy to talk to, because I knew it was a game" (fig.4).

Figure 4. [Elderly participants interacting with the robotic platform]. (© [2011], [Fundació Privada Sant Antoni Abat]. Used with permission.).

From this experience we learned that play is ageless and that humans have an innate need for leisure, which initially is expressed as "functional" play but soon turns into a social product resulting from the integration of persons into their environment. Such an innate need, conveyed by functional aspects, eventually results in leisure enjoyment. Patients interacted with the robot just for fun. They played spontaneously only to have a nice time; they played just for play's sake.

The idea of incorporating a social robot is intended for several different scenarios and use cases. In the first use case there are the two devised scenarios or environments for the application were Social Assistance and Independent Living. As for Social Assistance, two use cases were proposed: a robot as a support for reminiscence workshops and a robot as a support for memory workshops. As to Independent Living, the use of a robot was proposed as a support to the Activities of Daily Living.

Finally it was decided to conduct the pilot test in a Day Care Hospital environment, using the platform as a support for reminiscence workshops.

The preparation of the pilot was conducted in two areas. One was the analysis and the adequacy of the platform and the other was related to user sensitization.

With respect to the adequacy of the platform, the adaptation process for this use case involved a previous assessment of the robot's technical and functional aspects to ensure the usability required by patients who participate in the pilot.

Some of these issues were: visibility of the screen, interacting with the display, sound, motion, rotation, movements, opportunities for verbal interaction, quality of projected image, audio, etc.

In relation to the process of user sensitization, this is referred to the gradual and transversal providing of information about new technologies. The information provided helped potential users to learn and at the same time participate in the proposed improvements and uses of these new technologies: in our case social robotics.

With regard to the inclusion criteria of patients who participated in the pilot, the following aspects were taken into consideration:

- Patients should have a minimum stay of three months at the Day Care Hospital. This would allow monitoring and impact assessment.
- Patients should be informed as well as agree to participate voluntarily. For this purpose they signed an informed consent.
- Finally all test participants have to present a spatial-temporal-personal orientation.

Following are the detailed characteristics of the reminiscence sessions adapted for use with the robotic platform (*Roinbot*®, m-BOT):

- 6 / 8 patients per group, a practitioner who runs the meeting and *Roinbot*® robotics platform.
- The duration of each session was 45 min. approx.
- Place where meetings were held: Day Hospital room (table free space).
- Participants were seated in a circle.
- The practitioner was sitting in front of the users.
- The robotic platform was located on the right side of the practitioner.
- The activity that took place: A TRIP TO THE CHILDHOOD. By means of reminiscence, this activity was related with games and toys from the participant's childhood through the display of images, videos and listening to songs.

We proposed to start the pilot with this theme as a way to introduce users to the new technologies used in rehabilitation therapies. While *Roinbot*® is intended as a tool to facilitate therapeutic work, by its characteristics and applications we can see it as closer to recreational, play and participation aspects. A recreational tool to serve customers that allows interaction, learning and above all meaningful participation.

The activity was developed using the platform as a support. The professional directed and guided the workshop by motivating and inviting users to participate. The platform has become a participation-enhancing tool. To achieve this goal, the professional provided a certain degree of autonomy to the robot. In this first pilot, this was achieved through remote control (the engineers are working on giving more autonomy to the robot. This development is expected to be available for the next pilot.)

Throughout the activity interaction between patients and the robot was promoted. Through "dialogues" with the users, the platform interacted with individual participants and groups. These interactions were strengthened by frequent movements of the platform, rotations, translations, etc.

Through music, sounds and images *Roinbot* ® invited the group of users to share experiences of their childhood. Patients participating at the group level recalled toys, games and songs from their childhood. It was a recreation and entertainment space where memories, laughter and above all game prevailed.

This activity was intended to assess the reasons of usability, acceptance and satisfaction that users might experience when interacting with a social robot. This first pilot was not intended to evaluate improvements in or impact on cognitive indicators.

As preliminary findings of the pilot carried out in the independent life setting, Abat researchers include:

> 1. It is achievable to incorporate an aid robot in a hospital setting for group therapeutic purposes (a recreational tool one which promotes interaction and participation, as a support to psycho-social rehabilitation).
>
> 2. It is feasible to use individual cognitive stimulation, but this requires adaptation to each user needs.
>
> 3. It is absolutely necessary to incorporate user's opinions from early stages to generate greater satisfaction and impact.
>
> 4. It is necessary to involve health care professionals in the design of rehabilitation programs with the platform, in order to create meaningful content for the patient.
>
> 5. Cooperative work with technology partners (m-BOT) has been crucial in this pilot in order to achieve usability improvements prior to the pilot stage.
>
> Some of these improvements were: the inclination, position and height of the touch screen (adaptation to seated users), increasing audio range, adjusting the movements of the platform to the pace of patients. Issues such as sound, picture clarity, safety distance, touch screen, are appropriate to user profiles.
>
> 6. The pilot in the real scenario allowed us to explore other forms of interaction (verbal, visual, etc.).
>
> 7. To achieve the targets set (giving more autonomy to the robot and ability to interact), we need progress and coordination between research institutes, universities and companies, along with the scenarios presented in the project.

Finally, and returning to our initial topic of discussion, from this experience we learned that play is ageless and that humans have an innate need for leisure, which initially is expressed as "functional" play but soon turns into a social product resulting from the integration of persons into their environment. Such an innate need, conveyed by functional aspects, eventually results in leisure enjoyment. Patients interacted with the robot just for fun. They played spontaneously only to have a nice time; they played just for play's sake.

Below, the second and third use cases are described. These use cases are centred in paediatric patients with motor and cognitive impairments. Both use cases are being implemented in Virgen del Rocio University Hospital. Each rehabilitation session in both use cases is composed of two parts:

In the first part, paediatric patients start training with clinicians their conventional rehabilitation treatment. Concretely, in the second use case the paediatric patient has motor training which focuses on the affected upper limp. The clinician does an activity and the paediatric patient repeats it. For example, raise, lower or flex their arm.

The second part of the rehabilitation treatment in both use cases is composed of two phases:

In the first phase paediatric patients train using a video which is projected on the wall by the robotic platform and augmented reality technologies where at beginning of each motor or cognitive exercise a trainer shows how to do them. After watching the video, in the second use case, the child does the motor exercise that the robotic platform doest. If the child doesn't do the exercise, the robotic platform shows them how to do it. Furthermore, the robotic platform encourages the child, and digitally registers movements. And on the other hand, in the third use case the children have a cognitive treatment to acquire or improve language abilities and communication skills. In this use case clinicians teach them and the children learn them. For example, the clinician shows the child a picture of an apple, and asks him/her to relate to an appropriate group: fruit or toys; and where it can be found: hardware store or supermarket.

Finally, the second phase in both use cases the child plays interactive games with augmentative reality in where the motor or cognitive training is reinforced. Some second use case interactive games proposed are one where some apples are fallen from the tree and the child has to bring them in his basket. Another will consist in that will appear some colour balls which have to be inserted in the same colour boxes. To realize that games it will be necessary that children have to do the same movements that they trained in the first phase.

In the robotic platform of the second and third use case, some information of each patient will be implemented so they can receive personalized attention to promote better bonding between children and the robotic platform. Besides, we will register some data during the therapeutic sessions and subsequently, they will be statistically analysed.

Some of this data will be collect and stored by the platform, while other data will be collected on paper. The robotic platform can detect the children. For doing that, it's necessary to put coloured markers in their arms. Through these makers, the platform will register the clinic variables and data registered in the interactive games.

The clinical variables in motor training (second use case) are: passive and active articular balance of shoulder, elbow and hand; degree of concordance (precision of the movements realized by the child in respect to the theoretical levels established by clinical specialists); motor function of members; and the satisfaction (it will be measure through *Goal Attainment Scale*).

The clinic variables in communicational training (third use case) are: intelligence level; language impairments/disorders; verbal aptitude and vocabulary level. The same data in the second and third use case will be registered in the interactive games, and they will be: final score; percentage of exercises done correctly; numbers of errors done in each try; time needed to finish the game correctly and number of times each game is played.

On the other hand, other information about paediatric patients will be collected on paper from an initial interview with the main caregiver in both use cases, and some of this information is: name and surname, date of birth, Clinic History Number, diagnostic and treatments, alphanumeric code identification in order to identify patients in the study and to fulfil the confidential Data Protection Law, and so on.

To conclude, note that, in contrast with the first use case, in the second and third use case the preliminary test done have consisted in meetings in which the therapists assessed *Ursus*, and suggested to the robot developers some new improvement to ensure patient acceptance. Shorty, the first tests with paediatric patients will be carried out in Virgen del Rocio University Hospital.

Issues, Problems and Solutions

The concept of health has changed in the last decades. In 1946, the WHO defined health, not only as the absence of injury or disease, but as a perfect state of physical, mental and social wellbeing. However, health-studies in the sixties incorporated the concept of *quality of life*, which may contribute to improve our society – a society under continuous social, political, economic and technological transformation.

Within the theoretical frame proposed by Schalock and Verdugo (2002;2007), quality of life is a multi-dimensional concept, composed by the same dimensions for all persons, influenced by environmental and personal factors, as well as by the interactions between them, and improvable through self-determination, resources, integration and life-goals. Measuring a person's quality of life refers to valuable life-experiences and to the dimensions that contribute to a plenty interconnected life, takes the relevant physical, social and cultural contexts into account, and includes both common and unique human experiences (Verdugo et al, 2005).

If quality of life is considered a transversal integrative concept, then services for the elderly population should have a holistic design, beyond simple detection of and assistance for basic physiological needs (oxygenation, nourishing, hydration, evacuation, movement, sleep, etc.). The abilities to play or to participate in recreational activities, to learn, to discover and to satisfy curiosity, are also essential human needs. Thus, management of leisure time should be included in the services that are offered to persons in health and social care settings.

Considering that games are natural and that they usually have a positive effect on who plays them. The ACROSS project – aimed at introducing "intelligent" robots capable of adapting to the needs and requirements of different people – pursues to provide experiences of fun and entertainment, besides cognitive and motor stimulation, to elderly people with different degrees of dependence in different settings (home, community care setting, admitted to healthcare units) and paediatric patients that present motor and communicative impairments. One of the principal reasons to use games in children's cases is to take advantage of their properties, so we hope that they allow to reduce the stress and/or fear that is produced in children when they have to face up to new task or issue like the rehabilitation process. In these cases, the use of "serious games" becomes a preventive, leisure and therapeutic tool which add value to current care services.

Nevertheless, in our project we have found some difficulties in the acceptance of the games and technologies. The need to adapt the games and the robotic platforms to the users, to stay within in the project budget for at technical development of robotic platform, interaction between users and robot, and so on.

In respect to the physical appearance of platform robotics and games some features needed to be adapted. *Roinbot®* platform is generally used by people that are on foot, but elderly participants are usually seated. *Ursus* developers modified its height due to that it was taller than the patient. The first version of *Ursus* has been reduced by forty centimetres to achieve a more friendly size in relation with the one of the children. On the other hand, to get a good acceptance, games and robots have been adapted to the user. In depth, an elderly avatar has been implemented in *Roinbot®*, while in paediatric patients the games developed appears more childlike. Likewise, the voices of both platforms and the games are similar to elderly and child population. Besides, the intonation, the words used, male/female voices, and so on, are essential to get the desired interaction with the user.

From the technical point of view during the design process and initial testing, three different types of problems were found: autonomy, security and empathy. In order to enable an autonomous robot to work during long periods of time without technical supervision, it is necessary to provide it with a battery and the corresponding skills to drive itself to a dock station periodically. This skill is not a completely closed issue in autonomous robotics, and it would not be possible to guarantee that the system would perform robustly when unexpected events occur. Finally, we found the autonomy was to be dispensable since most of the expressiveness is generated with the arms and the head, so *Ursus* was modified to be a static robot. Since the arms of the robot are not powerful enough to cause any harm, and the base of the robot was not able to move anymore, the security issues were considered solved. As a minor price to pay, the new static robot cannot walk the patients to the therapy room or approach them directly while seated.

Taking into account security, introducing a robot into a clinic environment introduces the risk of harming patients and/or therapists. Thus, this must be taken very seriously. Robot autonomy does not only involve the challenge of docking, but also of security. Depending on the characteristics of a robot, autonomous navigation might also be a threat for the security of the people around. In the use cases two and three, which use *Ursus* robot, this threat could be important because the robot platform is heavy and powerful enough to cause physical harm.

There are several problems that limit the desirable level of empathy. One of them is the lack of expressiveness in the synthesized voice used by *Ursus*. The voice synthesizer is a commercial one developed by Verbio but, although some intonation adjustments are possible, in the long term the perceived voice is not expressive enough. We need a better synthetic voice if we want to establish and maintain a deeper connection with the patients. Moreover, the lack of movement in the head and mouth also limits the final empathy. Three ways to increase the level of empathy in *Ursus* have been developed: firstly, incorporate three degrees of freedom in the neck so the robot can make accompanying movements with its head; secondly, incorporate one degree of freedom in the mouth and synchronize its movements with the stream of synthetic speech; and finally, to get more expressiveness in the synthetic voice will be compensated with a set of pre-recorded expressions. These utterances will be interspersed with synthetic voice generated on-line.

Furthermore, as it can be seen, there are a large number of sensor systems capable of capturing information about the environment of a robot. Each of these sensors has some specific limitations, which is why robotic platforms are equipped with different sensors to analyse the different external variables.

These devices are generally not capable of analysing the entire environment around them as each sensor has its limitations, mainly generated by the physical constitution of the sensor and the technology used for manufacturing it.

As for intelligent vision systems, some allow an analysis of 360 º of their surroundings but are systems of high cost and require a high computer capacity for analysis and implementation of algorithms capable of recognizing and interpreting the elements in the environment. Moreover, the optics used in these cameras alter significantly the spatial characteristics of the received image, making it impractical for use in machine vision tasks, so it is necessary to use multiple cameras to analyse the whole environment surrounding a device.

In this sense, artificial vision systems responsible of analysing the movement that patients make presents a major drawback: they are limited to two dimensions, due to the inability of the cameras to detect depth, so these systems can not ensure proper implementation of rehabilitation exercises. To solve this problem, specially designed stereo cameras can be used to capture distances in the images taken, although these cameras cannot move in anyway and the whole system must be calibrated.

Another possible solution is to use coloured markers or markers based on different patterns or graphics. In case of using these markers for motor rehabilitation exercises, they should be placed at the extremities of the person performing such exercises. In this way the system can recognize the movements and applying mathematical algorithms it will decide the correct or incorrect execution thereof. In any case, the design of the markers and their placement are important parameters to consider for the interpretation of the exercises to be as real as possible.

In the field of cognitive rehabilitation, vision systems are used primarily for face detection and emotions recognition using patterns and complex algorithms able to learn over time, so that the correct interpretation of the environment depends directly on the temporal variable.

FUTURE RESEARCH DIRECTIONS

Social robotics is progressing with the aim of broadening its scope, leading to the emergence of robotic platforms that carry on different functions within that area.

Although the platform has a good design and has an excellent sensory system, the systems responsible of data acquisition and subsequent processing are which make up the intelligence of the robot and give the ability to respond appropriately to the situation previously recognized. So the advances in social robotics are linked closely to the progress in the technology related to sensors and computer engineering, specifically in the field of artificial intelligence, which would be defined as the science that mimics the human brain. In this sense, some of the researches in this field are focused on the rational side of the brain, allowing logical decisions. However, others focus on the interpretation of emotions as "status indicators", and it is in this line where the incorporation of cognitive skills in a social robot makes it evolve the human-machine interaction to communication between human-human as much as possible.

It is evident the importance of selecting a proper sensory system to endow the robot the capability of analysing its surroundings, and in many cases the inclusion of augmented reality facilitates and helps the robot in the complex task of recognizing its environment. This capacity is needed to implement the planned activities according to what happens around him. It is in this line that many research groups focus their efforts to achieve the incorporation and integration of social robots in our daily life.

A robot designed to create a non-physical therapeutic interaction with the patients has to be able to maintain an entertaining and creative interaction with them. That is one of the main future improvements and a current line of research with the robot *Ursus*. In order to design useful interaction patterns between the robot and the patient we are developing a graphical tool to build hierarchical state machines (Manso et al, 2010). These machines are specifically designed to represent interaction diagrams that can be readily executed through the RoboComp robotics framework developed by RoboLab at the University of Extremadura (Pinero et al, 2010). This underlying framework provides perception, action and low-level cognitive primitives that work as the raw material for building human-robot interaction patterns. By creating many of these interaction diagrams and evaluating them on real experimental setups, we expect to discover patterns of multimodal interaction capable of attracting the attention of children and maintaining it through extended periods of time.

The other main improvement and research topic is child modelling. To achieve useful interactions the robot needs to perceive the physical and cognitive state of the patient. This state includes the pose of its body, the direction of gaze and the emotional state. This information is crucial for the correct execution of the exercise, and also to provide quantitative information for therapists. Because of this, it must be as precise as possible. In order to improve the perception of the body of the patient we are developing a new upper-limb detector algorithm based on RGBD devices (which provide not only colour information as regular cameras do, but also depth information). Since the position of the body is not the only interesting variable to measure, there are other properties which are being considered for improvements. Specifically, we are investigating on how to implement emotive state detectors (e.g. neutral, bore, rage, despair, happiness) in *Ursus*. They would be very useful in order to provide a more complete state of the patient and to react consequently.

CONCLUSION

Children are beautiful beings for the freedom that they have. They act freely, and aren't coerced by social rules, aren't influenced by what other people think of them, and so on. While children play, they create the world in which the game is going to be developed and they control it. They decide the role that they are going to interpret, and they create their rules with amazing freedom and arbitrariness. When the game starts, they reach a consensus for some basic rules but according to how the game advances those rules are changed and adapted, and they usually don't care.

In symbolic/role games children recreate known situations and they reproduce them in order to understand the world while they learn values, feelings and attitudes from these situations. It's common for children to play as if they were mothers, fathers, physicians, patients, etc. From those role-plays, children understand the society in which they are submerged. One thing that children learn from games is the importance to share, to know that in the world there are other people besides themselves and their parents.

However, children aren't the only ones who play. Adults also do it although it's possible they don't understand it like "play" because it is a childhood activity. Adults have created a wonderful way to play, a wonderful way to vent their energy and to socialize: sports. However, it's true that sometimes, adults experiment it differently than children. Sometimes, they don't do it for the pleasure of the game, but for what the sport entails and sometimes that creates frustration between players. Usually, when a sport is played there are winners and losers, so the goal could be not to have fun but to beat the rival. Nevertheless, it's possible to find a positive use of sports, because you can find cooperation instead of competition. In fact, some companies and organizations use sports, for example, paintball or gymkhanas, as strategy to encourage bonding between team members, and they play games in which it's necessary for everybody to participate to achieve a common goal and to fight for this goal.

On the other hand, some sports and games are more typical of senior citizens. Some of these activities are chess or dominoes. Likewise, it's common that groups of elderly people like card games and go to bars or their houses to play together. However, it isn't so usual to see elderly people playing with robotic platforms similar our project, so we hope to obtain positive results that prove that elderly people are absolutely prepared to use technology and profit from the potential of games.

The quality of life concept is particularly useful in models of service to people, bearing in mind the importance that the elderly population gives to leisure-time. It promotes person-centred planning and adoption of models of support and quality-improving techniques. This concept may be used to evaluate people's needs and degree of satisfaction in the use of new technologies for the elderly. The results of programs and services, the management and guidance of service provision and the formulation of national and international policies aimed at the general population or at specific groups, such as disabled or dependent people. Promoting and improving quality of life, active ageing and implantation of the Law of Dependence are priorities of current Health and Social Care Policies in Spain and other European countries and we hope to contribute in getting more autonomy for people that have special needs.

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ADDITIONAL READING SECTION

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KEY TERMS & DEFINITIONS

Keywords: Augmented reality, cerebral palsy, cognitive training, dementia, games, motor training, obstetrical brachial paralysis, robot assistant, social robotic.

Augmented reality*:* is a term for a live direct or an indirect view of a physical, real-world environment whose elements are augmented by computer-generated sensory input, such as sound or graphics. It is related to a more general concept called mediated reality, in which a view of reality is modified by a computer. As a result, the technology functions by enhancing one's current perception of reality. By contrast, virtual reality replaces the real-world with a simulated one. Augmentation is in real-time and in semantic context with environmental elements. With the help of advanced AR technology (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulable. Artificial information about the environment and its objects can be overlaid on the real world

Cerebral palsy: is a neurological disorder of the brain with other possible clinical signs such as muscle tone disorders, movement and posture disorders, mental disability, and so on. Cerebral refers to the cerebrum, which is the affected area of the brain (although the disorder most likely involves connections between the cortex and other parts of the brain such as the cerebellum), and palsy refers to disorder of movement. Cerebral palsy is caused by damage to the motor control centres of the developing brain and can occur during pregnancy, during childbirth or after birth up to about age three. Resulting limits in movement and posture cause activity limitation and are often accompanied by disturbances of sensation, depth perception and other sight-based perceptual problems, communication ability, and so on.

Cognitive training*:* encloses a set of psychotherapy practices that address the resolution of people´s problem, by changing people's attitudes and behaviour, and focusing on thoughts, images, beliefs and attitudes and attitudes that we hold and how this relates to the way we behave, as a way of dealing with emotional problems.

Dementia: a clinical syndrome characterized by an overall cognitive impairment, usually chronic and progressive, that represents decreasing functional activities and social relations. Sometimes, it is associated with a behavioural disorder, which affects the patient, his relatives and friends.

Games*:* are sources of fun and satisfaction that allow children to motivate themselves in order to do some actions, learns, and so on, and it's essential to their development as a person. Games and its basic manifestations should be considered one of the most genuine human activities, which is present throughout life. Engaged under different circumstances and approached in different ways during the different stages of life, play acquires its typical socio-cultural elements from the beginning. Thus, play is determined by culture, while generating culture at the same time. In this chapter, the game is as a rehabilitation therapy for older patients with dementia and for children with neuro-cognitive.

Motor training*:* includes physical training to improve upper limb motor affected side. Physical training is conducted through the replication of exercises and video projected through the implementation of interactive games which use augmented reality.

Obstetrical brachial paralysis: is a mechanical lesion of the brachial plexus.

Robot Assistant: is the designed robotic platform which through augmented reality will become a coach and assistant in the training of children. To do this, it has patient´s information to ensure a personalized treatment and to increase the affectivity encouraging the patient to exercise performance.

Social Robotic**:** robots which interacts and communicates with people (in a simple and natural way) following behaviours, patterns and social norms. For this it is necessary that the robot has cognitive abilities that are located within called "social intelligence." Three levels of interaction are considered according to their degree of complexity: robots monitored directly by the user, robots used as a technological tools and robots equipped with advanced interaction fully adapted to user behaviour.

[i] The pilot session was conducted in the Geriatric Day Hospital of the Consorci Sanitari del Garraf. The selected target population consisted of older-than-65 persons with time-space-personal orientation, without cognitive deterioration or mild-moderate cognitive deterioration (MMSE>21/30).