Social Robots to enhance therapy and interaction for children: From the design to the implementation "in the wild"

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DOCTORAL THESIS

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Social Robots to enhance therapy and interaction for children: From the design to the implementation ”in the wild”

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Abstract

Over the past two decades social robots have become an emerging field where there are many things still to work on. This field not only requires knowledge in mechanics, control, artificial intelligence, systems, etc., but also in psychology, design, ethics, etc. Our multidisciplinary research group has been working on designing social robotic platforms in different applications for children with special needs.

The aim of this thesis is to investigate different scenarios in therapy or education where social robots could be a useful tool for children. We ran 4 studies with different purposes: (1) to design activities with LEGO robotics to assess children with autism spectrum disorder (ASD) social behaviour (between peers and with adults) and to analyze the effectiveness, (2) to design a social robotic platform to recover the functionalities most affected by traumatic brain injuries (TBI) in children and see the effectiveness of the treatment, (3) to provide a pet robot to alleviate feelings of anxiety, loneliness and stress of long-term children inpatient and their bystanders, and (4) to verify how a robot with social behaviour and personalization verses those robots without, shows differences in terms of interaction with children and thus, helps the effectiveness of different treatments as we mention above.

The results revealed different outcomes depending on the application: (1) effectiveness with the social robotic platform that we designed in neuropsychological treatment in those areas affected by TBI, (2) effectiveness with the LEGO robotics activities designed by a group of therapists in terms of improvement of the social skills and engagement, (3) a positive effect within mediators and facilitators of interaction and relationships between the different agents involved in the caring process: in-patients, relatives, volunteers and clinical staff (4) slight evidence towards a different interaction, in terms of time, between both groups in the average of a two-week period.

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Chapter 1

Introduction

1.1 Motivation

Robotics is an engaging tool as it is attractive to elderly people, adults and specially children **O'Brien & Toms [2008]; O'Reilly *et al.* [2005]**. Much research with social robots has been done in different scenarios as it could be it at schools, at home, in museums, in hospitals, etc. Besides these applications healthcare, therapy, and education are areas where social robots can enhance promising outcomes, improving quality of life, and social skills. Robotics are beginning to be used as a complementary tool to the regular therapies and to the regular classes in education.

Since our knowledge was focused on robotics and our awareness in children with special needs was high, we decided to use it to help them with their special needs. We began in 2010 with a pilot intervention at Sant Joan de Déu hospital with the aim to assess social interaction with a robotic system in children with Autism Spectrum Disorder (ASD) **Díaz *et al.* [2012]**. After promising results with this first study we became more excited about implementing new ideas for not only this population but also with others. In addition, the staff from the hospital, initially resistant to robotics, became very collaborative with us.

Despite the many studies in the field of therapy and education, further analysis needs to be done in order to improve the efficacy of the treatments and to make the experience between the user and the robot more enjoyable. There are still many things to work on, from the design of the robots, the design of the activities, to the intelligence of the robots, the cloud connectivity and the cognitive systems.

The idea of combining electronics to build a robot, computer science to program it, and psychology to understand better the interaction that can be elicited between the child and the robot is the reason for my interest in this thesis. Interdisciplinary teams are sometimes challenging, but more importantly, they are motivating, specially when the final goal is trying to help a part of society which is weaker than others. Technology, and robots in particular, could be a very useful tool to help those people and the most important make them happier and have a better quality of life.

The powerful of robotics in terms of engagement in children is something that we can use for a good profit. Robotics, as we understand in our studies, could be a tool that practitioners, therapists, educators, etc. can use in their work and take advantage of in order to accomplish their goals.

1.2 Thesis aims

In this thesis we propose to design or provide a social robotic platform for therapeutical purposes (autism spectrum disorder, traumatic brain injuries, hospitalized) or for educational purposes, with children. Thus, we present our four studies presenting the different platforms and its purpose:

1. Designing LEGO robotic activities to encourage social behaviour for children with ASD. But also, LEGO robotics as a social agent to interact with children during play. Two different children's profile participated in a robot-based activities program to assess ASD social behaviour and to analyze the effectiveness; one with high functioning autism, and the other one with low functioning autism.

2. A design of a social robotic platform made of LEGO robotics and an iPod Touch connected through an Arduino-based board called Teensy for a study to compare a long-term program of counselling and education directed to parents with a cognitive rehabilitation program aimed at children through robotics and determine which treatment was more effective, in terms of

recovering the functionalities most affected (executive functions) by TBI (Traumatic Brain Injuries).

3. A study to provide a commercial social pet robot called PLEO as a supplement of smart company to alleviate feelings of anxiety, loneliness and stress of long-term inpatient and their bystanders.

4. Incorporating the same robot used in (2.) in a long-term study to verify that a social behaviour manipulation and a personalization of a robot could establish a different interaction, in terms of time, in comparison with those robots where a social behaviour and a personalization was not applied over two weeks.

By doing so, we expect to find answers to the following research questions corresponding to the same studies we mentioned above:

1. Is the treatment with a robot-based activities designed in a program of social skills training for children with high and low functioning ASD feasible and effective? Can the preferences of the children help make funnier activities and thus, have a better impact on child's behaviour? Is the treatment engaging during therapy for those children with high and low functioning ASD?

2. Is the designed social robot enough feasible, appropriate and robust during the neuropsychological treatment for children with TBI? Can the treatment with a social robot have a better performance on cognitive functions, especially in tasks related to executive functions, after 6 months?

3. Is the PLEO appropriate and enough interactive for the study? Could the PLEO be engaging and enjoyable for a wide array of children profiles and situations during hospitalization and have an effect on children quality life and a good effect on the staff of the hospital?

4. Can a social behaviour combined with a personalization increase and maintain the interaction between a social robot and a child over time?

1.3 Expected Contributions

By addressing the research questions presented before, in this thesis we expect to enrich those areas of social robotics and long-term human-robot interactions by making the following contributions:

Contribution 1: Brief but useful guidelines in therapy for children with ASD (high and low functioning) from activities designed using LEGO-robotics.

Contribution 2: Knowledge on the design of a social robotic platform as an effective tool in long-term treatments, from the user and the specialist perception.

Contribution 3: A pet robot in hospital can help those children hospitalized who are sometimes bored, sometimes angry, sometimes sad, sometimes stressed, etc. in different rooms (oncology room, pre-surgery room, etc.) but also help the staff of the hospital in those situations.

Contribution 4: Adding a social behaviour and personalizing the robots can be very useful to increase the interaction and thus, to improve the bonding between the robot and the child in long-term interactions.

1.4 Thesis outline

The rest of the chapters in this thesis are organized as follows:

"Theory and Background" chapter (Chapter 2) is a short introduction to different relationships the humans could have: human-human relationships, human-pet relationships, human-technology relationships, and human-robot relationships. It also talks about long-term relationships in human-robot interaction (HRI), and about peronalization and social behaviour in social robots. "Review of Social Robots in different scenarios" chapter (Chapter 3) is a review of different social robots for long treatments for two different purposes: healthcare and therapy, and education. "Human Factors Engineering in Social Robotics" chapter (Chapter 4) talks about the design process we have followed with our studies. "Case Studies in different treatments" chapter (Chapter 5) presents the four main studies we conducted during the thesis. The first one introducing a social skills program through robotics for children with ASD (high and low functioning). The second explaining a cognitive rehabilitation with children with a brain trauma through robotics. The third one explains a social robot interaction with children to improve patient experience in hospitals. Finally, the fourth project talks about the effect of a robot with a social behaviour and personalization, in terms of interaction, with children for educational purposes. Lastly, "Conclusions and Future Lines" chapter (Chapter 6) discusses about the conclusions and the future directions of this dissertation.

Chapter 2

Theory and Background

2.1 Introduction

For thousand of years humans have been interacting defining us as "social animal" like Aristotle did. This interaction has been evolving over time and not only between humans but also with animals. Today, humanity faces new types of relationships though. Technology in the last 50 years has been deeply introduced into our everyday lives and such technology has evolved to become into robots, to be precise, into social robots.

2.2 Human-Human relationships

Human relationships lie in the interactions that take place between the relationship partners. According to **Berscheid *et al.*** [**2004**], the concept of a relationship: "refers to two people whose behaviour is interdependent in that a change in behaviour in one is likely to produce a change in behaviour of the other".

Some of the types of support that relationships have been found to provide are: emotional support (e.g., esteem, reassurance of worth, affection, attachment, intimacy), appraisal support (e.g., advice and guidance, information, feedback), instrumental support (e.g., material assistance), group belonging, opportunities to nurture, autonomy support, and social network support (e.g., providing introductions to other people) **Berscheid *et al.*** [**1998**]. Furthermore, a large amount of empirical work has been done in social psychology and other fields that demonstrate a significant association between social support and health. Health and well-being may also be augmented simply because relationships are emotionally gratifying **Berscheid *et al.*** [**1998**]. People who participate in successful, satisfying relationships, experience better health **Cohen *et al.*** [**1998**], heal more quickly **Kiecolt-Glaser *et al.*** [**2005**], and tend to live longer **Holt-Lunstad *et al.*** [**2010**]; **House *et al.*** [**1988**]; **King & Reis** [**2012**].

Figure 2.1: Human-human relationship.

The concept of relationship encompasses many different nominal types of relationships: romantic, parental, friendship, coworker, neighbour. Thus, there are two type of relationships those ones that are non-voluntary (parent-child, coworker, arranged marriage, neighbour) and those ones that are voluntary (friendship, romantic relationship). The last are born within an open interaction field in which each potential partner is relatively free to initiate (or refrain from initiating) the relationship; consequently, the development and continued survival of these relationships is heavily dependent on the partners' degree of attraction, familiarity, similarity, responsiveness, desirable partner attributes, physical attractiveness, proximity, and receptivity to one another **Berscheid *et al.*** [**1998**].

All relationships, like lives, have beginnings, all have ends, if only through death, and many have substantial middles as well. Relationships change and evolve over time crossing different stages. Levinger's model, has five stages **Kelley *et al.*** [**1983**] and it is introduced later on this chapter when talking about long-term relationships in HRI.

2.3 Human-Pet relationships

Animals, specially dogs and cats, have been living with humans for thousand of years. In the beginning this was for functional purposes (to hunt and guard) but later this relationship evolved into more social purposes (to provide warmth and companionship) **Podberscek *et al.*** [**2000**]. Nowadays the main reason to own pets is for companionship, not only for people who live alone, but also for people living in families **Endenburg *et al.*** [**1994**]. This relationship between the owner and the animal establishes, in the majority of the cases, a strong bond, similar to the band between humans **Archer** [**1997**].

Dogs, which are the most popular pet, have a very positive impact in the interaction with the human due to its capacity to adapt its behaviour to the owner's preferences, more so than other pets. Furthermore, dog owners, based on intimate interactions with their dogs, come to regard them as "unique individuals who are minded, empathetic, reciprocating, and well-aware of the basic rules and roles that govern the relationship" **Sanders** [**1993**].

Figure 2.2: Human-pet relationship.

If we talk about a positive benefit on human health it can be ranged from: higher survival rates from myocardial infarction **Friedmann *et al.*** [**1980**]; a significantly lower use of general practitioner services (prompting some researchers to speculate on considerable potential savings to health expenditure) **Headey** [**1999**]; a reduced risk of asthma and allergic rhinitis in children exposed to pet allergens during the first year of life **Nafstad *et al.*** [**2001**]; **Ownby *et al.*** [**2002**]; and better physical and psychological wellbeing in community dwelling older people **Raina *et al.*** [**1999**]. Therapy with pets has been proved to be successful in several situations for paediatric purposes **Gagnon *et al.*** [**2004**] provided children tend to develop engagement, empathy, and enjoyable feelings with their animal pets **Halm** [**2008**]. Furthermore, several studies suggest beneficial effects of animal assisted therapy **Fine** [**2010**]; for instance, **Barker & Dawson** [**1998**] studied whether a session of animal-assisted therapy (AAT) reduced the anxiety levels of hospitalized psychiatric patients and whether any differences in reductions in anxiety were associated with patients' diagnoses. Lastly, **Yeh** [**2008**] suggested several interesting outcomes from her three years of research in evaluating a canine assisted therapy treatment for children with ASD in Taiwan. She reported significant improvements for the children who received the AAT treatment on the social skills subscale. These studies helped us in our decision to apply pet robots in a hospital as it will be explained in the following chapters.

2.4 Human-Technology relationships

For the past decades we are facing and interacting with more and more technology. This technology is evolving very fast and has been changing our lives significantly compared to the past.

From this interaction, Reeves and Nass published their book "The Media Equation" **Reeves & Nass** [**1997**], in which through a series of experiments they show that people treat computers and other media in a very similar way as they treat other humans, and they do so unconsciously.

Figure 2.3: Human-technology relationship.

For instance, smart phones can be one of the greatest examples of human technology interaction at the moment. Smart phones are influencing the community and also those are going to transform the culture, social attitude, technology landscape and other various aspects of modern community **Sarwar & Soomro** [**2013**]. Also, Chesney and Lawson **Chesney & Lawson** [**2007**] investigated the interactions of players with Nintendogs, a very popular Nintendo DS game where players need to take care of a screen based virtual pet. The results suggest that Nintendogs pets provided companionship to players, even though the levels of companionship were significantly lower that the ones provided by real pets. In **Kidd & Breazeal** [**2004**], following a cooperative block-stacking task with a talking agent, participants found an agent more engaging, enjoyable, informative, and credible if it were a physically embodied robot, than if it were a virtually embodied animated character. For a verbal, desert survival, role-playing task, however, participants did not report any significant differences in their social perceptions of a physically embodied robot whether it was in the same room or video-displayed remotely from another room. In another study **Jung & Lee** [**2004**], lonely people have been observed to prefer interacting with a physically present Sony AIBO (pet robot), as opposed to a video-display of the AIBO. People who are not lonely, however, do not exhibit this preference, suggesting that co-location influences people's emotional responses to an agent.

2.5 Human-Robot relationships

Human relationships lie in the interactions that take place between a human and a robot. This interaction has become more and more popular since robots are becoming more present in our everyday life. Thus, studies trying to understand how this relationship begins and evolves over time are becoming more popular.

Even with the Roomba, a popular domestic robot regarded by many people as a pet for the first couple of month after purchase, but after the novelty fades it falls back to household appliance status though **Sung *et al.*** [**2009b**]. This transient effect of novelty is well known in social robotics **Huttenrauch & Severinson Eklundh** [**2002**]; **Kanda *et al.*** [**2007**].

Gates [**2008**] published that the current state of robotics was equivalent to that of the 80's with computers, and that soon we would live in the "era of the robot", so much so that we will have a robot in every home and a robot in every working place and every single house. Moreover, in December 2013,

Figure 2.4: Human-robot relationship.

Google completed the acquisition of robot-maker Boston Dynamics, as well as 8 robotics companies in the next 6 months. These robots will be tools, colleagues, and superiors with the skills to help humans with a performance more efficient than humans in their areas of work. Robotics concepts have revolutionized the manufacturing processes in industries since the industrial revolution. Now, they are being integrated into everyday life environments such as vehicles, homes, offices, schools and hospitals. Living with robots is already a reality, as also happened with the interaction with computers.

2.6 Conclusions

Humans come from a human-human and human-pet type of relationship but the world is becoming more and more technological and so, new type of relationships are emerging. Robots as part of technology is the new paradigm of relationship. Humans are interacting with robots that are becoming more social, and they are starting to do it over time creating a relationship. Taking into consideration how the relationships are built between humans, and humans with their pets, we have to start thinking how to build this new type of relationship. From these new relationships with social robots we have to take advantage of its benefits in order to help those children with special needs as you will see in the next chapters of this thesis.

Chapter 3

Review of Social Robots in different scenarios

3.1 Introduction

In the last decade robots have been used effectively in therapy and educational interventions with children. There are many studies using robotics in therapy for autistic children **Dautenhahn *et al.*** [**2002**]; **Ferrari *et al.*** [**2009**]; **Goodrich *et al.*** [**2011**]; **Robins *et al.*** [**2005**], for children with motor and physical impairments **Kwee *et al.*** [**2002**] and long-term hospitalized children (**Díaz *et al.*** [**2010**]; **Díaz Boladeras *et al.*** [**2011**]; **Saldien *et al.*** [**2006**]), and also in educational activities **Caci *et al.*** [**2004**]; **Michaud *et al.*** [**2007**]; **Tanaka *et al.*** [**2007**]. In different contexts it has been established that the effectiveness of a robot can be related to the way it is experienced **Libin & Libin** [**2004**]; **Wada & Shibata** [**2006**]. Usually, this simply means that it is more effective in a therapeutic or educational sense when it is liked more. Of course, this is the case with technology in general **Demers *et al.*** [**1999**]; **Tam *et al.*** [**2007**] but robotic systems differ from other technologies, because they concern technology that is not always perceived as such: a robot can be (partly) perceived as a social actor, and it could be that interaction which follows the same principles as interpersonal communication rather than those of human-machine interaction. This is often found to show in the behaviour of people interacting with robots

Bartneck *et al.* [**2005**]. In the following lines we will explain how a "state of the art" in robots is used for healthcare and therapy, and education, which are the domains where our studies.

3.2 Healthcare and therapy

In recent years there has been an emergence of innovative technologies in healthcare and therapy. Such technologies include computerized rehabilitation programs, virtual reality, remote rehabilitation, and robotics **Matarić *et al.*** [**2009**]. Robotics is an emerging field especially in healthcare and therapy due to its potentiality and capacity of engagement for different profiles. Robots can be therapeutic and act as companions **Matarić *et al.*** [**2009**]; becoming an extension of the therapist.

There are many studies with different types of robots and for different purposes. **Dautenhahn *et al.*** [**2009**] used KASPAR (see Figure 3.1a) in different applications in robot-assisted play and therapy. One of these studies is the work by **Robins *et al.*** [**2009**] where children with low functioning autism are encouraged to interact (long-term) with a minimally expressive robot called KASPAR to break their isolation and the most importantly, to facilitate interaction with other people. Results showed promising results in terms of mediating and encouraging interaction between the children and co-present adults. The same group of research also worked **Wainer *et al.*** [**2010a**] with KASPAR to foster cooperative dyadic play among children with autism showing promising results in collaboration between peers. There are more studies where the focus is on autistic children; for instance in **Kozima *et al.*** [**2007**] they used the Keepon (see Figure 3.1b), a minimalistic yellow robot, with a 3 year old girl, diagnosed with autism with moderate mental retardation in 15 sessions over 5 months. They could observe how the child was attracted to the bobbing and rocking gestures of Keepon and how she initiated an imitation game by mimicking the robot's body movements. Moreover, there is a study using Robota **Robins *et al.*** [**2004**] where 4 children with autism, aged between 5-10 years through 9 trials worked imitation games. In some cases, the children started to use the robot as a mediator, an object of shared attention, for their interaction with their teachers. Another robot which was useful in therapy for autistic children is PROBO (see Figure 3.1c). It is a social robot that may have potential to be a good trigger for some social skills among some of the children with ASD **Simut *et al.* [2016]**. AIBO (see Figure 3.1d) is an autonomous robot with zoomorphic, dog-like appearance, used successfully in autism related therapy **Stanton *et al.* [2008]**. In **François *et al.* [2009]** they present a novel methodological approach of how to design, conduct and analyze robot-assisted play. The study was tested in a long-term study with 6 children with autism in a school setting with the AIBO robot. Children who proactively played socially progressively experienced higher levels of play and constructed more reasoning related to the robot. Other people have been researching with the Paro robot (see Figure 3.1e), finding that this seal robot has a positive effect on therapy with elderly people **Taggart *et al.* [2005]**.

There are other studies which focused their therapy in human-like shape robots such as (see Figure 3.1f). In **Shamsuddin *et al.* [2012]** they elaborated a case study where a child with ASD was exposed to the humanoid robot NAO in order to gauge his initial response and behaviour in the presence of a robot. They concluded that the humanoid robot NAO has potential to serve as a platform to support and initiate interaction in children with ASD. Also, in **Tapus *et al.* [2012]** they investigated whether children with autism show more social engagement when interacting with the NAO robot, compared to a human partner in a motor imitation task. The robot proved to be a better facilitator of shared attention only for one child. In **Kim *et al.* [2013]** they provide a demonstration of social human-robot interaction in children with autism suggesting that social robots (see Figure 3.1g) may be developed into useful tools for social skills and communication therapies, specifically by embedding social interaction into intrinsic reinforcers and motivators.

CosmoBot (see Figure 3.1h) is used to help children with and without disabilities to promote educational and therapeutic activities **Brisben *et al.* [2005]; Lathan *et al.* [2005]; Parmanto *et al.* [2008]**. The robot's mood-positive design and demeanour provide motivation for children to develop new skills, such as communication, motor and social, more quickly than traditional therapy. Therapists and educators have tested Cosmobot's HRI with a range of abilities including children with autism, down syndrome, cerebral palsy, muscular dystrophy,

(a) Kaspar robot.

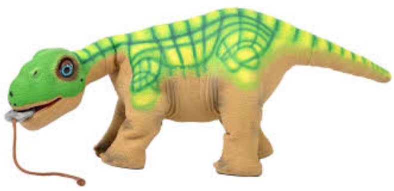
(b) Keepon robot.

(c) PROBO robot.

(d) AIBO robot.

(e) Paro robot.

(f) Nao robot.



(g) PLEO robot.

(h) Cosmobot robot.

Figure 3.1: Social robots used in healthcare and therapy.

apraxia, neurodevelopment disorders and language developmental disorders.

Kidd [2008] also studied the effectiveness of a weight loss coach sociable robot system for this very challenging health problem exhibited in much of the population. This robot showed how engaging it can be to work in ways that we find helpful and productive.

There are few antecedents of robots being deployed in paediatric hospitals supporting children and relatives well-being during hospitalization in a long-term basis. According to a recent survey **Leite *et al.* [2013]** the studies on long-term effects of social robots as companions in health organizations are focused on elderly people in nursing homes, featuring both robotic-pets like PARO **Wada & Shibata** [**2009**], anthropomorphic like ROBOVIE **Sabelli *et al.*** [**2011**]. Moreover, in the few studies on social HRI in the scenario of Paediatric Hospitals the robot took the role of a coach or assistant in rehabilitation routines **Calderita *et al.*** [**2015**], education, or a short time distractor during stressful or painful situation like vaccination **Beran *et al.*** [**2013**].

Even though some ad-hoc robots designed to assist children during hospitalization has been presented to the HRI community as the elephant's head PROBO **Saldien *et al.*** [**2006**], as far as we know, no results has been reported on deployment of companion robots in paediatric hospitals despite recent preliminary results with the Huggable robot aimed at mitigating stress and anxiety in patients who suffer from chronic and severe pain admitted to in-patient care for long periods **Jeong *et al.*** [**2015a**]. Another on-going innovative project is the European Funded MOnarCH Multi-Robot Cognitive Systems Operating in Hospital that focus on using networked heterogeneous ad-hoc designed robots and sensors to interact with children, staff, and visitors, engaging in edutainment activities in the paediatric infirmary of an oncological hospital, investigating the potential of hybrid human-robot collaborative systems as suppliers of health services.

3.3 Education

The use of robotics in education has traditionally been associated with teaching STEAM (Science, Technology, Engineering, Arts, and Maths) or MINT (Mathematics, Information sciences, Natural sciences, and Technology). However, in early education, technology can be also applied to help children's emotional and social development. Several studies **Cejka *et al.*** [**2006**]; **Danahy *et al.*** [**2014, 2008**]; **Kanda & Ishiguro** [**2005**]; **Kozima *et al.*** [**2009**]; **Tanaka** [**2014**]; **Tanaka *et al.*** [**2007**] point out how the education of people through interaction with robots adds further potential to the traditional approach focused on robot construction and programming (in educational environments). The main assumption in this approach is that interaction with robots can reinforce educative processes and outcomes such as conceptual learning and cognitive training, as well as motivate students, foment curiosity and raise awareness about robotics.

It has been shown **Han *et al.*** [**2008**] that young children performed better on post-learning examinations and generated more interest when language learning took place with the help of a robot in comparison with audiotapes and books.

Robotics introduce a wonderful dimension to the learning experience because computational power is located not only on a screen but also on tangible objects. By using a robot in an interaction, there is a different psychological response than with an animated character on a screen **Kidd** [**2008**]. The presence of a real, physical robot sharing space with a user has a marked effect on the impressions that the user has on the interaction. The manipulation of virtual objects on a screen has been widely used as an instrument for constructionism purposes **Turkle & Papert** [**1992**], but the same process occurs, and becomes even more powerful, when children are provided with objects that are physically tangible as well as digitally manipulated, such as robotic manipulatives **Piaget & Inhelder** [**1969**].

3.4 Long-term Human-Robot relationships

Long-term interactions between humans and robots are still at a primary stage of study, although human-human relationships are already well studied. Based on Levinger's model **Kelley *et al.*** [**1983**], any relationship, regardless of its relevance, has five stages: acquaintance (or attraction), building, continuation, deterioration, and ending, referring to all of them as the ABCDE model (see Figure 3.2). In a human-robot relationship these stages could be described as follows:

(A) Acquaintance (or attraction) Stage: children's initial attraction to the robot is due to their natural scientific curiosity **Jirout & Klahr** [**2012**] in response to novelty. In this case the novelty effects are those kind of responses that you have at the beginning of time with the technology, not the patterns of usage that will persist over time as the products newness fades. Studying the usage patterns beyond these novelty effects is crucial because it deepens our insights into what truly occurs when a robot becomes a part of people's everyday lives and can therefore improve product development by providing information that will remain useful beyond the initial adoption of the robot **Huttenrauch**

& Severinson Eklundh [**2002**]. Therefore, a major concern, **Kanda *et al.*** [**2004**] and our main one in this study, is to increase the time of interaction with the robot and try to maintain the interaction in the relationship over time; (B) Build-up Stage: the engagement with the robot increases until the child decides that the relationship is worthwhile; (C) Continuation (or consolidation) Stage: children make efforts to enhance the positive factors of the relationship by means of demonstrations of affection (children start naming the robot), trust, commitment and mutual satisfaction. During this phase, 'I' is usually replaced by 'We'; (D) Deterioration Stage: children no longer want to remain in the relationship, they feel the relationship is past the point of saving, or feel that the effort required is greater than the reward; and (E) Ending Stage: the relationship ends. It also gives each party a fresh start and the chance to seek happiness elsewhere, perhaps with a more compatible robot or with a robot with whom they may have more things in common.

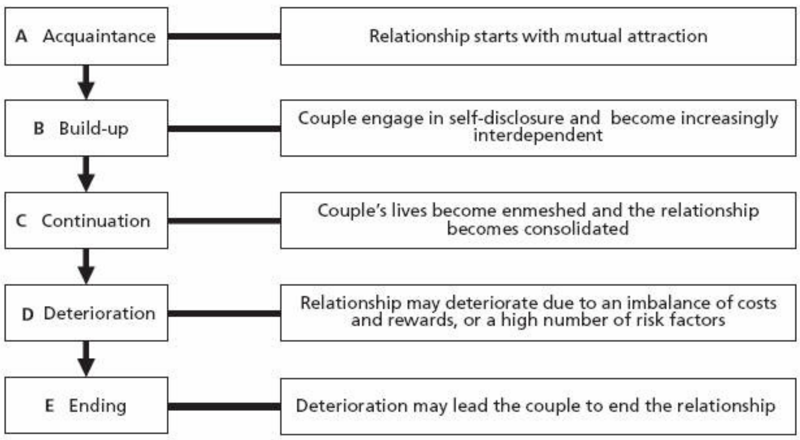


Figure 3.2: The five Levinger's stages.

The frontiers between stages are fuzzy, even more between A-B or B-C. In this sense, some research **Kidd & Breazeal** [**2008**] explicitly attempts a continuous guidance of the relationship from stage one (A) to stage three (C) and also to repair the relationship when stage four appears (D) and build it up again using different techniques as in the work by **Kanda *et al.*** [**2007**] who suggests telling secrets is a way to increase interaction and maintain a long-term friendly interaction. Levinger's model can only be followed in a long-term relationship but the time required to define any relationship as long-term is controversial. **Sung *et al.*** [**2009a**] suggested at least 2 months to see stable interactions between robots and users in their study called Robots in the Wild. **Kanda *et al.*** [**2007**] also established 2 months as the period between short-term and long-term. On the other hand, there is another study led by **Karapanos** [**2013**] in which they specify that the answer is at least 5 weeks. **Tanaka & Kimura** [**2009**] define a long-term interaction as 45 days of sessions spanning 5 months in their study of socialization between toddlers and robots at an early children's education centre. For **Kidd & Breazeal** [**2008**] a long-term interaction is about 6 weeks. Without any common agreement on this issue we ended up agreeing with the work done by **Leite *et al.*** [**2013**] who say that a long-term relationship is not defined by how many weeks the relationship lasts but the form the relationship takes. So in summary, a long-term interaction happens when the user becomes familiarized with the robot to the point that his/her perception of the robot is not biased on the novelty effect anymore.

Much less is clear about how human-robot interaction changes over time. And yet, some studies do hint at different interactions once the novelty effects become blurred. For example, **Kanda *et al.*** [**2007**] reported that the children voluntarily created a collective description of Robovies personality towards the end of a 9 week study. **Forlizzi** [**2007**] and **Kidd & Breazeal** [**2008**] reported how study participants had given names to their robots. In order to maintain and increase the interaction over time in the next section we talk about personalization and social behaviour add to a robot.

3.5 Personalization and social behaviour for social robots

The personalization of robots has been considered in some previous studies. For instance, in **Andrist *et al.*** [**2015**]; **Belpaeme *et al.*** [**2012**], they used a humanoid robot in therapy, and by changing its personality with different gaze behaviour or speech recognition, they measured the time children spent with it and their perception. Results showed how designing methods to adapt the robot to the personality of their users can improve the interaction. In another study **Sung *et al.*** [**2009b**] they used the Roomba robot in order to see how the users used a personalization toolkit in order to facilitate positive experiences over time asking them why they had personalized their robot or why they had not. Results showed how participants who personalized the Roomba were committed to using it more. Although the existing literature on Roomba usage shows that such a strong emotional engagement can exist without personalization **Sung *et al.*** [**2007**], their study suggested that customization can help accelerate that process. Moreover, in **Henkemans *et al.*** [**2013**] the personalization was based on the interests of the children (e.g., TV, maths, geography) and developed a user model and adapted the child-robot interaction accordingly. In the field of education there are also studies about personalizing robots such as the research done in **Leyzberg *et al.*** [**2014**] where they present results about how personalization in social robots, in this case based on the order of the lessons to suit the skills of individual participants, can yield significant benefits in educational or assistive human-robot interactions. In addition, **Kennedy *et al.*** [**2015**] showed how using a robot with social behaviour with different gestures, personalization (e.g. use the child's name in greetings) and gaze (e.g. be looking towards the touchscreen or in the direction of the child), and adapting it to the learning needs of the child can lead to a better performance in a math task than a robot with appropriate social behaviours. Finally, in **Janssen *et al.*** [**2011**] they presented work which showed how interacting with a personal robot that showed interest in the child (e.g., remembered his/her name) and showed social behaviour at appropriate moments (e.g., was motivating when necessary) can help improve learning and motivation.

Apart from personalizing, implementing social interaction in addition to a mere presentation of materials, is likely to be more effective and robots can serve as a means to realize such social interfaces **Saerbeck *et al.*** [**2010**]. Robots with social behaviour can be used to support and augment learning opportunities **Kennedy *et al.*** [**2015**] as well as in children's collaborative learning **Kanda *et al.*** [**2012**]. In **Saerbeck *et al.*** [**2010**] the participants learned more and were more motivated in the social supportive condition, although they spent the same amount of time with the robot tutor in the social supportive condition. In **Kanda *et al.*** [**2012**] they used a social robot called Robovie which managed the class and explained how to use LEGO Mindstorms in order to elicit relationships with the children, motivate them and encourage them to work more. There are also fully embodied robots used in both formal and informal education such as the NAO robot **Tanaka & Matsuzoe** [**2012**], or robots embodied as pet animals (PLEO the dinosaur **Heerink *et al.*** [**2012**]). All these platforms have the ability to engage in social interaction, by talking, moving, exhibiting facial expressions, etc. In **Fernández-Baena *et al.*** [**2015**] they created an interaction between the PLEO robot with a virtual PLEO, called Vleo, adding a new non-physical player in the interaction. Results suggested that virtual social robots are a good way to enhance interaction with physical social robots.

3.6 Conclusions

This section has shown us many social robots in different scenarios applied to different children's profile. However, there is still a need to work with robotics for children with ASD to develop social skills incoporating the robots during regular sessions and seeing the effectiveness in treatment. We have not seen neither many studies with social robots working with low functioning ASD children. Overall, there is a lack of guidelines when using robotics for children with ASD. In addition there is not a study yet working with children with a traumatic brain injured profile in a long-term rehabilitation program. There are not neither about pet robots in hospitals to reduce and to distract children during hospitalization. Antecedents point out the particular challenges of deploying robots to accompany children in hospitals. In addition to safety and technical issues related to navigating and interacting socially in open busy public spaces **Díaz-Boladeras *et al.*** [**2015**] particular ethical issues arise due to the sensitive nature of paediatric care context **Jeong *et al.*** [**2015b**]. Protecting privacy of patients, families and staff is one of the main concerns that often conflicts with the available techniques to obtain data for analysis (i.e. video record the activity or the facial expressions). Finally, we have to study more about long-term relationships. We have to research on adding personalization and a social behaviour to help to maintain and increase the interaction over time and see, if we could improve the efficiency of our treatments. These conclusions strengthen our thesis aims mentioned in 1.2.

Chapter 4

Human Factors Engineering in Social Robotics

4.1 Introduction

Human Factors Engineering (HFE) focuses on the application of human factors knowledge to the design and construction of socio-technical systems. The objective is to ensure systems that are designed in a way that optimizes the human contribution to production and minimizes potential for design-induced risks to health, personal or process safety or environmental performance.

4.2 Design process

The design process adopted during this thesis is built on and combines the methodological principles of the User-Centered Design (UCD) and the Scenario-Based Design (SBD) processes.

UCD places the user at the centre of the design and development process with the aim of creating a system or a product which meets user needs and is usable (ISO 13407). The ISO 13407 identifies 4 main activities of UCD, which are: (1) understand and specify context of use, (2) specify the user and organizational requirements, (3) produce design solutions, and (4) evaluate designs against requirements.

A drawback of UCD that made the TBI project process inspired by UCD principles but not adopting it rigidly is that, as mentioned by **Nesset & Large** [**2004**], user-centred design refers to a process undertaken once the technology has already been developed and released onto the market. In our project a major objective was the development of a novel robotic platform to support children with a brain damage in their recovery process; an objective that cannot be reached considering technology already available on the market.

Inspired by the UCD process, children have been involved in our projects (basically in the design process of the robot for the TBI study (see section **??**)), from the very beginning of the project when the robotic platform was still in the conception phase, to the final robot design; and as well as neuropsychologists, psychologists. teachers, therapists, nurses, etc., in the design process of the activities for the TBI project.

The other methodological principles that inspired all of our studies in the design process is the Scenario-Based Design (SBD). In the field of human computer interaction, scenarios have been used as tools in various stages of system development, from problem definition to envisioning solutions, helping all stake holders to contribute to the analysis, design and evaluation of systems. **Carroll & Rosson** [**2003**] described SBD as 'a family of techniques', describing the use of future systems at early points in their development. They can be in the form of textual narratives describing an activity in its context, video mock ups, storyboards of annotated cartoon panels or physical situations that contrive to support certain user activities.

In our studies we adopted the concept of scenarios and we used it like the IROMEC project did **Robins *et al.*** [**2010**]. We adopted a unified structure, modified from the SBD methodology **Carroll & Rosson** [**2003**] which is described in Table 4.1. From the scenario structure presented, we can present our different play scenarios (Table 4.2, Table 4.3, Table 4.4, Table 4.5, Table 4.6) based on our studies explained in Chapter 5:

Actors/ Roles	This identifies the roles of the different actors involved (children, therapists, parents...) highlighting the relationships among them. How are they involved in the activity? Is it appealing to all the participants?
Type of play	Is the activity a sensory motor play, and/or a symbolic play, and/or a constructive play, and/or a game with rules?
Activity description	Description of what happens as the activity is carried out. This points out the objectives of the different users who are taking part in the activity.
Activity model	Can the activity be simplified into an identifiable set of phases? This also highlights recursive passages and sequences.
Place/ Setting	Description of the characteristics of the physical or virtual context, including the environmental qualities, the space organization, and the morphology. Is the location of the activity affecting what is going on or is it irrelevant?
Artifacts/ media	Tools that are supporting the activity.
Time/ Flow	Which is the average duration of the activity? Is duration critical? Is the activity following a schedule? Does it repeat over time? Is it following a rhythm or a recursive pattern?
Keywords	Highlights of values of the activity with respect to the actors involved.

Table 4.1: Scenario structure.

During the design and evaluation processes of interactive products there are different roles for the end users. Some approaches consider the need to include users as full members of the design team. **Rogers & Scaife [1997]; Scaife & Rogers [1999]** proposed the notion of Informant Design, where the central point is to acknowledge the need to consider how different stakeholders with different knowledge/abilities/needs can inform the design at different stages of the development by being prompted by different types of material/artefacts/prototypes. Some other approaches consider users in a more reactive fashion where they are evaluating prototypes or final products. In the TBI project (Section 5.3) we run a study showing the children different robotic commercial platforms (PLEO, LEGO robotics, Keepon, and Furby). Among them, they had to pick three different adjectives from a bunch of them (attentive, artificial, useful, complex, funny, beautiful, bad, easy, simple, polite, silly, new, boor, intelligent, cute, boring, friendly, etc.). In Figure 4.1 we can see the results with the 2-3 top adjectives:

- PLEO: funny and loving.

Actors/ Roles	2 children were involved in the activities. The therapist had the role of managing and supervising and the technician to intervene if a technical issue occurred.
Type of play	Building and programming following instructions and interacting with the robot in a final game.
Activity description	Children were working in couples. They had to follow instructions in order to build a robot and then programming it with a computer. The objective of this activity was to engage them playing with the robot and thus, teach them: - asking for help. - turn-taking. - joint attention. - etc. The conductors of the activities, the therapist and the technician, explained the schedule and rules of each session. The therapist managed the session structure and the social dynamics, while the technician presented the robotic activity and solved the technical issues.
Activity model	Both children sit next to each other and they helped each other in order to accomplish the goal of the session.
Place/ Setting	The study was in a room from Hospital Sant Joan de Déu. This room was completely isolated from people not involved with the activity.
Artefacts/ media	Each group of 2 received a Lego Mindstorms set specific for each session. The activity in the room was videotaped with 2 cameras.
Time/ Flow	Robotics classes were 50 minutes long, allotting for 10 minutes of end free-game time. Children were placed together and given instructions on session rules and expectations, as well as the activity scheduling.
Keywords	Social interaction during activities designed with a robot.

Table 4.2: Example of play scenario for children with high functioning autism at Hospital Sant Joan de Déu.

Actors/ Roles	10 children were involved in the activities. The therapist had the role of managing and supervising and the technician to intervene if a technical issue occured.
Type of play	Interacting activities with LEGO Robotics.
Activity description	Activities were to include children with low functioning autism in their everyday-life teaching social skills and problem solving with LEGO robotics as facilitator.
Activity model	Both children sit next to each other and they helped each other in order to accomplish the goal of the session.
Place/ Setting	The study was in a room from the CASPAN centre. This room was completely isolated from people not involved with the activity.
Artifacts/ media	Each group of 2 received a Lego Mindstorms set specific for each session. The activity in the room was videotaped with 3 cameras.
Time/ Flow	Robotics classes were 1 hour long. Children were placed together and given instructions on session rules and expectations, as well as the activity scheduling.
Keywords	Social interaction during activities designed with a robot.

Table 4.3: Example of play scenario for children with low functioning autism at CASPAN centre.

Actors/ Roles	13 children were involved in the rehabilitation. The robot had the role of managing and monitoring the activities, the therapist haf the role of supervision and configuration of the activities; and the technician haf the role of fixing the technical issues.
Type of play	Interacting activities with a LEGO Mindstorms NXT attached to an iPod Touch 4G through a Teensy 2.0 board.
Activity description	Activities designed together with a group of neuropsychologist, had the purpose to recover those functionalities most affected by TBI which are the executive functions.
Activity model	Children individually had to do some activities interacting with the robot.
Place/ Setting	This study took place at home of each child. Once a week, though, all the children were meeting at the hospital to download any necessary information from the robot, as well as to set up new activities.
Artifacts/ media	Each child received a robot who was registering the performance from each activity.
Time/ Flow	A frequency of 30 minutes per day with the robot, from Monday to Friday.
Keywords	Social interaction during activities designed with a robot.

Table 4.4: Example of play scenario for children with a traumatic brain injury from Hospital Sant Joan de Déu.

Actors/ Roles	Hospitalized children. The robot had the role to have a positive effect during hospitalization.
Type of play	Free-play with the pet robot under different social situations.
Activity description	Ethnographic study to investigate a) how children interact with the robotic-pet in different situations and services, b) attitudes, perceptions of children, bystanders and hospital staff towards the robot and the deployment process c) which is the robot role -or roles- in the process of caring inpatient children d) how the deployment process have an impact on the organization and how the personnel involved themselves in this deployment.
Activity model	Children playing alone with the pet robot, playing in the presence of an adult, playing in pairs.
Place/ Setting	This study took place at the Hospital Sant Joan de Déu in different places: pre-surgery room, oncology ward, waiting rooms, etc.
Artifacts/ media	A pet robot (Pleo). The analysis was taken from field observations by the researchers.
Time/ Flow	The pet robot was deployed in different places for an undetermined period of time.
Keywords	Social interaction during activities designed with a robot.

Table 4.5: Example of play scenario for hospitalized children at Hospital Sant Joan de Déu.

Actors/ Roles	Neurotypical children from Col.legi Montserrat. The robot had the role of managing and monitoring the activities, the teacher had the role of supervision and configuration of the activities; and the technician had the role of fixing the technical issues.
Type of play	Interacting activities with a LEGO Mindstorms NXT attached to an iPod Touch 4G through a Teensy 2.0 board.
Activity description	Activities had the purpose to engage children to do the homework.
Activity model	Children individually had to do some activities interacting with the robot.
Place/ Setting	This study took place at home of each child. Once a week, though, all the children were meeting at the school to download any necessary information from the robot, as well as to set up new activities.
Artifacts/ media	Each child received a robot who was registering the performance from each activity.
Time/ Flow	A frequency of 30 minutes per day with the robot, from Monday to Friday.
Keywords	Social interaction during activities designed with a robot.

Table 4.6: Example of play scenario for neurotypical children from Col.legi Montserrat.

- LEGO Robotics: well-designed and useful.
- Keepon: funny, simple and stupid.
- Furby: funny, loving and intelligent (it was controlled by a smartphone).

From these results we took the conclusion that we expected a robot being useful, as it was the LEGO, loving as it was the PLEO, and intelligent, as it was the Furby (see Figure 4.1). Therefore, the design of our platform tried to pick these characteristics building the robot with LEGO pieces, including a pet behaviour in the robot, and adding intelligence through an iPod Touch (all the technical and behavioural characteristics are explained in detail in section **??**).

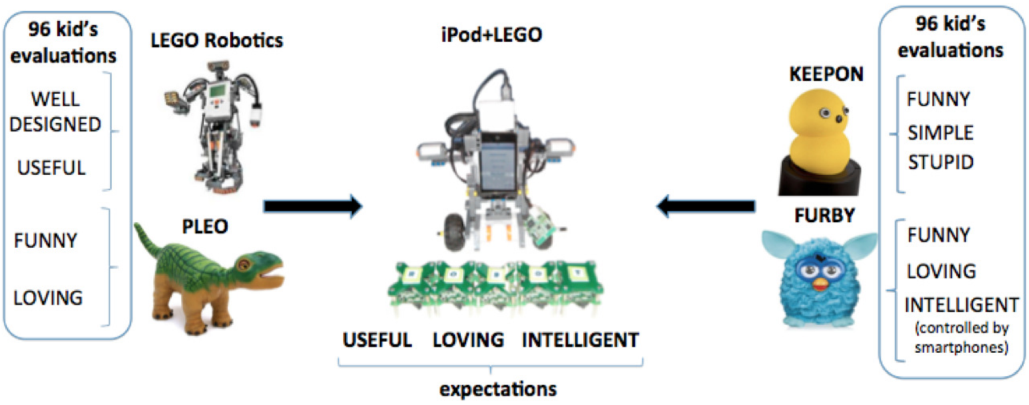


Figure 4.1: Expectations about our robotic platform after running a study with 4 different platforms.

In addition, the design of a social robot's behaviour, appearance, and cognitive and social skills are scientifically challenging, and requires interdisciplinary collaborations **Mataric [2005]**. Many technical definitions are available concerning social robot's motor, sensory functionalities, but little is being specified about the appearance, behaviour and interaction with people. Designing social robots, however, is about designing robots that work on the cognitive level and that can engage in social interactions, which are compelling and familiar to users, in this case, with cognitive impairments. Therefore, not only the physical embodiment, but also its personality and the ability to model some of the patient's motivational states is going to be crucial to effectively have a positive impact in robots employed in this context **Dautenhahn [2004]**.

In the following lines we suggest some initial design dimensions that are key to make certain the ability to engage users in affective interaction with social robots. In order to evoke innovative design methods that go beyond existing ones that fall short in coping with new HRI, e.g., cognitive HRI, the dimensions need to be defined according to disciplinary perspective that are relevant for the envisaged application context of the robot. Thus, at least, engineers, designers and ethicists need to be involved. What we identify as a robot? Its meaning, will change over time because of technology advancements or forthcoming human needs. Different from human beings, robots evolve in an artificial manner rather than in a biological sense. Robots are man-made machines, i.e. they are programmed and designed by humans, although machine-learning capabilities make robots learn as they operate without human supervision. Behaviour, embodiment, technical solutions of the robots are thus crucial, although they change day-by-day depending on the human use and development of new technology.

To reach this design method with an interdisciplinary way of thinking, we are going to focus on some of the current design methodologies, which are promising to be integrated into social robot design process. These key design dimensions are based on how we observe robots, engage robots and what we want robots to look like; what motivates us when we interact; as well as on the current legal requirements:

- Perception: The lifelikeness of a robot has a strong role in HRI, especially if it is designed to work at the emotional level **Graaf & Allouch [2016]**. In fact, the more social robots will become, the more the people will probably build intimate and trusting relationship with them **Leite *et al.* [2013]**. Social robots, therefore, should be designed to appear lifelike, which includes bio and non-biomimetic appearances. However, attention should be drawn to the implementation of these capabilities, because the intention of the robot's behaviour, Theory of Mind, or emotion expression may be perceived differently depending on the context in which the robot is going to be placed, the background of the users or the cultural differences. If not done appropriately, this could raise more ethical issues.

- Emotional attachment: As well as sharing emotions is a human social cue that makes feel closer to other humans, it seems that humans form emotional attachments to robots that are strong **Turkle [2010]**. Indeed, humans attribute social characteristics and roles to robots **Young [2010]**. When children use animistic intuitions in their learning process, they attribute agency to robotic animals in some studies **Okita & Schwartz [2006]**. In fact, robots are physical, can behave autonomously, and they display social behaviour? which can lead humans to respond to cues even if they are not alive **Darling [2014]**. As this attachment is in human nature, and social robots are designed to work with people with disabilities, it is of paramount importance to address these features of the robot. This can help increase emotional attachment, which can lead to intensified HRI and, therefore, to faster rehabilitation. As examples of the design of robots that follow this dimension we can find Paro that seems to be an exact copy of the real animal. PROBO, PLEO, and Maggie, on their side, are hybrids inspired by at least one animal species (including human) by often combining different morphological features instead of whole body parts, as in the case of PROBO that uses its trunk to communicate emotions **Graaf & Allouch [2016]**.

- Embodiment: The physical embodiment is what makes the difference between robots and other non-embodied agents. Physically embodied agents appear to possess what **Jung & Lee [2004]** refers to as "social presence" to a greater extent than virtually embodied agents do. The results of the embodiment comparison show a strong preference among the participants for the physically embodied robot over the virtually embodied robot and demonstrate the positive effect that physical embodiment has on participant evaluations of both the interaction and the robot **Bainbridge *et al.* [2011]; Fasola & Mataric [2013]; Kidd [2003]; Yamato *et al.* [2001]**. Also **Bainbridge *et al.* [2011]** found that users in a book-moving task were more likely to fulfil an unusual request and afford more personal space to the agent when interacting with a physically present robot than when interacting with a live video feed of the same robot on a computer screen.

Kidd [**2008**] compared a robotic weight-loss coach (a touch screen with a physical head capable of looking at and speaking to the user) to a similar touch-screen-only device and found that participants interacting with the robotic coach chose to continue with the weight-loss program for twice as long as those interacting with the computer-only device.

Social robots embodiment and their behaviour are crucial in HRI, especially in therapeutic contexts. This is because the embodiment affects users' perceptions of the robot's personality, mind **Broadbent *et al.*** [**2013**] and intention **Mutlu *et al.*** [**2009**] (see perception). Social robots should be embedded with behaviours that enriched the interaction with humans, making such interaction natural. Behaviours and appearances of robots have dramatically changed since the early 1990s, and they continue to change (new robots appearing on the market, other robots becoming obsolete). The design range of robot appearances extends from mechanic-like or functional, zoomorphic to humanoid, as well as android robots at the extreme end of human-likeness **Leite *et al.*** [**2013**]; and normally depends on the therapy and the intentions of this one: zoomorphic if it intends to replace pet therapies (like Paro) or non-biomimetic if it is intended to be used with children under the autistic spectrum disorder, although some authors suggest human-like as preferred **Cabibihan *et al.*** [**2013**].

Finally, if a robot needs to portray a living creature, it is critical that an appropriate degree of familiarity be maintained. Mashiro Mori contends that the progression from a non-realistic to realistic portrayal of a living thing is non-linear. In particular, there is an 'uncanny valley' **Mori *et al.*** [**2012**] (see Figure 4.2) as similarity becomes almost, but not quite perfect. At this point, the subtle imperfections of the recreation become highly disturbing, or even repulsive **Reichard** [**1978**]. Consequently, caricatured representations may be more useful, or effective, than more complex, 'realistic' representations.

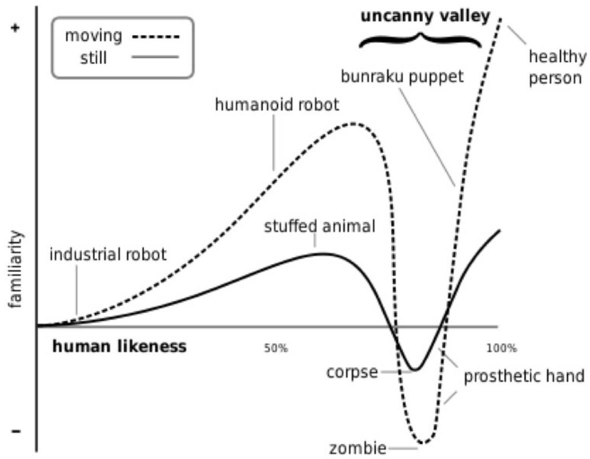


Figure 4.2: The uncanny valley theory.

- Motivation: Social robots may act intrinsically rewarding as sidekicks/social partners, especially for children with special needs. Social robots reproduces the social and emotional benefits associated with the interaction and the emotional bond between children and companion animals such as entertainment, relief, support and enjoyment **Weiss *et al.* [2009]**. For the pet-robot AIBO users tend to give reward in a similar way as giving reward to a real dog by touching it and commenting on its performance by uttering feedback like "well done" or "that was right". For the humanoid ASIMO, users did not use touch as a reward and rather used personal expressions like "thank you" to give positive feedback to the robot **Turkle [2010]**. The "+me" prototype is a transitional wearable companion (TWC) which is an embedded social robot that responds to the user's manipulations by emitting lights, sounds, or vibrations usable for multiple purposes such as to motivate the children to engage and interact socially **Okita & Schwartz [2006]**.

- Interaction: Through social interactions, human are constantly responsive to social cues from others that make us how to behave in response to how the others are acting and feeling. Social robots should be designed with similar social capabilities to be integrated into human's life **Leite *et al.* [2013]**. Humans are to enhance the anthropomorphic qualities (e.g. form and/or behaviour) of a robot, in order to create a way for humans to interact with the robots and vice-versa, in order to equip the robots for a meaningful interaction **Kahn *et al.* [2013]**. The more robots are expected to interact with humans in a social, easily understandable manner, the more effective the use of the robot is taken to be.

- Legal and Ethical principles: As robots can have moral and ethical implications, the more urgent it is to try and accommodate the design of the robot to ethical and legal considerations. Privacy-by-Design (PbD) is a concept developed by **Cavoukian *et al.* [2010]** in the 1990s. PbD is born under the idea that the mere compliance with regulations cannot guarantee the protection of privacy, but the inclusion of this philosophy in the organization's modus operandi. Although lacking of concrete guidance to the data controller **van Rest *et al.* [2012]**, it will be enforced in Europe after article 25 of the European 2016/679 Regulation on Data Protection (GDPR) **Hoel & Chen [2016]**. This article obliges the data controller, at the time of the determination of the means for processing and at the time of the processing itself, to implement appropriate measures for ensuring that all the requirements of the regulation are met. This implementation needs to be pro-active, embedded into the design as a default setting, with a full functionality, offering a full lifecycle protection, open and user-centric **Cavoukian *et al.* [2010]**. Although not relieving from responsibility, a voluntary certification issued by the Data Protection Authority (art. 42 GDPR) includes that one will demonstrate on demand that one is in compliance with these requirements.

From what we have seen, at the moment there seems to be no design rules for social robots that can embrace all these dimensions. In fact, very often the behaviour of the companion robots is not in line with their embodiment **Graaf & Allouch [2016]**.

4.3 Conclusions

Novel service robot standards focus on physical human-robot interaction (HRI) hazards by stipulating safety requirements on several design factors such as robot shape, robot motion, energy supply and storage or incorrect autonomous decisions **ISO13482** [**2014**]. Current robot technology capabilities, nonetheless, and as we have seen, go beyond mere physical HRI and can have moral **Steinert** [**2014**] and ethical **Salem *et al.*** [**2015**] implications, especially if they work not at the physical but at the cognitive level **Villaronga & Virk** [**2016**].

Chapter 5

Studies in different scenarios

5.1 Introduction

In this chapter we are describing our 4 projects that we have conducted for the last 5 years in order to help us to reach conclusions for our research questions mentioned in Chapter 1. First, we split them in different categories in order to have a clearer idea about what they are facing (see Table 5.1):

- **Children's profile:** we worked with different profiles. One of advantages in using robotics is the adaptability for each user, therefore we could work with children with ASD, with TBI, hospitalized, and neurotypical children.
- **Goal of the study:** during this thesis we had to address to different goals depending on the needs of the children, therefore we used robotics, trying to teach social skills to children with ASD (high and low functioning), to do a cognitive rehabilitation for children with TBI, to distract those children who are hospitalized, and to teach educational concepts for neurotypical children.
- **Application domain:** depending on the goal, our domain was different for either healthcare and therapy, or education.
- **Duration of interaction:** our interventions with robots have been either a short-term or a long-term duration.

- **Type of robot:** we worked basically with robots as social agents that encourage the interaction and through that can accomplish those goals specialists desire, but also in the study with children with ASD we worked with robotics as a design tool used to define role-based functions in working groups (i.e. programmer, and builder) that engage children.
- **Results:** we obtained different type of results, with qualitative and quantitative analysis.

	Children's profile	Goal of the study	Application domain	Duration of interaction	Type of robot	Results
1	ASD	social skills	healthcare and therapy	long-term	robot as a tool + social robot	Qualitative
2	TBI	cognitive rehabilitation	healthcare and therapy	long-term	social robot	Quantitative
3	Hospitalized	distraction	healthcare and therapy	short-term	social robot (pet robot)	Qualitative
4	Neurotypical	educational learning	education	long-term	social robot	Quantitative

Table 5.1: Categorization of the 4 projects described within this thesis.

In the following sections all these 4 projects will be explained in detail with a brief introduction about the purpose of the study, the development of the study with the different methodologies used, and the different activities made, their results and discussion, and finally some conclusions.

5.2 Design, implementation and evaluation of a social skills group program of robot-based activities for children with ASD

5.2.1 Introduction

Autism Spectrum Disorders (ASD), defined in **Frances [1994]**, are a group of neurodevelopmental disorders characterized by impairments in social interactions, communication and repetitive behaviours or interests. Social delays include qualitative delays in social interactions, social relationships and imaginative thought

Sicile-Kira [**2004**]. This delay in social skills makes it difficult for children with ASD to interact in teamwork activities with others **Wainer *et al.*** [**2010b**]. In related literature we can find indications that social play interventions and engaging activities can be successful in training social skills as well as giving the children a sense of achievement by working in groups **Baker** [**2000**]; **Gattino *et al.*** [**2011**]; **Kim *et al.*** [**2008**]; **Reichow & Volkmar** [**2010**]; **Wigram & Gold** [**2006**].

Based on previous studies in **Díaz *et al.*** [**2012**] and **Finio *et al.*** [**2012**] which proved that robot features and behaviours are likely to elicit desired social behaviour in children we carried out a study with children participating in a robot-based activities program to assess children's social behaviour (between peers and with adults) and to analyze the effectiveness of drawing conclusions in order to design robot-based interventions.

The same type of the study was conducted with two different children's profiles: high functioning and low functioning ASD. This division of the autism spectrum into "high" and "low" functionality in part comes from the inaccurate term "spectrum" itself. Because of the wide range of degrees of autism, a concept arose early on in the scientific community that ASD is a linear spectrum, with the high functioning, less-severely affected individuals at one end, and the low functioning, more severely affected at the other. In this case when we are talking about high functioning children we are referring to those ones who have a lack of interaction skills, have a limited understanding of the abstract uses of language, such as humour or give-and-take in a conversation, and obsessive interests in specific items or information. If we talk about low functioning children we are referring at those ones who are often nonverbal, with low intellectual abilities, extreme difficulty understanding daily instructions, and who need a lot of assistance in doing their daily routine.

Children with high functioning ASD

The team in charge was composed by engineers from la Salle - Ramon Llull University, and psychologists from the Sant Joan de Dééu hospital. Work began in 2010 with the recruitment of patients with the following criteria: children with high functioning ASD with a normal cognitive scale, between 9 and 12 years old. These patients did not participate in any parallel social skill training sessions during this time.

The main goals were:

- Explore the feasibility and effectiveness of introducing the LEGO MINDSTORMS NXT 2.0, as a tool in the long-term program of social skills training for children with ASD.
- Describe and measure children's behaviour during (e.g. look at behaviour) and after the session (e.g. recalling situations and explaining it to their parents) to assess the intended social behaviors (e.g. initiating an interaction, asking for help, gaze behaviour, joint attention) and psychological states such as attention, enjoyment or engagement.
- Understand and model the play/activity dynamics and their potential to facilitate children's intended behaviours.
- Adapt the game/activity based on the empirical evidence (e.g. social scenarios, roles) to optimize children's engagement with the activity and emergence of intended behaviours.

From these goals we could affirm the following hypothesis:

- (1st) hypothesis declared that LEGO MINDSTORMS NXT 2.0 is a feasible and effective robotic tool in a long-term program for children with ASD.
- (2nd) hypothesis declared that adapting the activities could be a good practice in order to engage the children with the sessions.

Children with low functioning ASD

The team in charge was composed by engineers from la Salle - Ramon Llull University, and specialists from Centro Ann Sullivan of PANama (CASPAN). Work began in 2014 recruiting children with low functioning ASD between 10-16 years old.

The main goal was:

- To include children with ASD in everyday-life. Although there is no treatment that eliminates the deficiencies of communication, socialization, and behaviour, many researchers have shown that there are strategies and techniques for teaching communication and effective responses in various social situations, and those skills could improve the success rate of adaptation of an individual in society **Laushey & Heflin** [**2000**]; **Rao** ***et al.*** [**2008**]; **Tse** ***et al.*** [**2007**]; **White** ***et al.*** [**2010**].

From this goal we could affirm these hypothesis:

- (1st) hypothesis declared that robotics is a useful tool for children of this profile and could be seen as a useful tool to learn social skills as well as being a useful tool for the specialists from the centre.

5.2.2 Development

In this section we explain in detail about how the studies were designed, the methodology implemented and the evaluation plan for the children with high functioning ASD and for the children with low functioning ASD.

Children with high functioning ASD

The study was composed of 16 children aged between 9 and 12 years old with high functioning ASD who took part in a long-term 6 months program with 12 sessions in total, on social skills training in the Psychiatry department in the Sant Joan de Dééu Hospital (Barcelona, Spain). 4 groups of 4 children were formed according to therapeutic criteria to guarantee the effectiveness of group dynamics (effective therapy groups).

The 4 groups were randomly assigned to either the intervention group (group A) or the comparison group (group B). The intervention group carried out the robot based activity while the comparison group followed a conventional social skills training program. The activities took place every two weeks for each group, Wednesdays and Thursdays, one week group A and the following week group B. Each session took 1 hour, 50 minutes of session, and 10 minutes for a free-game time chosen by the children. Children were placed together and given instructions on session rules and expectations, as well as the activity scheduling. Both groups carried out comparable activities according to their therapeutic and educative goals and the social skills involved in each session.

The activities with the intervention group consisted in LEGO robotics where the children had to program (either Mindstorms or LabVIEW), and build a robot. Apart from the play-based activity role that was designed to teach basic social interaction skills using turn taking, the social robot also acted as mediator and as an object of shared attention. That social robot that played with them during the game at the end of some of the sessions was helping to encourage interaction between peers and adults.

The training program was designed progressively to make it flexible and adaptable to the needs and interests of the participants, therefore the game at the end of the session was one chosen by a child to make it more engaging.

The same therapist assisted by a technician conducted both groups. Both groups took their sessions in the same classroom at Hospital Sant Joan de Dééu with two cameras placed in two corners of the classroom to cover the activity. The therapist managed the session structure and the social dynamics, while the technician presented the robotic activity and solved the technical issues. The evaluation plan included a mix of three different ways to extract results:

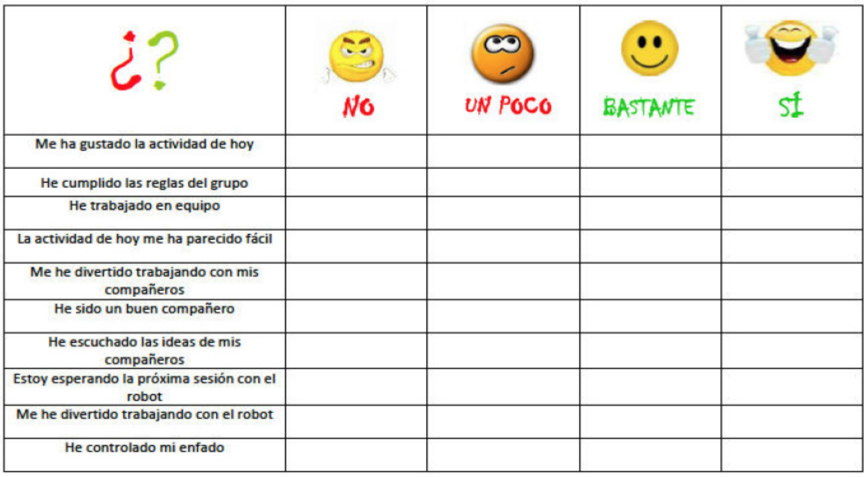
- A pre and post assessment of children's social skills with standardized tests (ATEC, Achenbach, ABC and SSRS).
- A pre and post evaluation of children's behaviour during the sessions (e.g. occurrence of desirable social skills) made by three external experts from the videotaped data.
- Thorough analyses of all the episodes of robot based activities from the observed data as well. The code scheme for the observational data is presented in Table 5.2.

Apart from these tests a questionnaire was distributed to collect feedback on each programming software used (Mindstorms and LabVIEW). Finally, the

Group	**Behavior**	**Description**
Social Interaction	Ask for Help	How many times the children ask for help from therapist or technician
	Ask for permission	How many times the children ask for permission from therapist or technician
	Group proxemics	When groupmates stand within 120 cm, or what is describes as the limit of "personal distance" in conversational interaction
	Shared gaze	When groupmates look at the same object or at each other
	Pointing Behaviour	Indicating the robots, computers or activity material (i.e.: cards, board, etc.) to either the experimenter or group-mates (i.e.: during a conversation/explanation even if they don't saying nothing) through pointing at them
	Shared Positive affect	How many times the children would laugh or smile with group-mates
	Joint attention	Initiation and response
States of play	No playing	The play it hasn't started or user it isn't doing nothing related with the play
	Disengagement	Participant is no focusing to the task or other individuals within the group or the other group (not really interested)
	Cooperative activity	Subject works with another person by turn-taking, or discussing play outcomes but where tasks are distributed Individual works together with somebody e.g. hands on something at same time or discussing outcome together
	Onlooker	Participant is watching what the other individuals within the own group are doing but does not actively take part or is watching the experimenter
	Onlooker of the other group	Participant is watching what the other group are doing and isn't playing or are speaking with the other group
	Playing alone	Subject is playing (with activity material, pc or computer) or focused to the task alone (the other user can be onlooker)
Children System Interact	Robot manipulation	Direct interaction manipulation with the robot (e.g. holding, connecting, assembling)
	PC Manipulation	Direct or indirect (watching what the other individual is doing) with the PC

Table 5.2: Code scheme for the observational data.

children and the therapist filled in a questionnaire about the activity at the end of each session (see Figure 5.1).



¿?	NO	UN POCO	BASTANTE	SÍ
Me ha gustado la actividad de hoy				
He cumplido las reglas del grupo				
He trabajado en equipo				
La actividad de hoy me ha parecido fácil				
Me he divertido trabajando con mis compañeros				
He sido un buen compañero				
He escuchado las ideas de mis compañeros				
Estoy esperando la próxima sesión con el robot				
Me he divertido trabajando con el robot				
He controlado mi enfado				

Figure 5.1: Session questionnaire.

Children with low functioning ASD

The study was composed by 10 children aged between 10 and 16 years old with low functioning ASD who took part in a 1 month program with 10 sessions in total, on social skills training in the CASPAN centre (Ciudad de Panamáá, Panamáá). A group of children was formed according to therapeutic criteria to guarantee the effectiveness of group dynamics. We programmed daily activities to train social skills and problem solving. The driver and facilitator for this purpose was the platform EV3 LEGO Robotics along with the therapist. Each intervention was twice a week for 1 hour.

The activities consisted in LEGO robotics where the children had to interact with the robot in order to learn different basic concepts such as numbers and colours. The robot played a very basic game and the children had to identify what was the correct item. When they were doing it correctly the robot was moving and cheering as a positive feedback.

The training program was designed by the therapist with the technician's help, and adapted to the regular therapy that was running before the introduction of

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following? Please select one.	**1 Never**	**2 Almost Never**	**3 Sometimes**	**4 Often**	**5 Always**	**N/A or Not Observable**
Communication						
Students are exchanging ideas with others.						
Students feel comfortable seeking help and asking questions with adults.						
Students feel comfortable seeking help and asking questions with peers.						
Collaboration						
Students are helping each other to understand materials.						
Students are receiving help from others and are appreciating it.						
Students are borrowing or lending materials from/to one another.						
Students are working together towards a common goal.						
On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	**1 Never**	**2 Almost Never**	**3 Sometimes**	**4 Often**	**5 Always**	**N/A or Not Observable**
Community Building						
Student are participating in,community-related tasks (ex. helping with clean-up, set up, etc.).						
Content Creation						
Students know how to use the technology to make an activity.						
Students are interested and enthusiastic about their activities.						
On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	**1 Never**	**2 Almost Never**	**3 Sometimes**	**4 Often**	**5 Always**	**N/A or Not Observable**
Creativity						
Student are using technology in an unexpected way.						
Students exhibit confidence and can initiate and complete a task with limited coaching.						
There are a variety of materials available for students to choose from.						
On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	**1 Never**	**2 Almost Never**	**3 Sometimes**	**4 Often**	**5 Always**	**N/A or Not Observable**
Choice of Conduct						
Students are focused on the activity and choose to engage with it.						
Student are following classroom rules.						
Students are aware that their actions with the technology will have an impact on others.						
Student are using materials and resources responsibly.						
Student are showing respectful behaviors to peers and teachers.						

Table 5.3: Positive Technological Development (PTD) Engagement Checklist

the robots. The intervention with the robots was conducted by both of them. The first one presenting the activity and the goals of the session, and the second one introducing the robot and fixing the technical issues. The evaluation plan included:

- A qualitative analysis during the activities carried out by an external observer.
- An evaluation of children's behaviour during the sessions (i.e. occurrence of desirable social skills) made by the therapist.
- Thorough analyses of all the episodes of robot based activities from the observed video-tape data. The observational data was based on the Positive Technological Development (PTD) Engagement Checklist **Bers [2012]** (see Table 5.3).

5.2.3 Results and discussion

We obtained different results due to the big differences of children's profile we have worked with, ones with high functioning ASD and the others with low functioning

ASD.

Children with high functioning ASD

In the end we were not able to obtain results with the mix of those assessments we presented before due to the commitment with the TBI project mentioned before. Although we could gather some qualitative results in initial observations of the social skills intervention with 9-12 years old children with high functioning ASD. These results showed effectiveness in terms of improvement of the social skills and engagement.

We were able to obtain some results on the questionnaire about programming software. This may not be accurate given the reluctance of the children in the study to admit difficulty programming with LabVIEW software. In spite of the general thought that children with ASD are not good at telling lies **Li *et al.*** [**2011**], it is possible that the high-functioning children with ASD in this group were able to do so, however they had more difficulty in covering up these lies. We could appreciate this fact in the video recordings and interviews with the session's conductors. The time period dedicated to help children using LabVIEW was much greater (12'44" vs 5'50" in one session), more often (11 times vs 8 times), and after two rounds of using both software platforms, children asked to use only the NXT-G Mindstorms program in future sessions.

Children with low functioning ASD

Observational results showed how children engaged with robotics activities focusing their attention on the robot. During the sessions, therapists did not have to encourage the interaction with the robot due to the willingness of the children to play with it. Children showed interest in all the activities proposed by the therapist, pointing and touching the robot, clapping their hands and yelling at it. Also some children shared the robot during the sessions or even communicate with each other laughing or smiling. These satisfactory behaviors suggested that introducing the robots during the daily sessions can help them to interact better with them and so, improve their social skills.

Besides, during the robot sessions we could see how the level of noise in the room was lower in comparison with the daily activities where no intervention was done. This suggests that the attraction with the robot can help the activities to make the sessions less noisy and so, less stressful for the children and even the therapists.

5.2.4 Conclusions

These conclusions are based on the two profiles of children that we have been working with: children with high functioning ASD from Hospital Sant Joan de DÈu, and children with low functioning ASD from CASPAN centre.

Children with high functioning ASD

The control group sessions took place in the same room as the robotic group and sometimes the participants were distracted by the equipment as children tend to be attracted by technologic devices.

With regard to the software we consider that the best way to program the robot is using a customized interface based in a LabVIEW PILOT adapted to the preference of many children with ASD for visual cues and simplified programming software.

A consistent schedule and a routine are key factors to ensure a predictable and secure environment, as well as the formation of balanced groups. Giving feedback to parents at the end of each session has an effect on the program effectiveness not only by reinforcing the skills with the training at home but it also enhances the therapeutic alliance, which presumably would have a positive effect on therapy adherence and clinical outcomes.

Adapting the final game to their preferences it was a very good point. They felt more attracted to participating in the sessions and they could have more fun validating the second hypothesis. Also incorporating a robot with a social behaviour it was very engaging for them.

The majority of participants in the intervention and comparison group, experienced an improvement in their social skills by the end of the program validating the first hypothesis. Specifically, we observed that interaction between children increased, they shared their interests, they established conversations more easily, they had fun when they were together, and in both groups existed between them a feeling of friendship and trust.

Children with low functioning ASD

Children's behaviour is significantly unpredictable in this case. In some sessions were most of the children were quite and paid attention to the specialist, while in others the behaviour of a child was completely unpredictable and they would shout and move all over the room.

Low functioning ASD children are a big challenge due to their cognitive problems. Using robotics has shown us that it could be a very useful tool for them, but the most important outcome is that, it has been seen as a very useful tool for the therapists thus validating our hypothesis. The adoption of technology can be something hard to do, and it is our work to make the sceptics realize that robotics could be a complementary tool for their work and help them in their therapies.

5.3 A Social Robotic platform for a long-term rehabilitation in children with Traumatic Brain Injury

5.3.1 Introduction

In Spain it is estimated that in one year 235 out of 100,000 people experience a head injury. Of that number, children can face Traumatic Brain Injury (TBI). At least 50% are children under 15, in which 79% will be considered with mild TBI, 12% with moderate TBI and 9% with severe TBI **Manrique** [**2010**]. Compared to adults, children usually maintain the consolidated cognitive functions after being diagnosed with TBI, but may face these types of problems in the future. Problems can arise even years after suffering brain damage which can cause academic issues and social demands incerease **Anderson & Catroppa** [**2006**].

There is wide evidence that cognitive stimulation is beneficial for adults who have suffered TBI **Cicerone *et al.*** [**2005**]; **Kennedy *et al.*** [**2008**]; **Rohling *et al.*** [**2009**], however, research on the effectiveness of cognitive rehabilitation on a pediatric population remains scarce **Limond & Leeke** [**2005**]. Although the results tend to suggest that these interventions may provide positive results, there is a lack of randomized studies evaluating the effectiveness of rehabilitation treatment in children with TBI. There is only one class A study that has shown good results **Braga *et al.*** [**2005**].

In a previous section done by our research team we focused on how LEGO robotics can help autistic children improve their social skills **Albo-Canals *et al.*** [**2013**]. We also worked on pet robots to evaluate a child's perception of them **Heerink *et al.*** [**2012**]. Furthermore, we presented the objectives and preliminary design of this section using the same social robotic platform in a previous work **Barco *et al.*** [**2013**]. In the next lines we give first the description of the project scope and organization. We will then explain the robot design, and a description of the activities. Finally, we present results about the effectiveness of the rehabilitation treatment in children with TBI with our robotic tool in a long-term interaction, and draw some conclusions.

5.3.2 Development

The project was composed by engineers from la Salle - Ramon Llull University, and neuropsychologists from Sant Joan de Déu hospital, from Barcelona. Work began in 2012 with the recruitment of patients, with a focus on the design and implementation of the robots and their respective activities (see table 5.4). After we got ethical approval from the medical institution (CIEC Sant Joan de Dééu Foundation with number of trial registration: PIC-63-11) we followed to the patient recruitment criteria which was based on the following parameters: children were between 6 and 18 years old, with a history of moderate or severe TBI for least 6 months prior to the beginning of the study, and a willingness to participate was also necessary. The exclusion parameters were: previous diagnosis of severe psychiatric disorder, IQ (Intelligent Quotient) below 70, significant vision, motor or hearing loss, language barriers, and psychological assessment without any significant alteration. The studies on children that passed the criteria took place during 2013. During 2014 the therapists analyzed the clinic results in order to draw conclusions about the effectiveness of our treatment.

Months	06	12	18	24	30	36
1) Patient recruitment	■	■				
2) Robot design	■	■	■			
3) Neuropsychological studies (pre-test)		■				
4) Intervention with the patients			■	■		
5) Neuropsychological control (3rd month)			■			
6) Neuropsychological studies (post-test)				■		
7) Neuropsychological studies (long-term)						■
8) Analysis of data and conclusions					■	■

Table 5.4: Timeline of project.

Initially, we split the patients in two groups: 13 in the control group and 13 in the group with the robot. For ethical issues, inclusion in the control group was not random and consisted of those patients who at the time of the study were not able to access to treatment for schedule, distance or other reasons; they did not participate in a specific treatment during the six months of study. The other group with the robot spent, at the beginning of the study, 2 hours every day for 2 weeks to get trained on the use of the robotic device. After these 2 weeks the children took the robot home, and came back once every week to download any necessary information from the robot, as well as to set up new activities. Those who lived far away from Barcelona had information sent to them through the Internet. This process took place for 6 months with a frequency of 30 minutes per day with the robot, from Monday to Friday, with a total of 60 hours of treatment. Thus, the following was our hypothesis:

- the hypothesis declared that a rehabilitation with a social robot can have a better impact in those areas most affected by TBI in comparison with the control group.

In order to evaluate the effectiveness of the treatment we performed cognitive measurements of the child during pre and post treatment. Patients with TBI have affected executive functions in their behavior; therefore, the following neuropsychological and behavioural questionnaires are used for evaluation.

- **Executive Functions**
  - Attentional control: Direct Digits (DD), Intelligence Scale subtests of the Weschler Intelligence Children Version IV. The child must repeat aloud a series of numbers in the same order as said by the therapists.
  - Cognitive flexibility: Inverse Digits (ID), Intelligence Scale subtests of the Weschler Intelligence Children Version IV. The child must repeat aloud a series of numbers in reverse order as said by the therapists.
  - Goal Setting: Total of movement of Tower of London Test (TOL). This test measures the capacity of planning and problem solving. The test consists of two boards with pegs and several beads with different colours. The examiner uses the beads to present the examinee with problem-solving tasks. The goal was to go from an initial configuration to a final configuration following a set of rules.
  - Information processing: Speed naming test (Naming), subtest of Nepsy-II. This timed subtest is designed to assess rapid semantic access to identify colours, shapes, sizes, letters, or numbers. He or she names them in order as quickly as possible.
- **Behaviour**
  - Child Behavior Checklist (CBCL): Presence of psychopathology in children/adolescents in the last 6 months. This instrument also includes demographic information, skills, possible illnesses and/or disabilities, and concerns towards the child and positive aspects from this.

The tool used for the study was made using LEGO® pieces. LEGO® has experience with child play and turns out to be a multidisciplinary tool that enhances children's motivation. LEGO® has already been used in similar rehabilitation programs addressed to autistic children to improve their social skills **Finio *et al.* [2012]; Wainer *et al.* [2010b]**. Nevertheless, few studies have been done in long-term rehabilitations with robotics. The robot was composed of a LEGO® Mindstorms® NXT 2.0 attached to an iPod Touch 4G through a Teensy 2.0 board to establish a bidirectional communication between both devices. The architecture of the robotic platform and its appearance is presented in figure 5.2. This design is based on what we explained in Chapter 4.

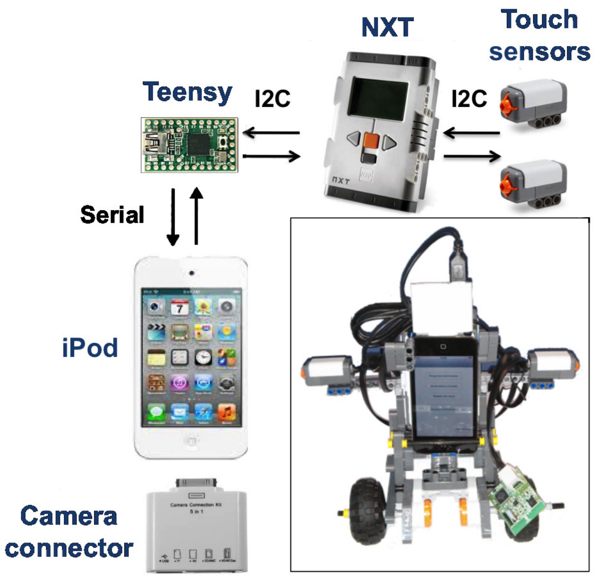


Figure 5.2: Robot structure and robot appearance.

The main part of the software relied on the iPod Touch 4G where there existed 3 different modules: one used by the therapist to configure a specific rehabilitation program for each patient, another one used by the patient to execute the sequence of the activities proposed by the therapist, and a final one used to download the results of the activities.

The therapist had to configure the robot once per week, therefore a friendly user interface was designed. This interface allowed the therapist to select which activity had to be done for each weekday and also the sequence of the daily activities. Its view consisted of 5 rows, each of which represented the days of the week. Here the therapist was able to select the activities for each day, and the sequence of these daily activities (see example in Figure 5.3). This information was stored in a register called the Sequence Parameters register. This module was only accessible with a password.

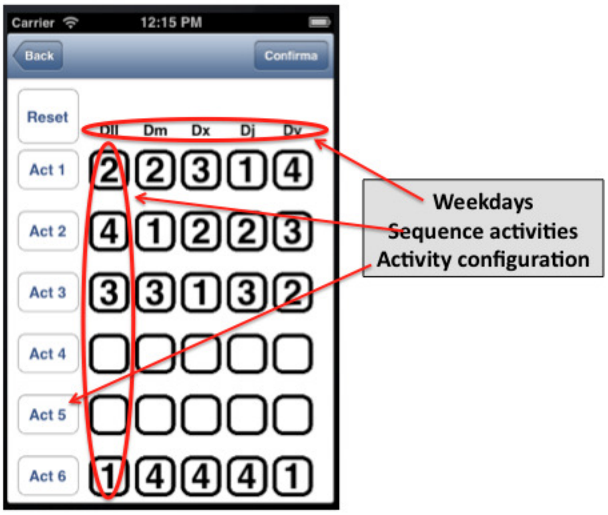


Figure 5.3: Display for sequencing the activities. The language on the configuration screens for weekdays is catalan.

The activities themselves also had different parameters such as: the difficulty or the length of time to be stored in a register (called the Input Parameters register). After choosing the sequence of each activity the therapists could select each one (see Figure 5.4) to determine any additional parameters; some of which may not be required depending on the activity.

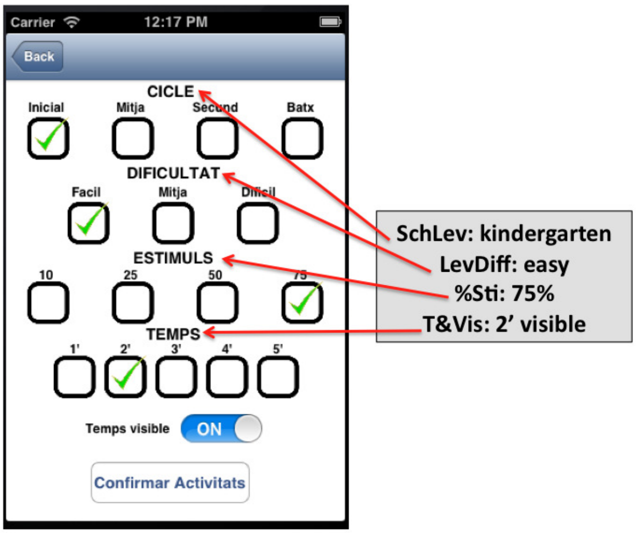


Figure 5.4: Example of activity configuration.

Additional Parameters to Software:

- School level (SchLev): choose from pre-elementary, elementary school, middle school or high school. Depending on the school level the activities are more child-like or less.
- Level of difficulty (LevDiff): easy, medium or difficult.
- Percentage of stimuli (%Sti): depending on the percentage of stimuli, the number of correct items on the screen may vary (10% 25% 50% 75%). In Figure 5.7 we can see how the activity is programmed with 75% of stimuli. For instance, there could be 12 Sponge Bob's but only 9 of them are the ones the child has to press (75% of them) in order to pass the activity.
- Time and visibility (T&Vis): gives the option to choose up to 1-5 minutes to pass the activity with visible time remaining on the screen , or 1-5 minutes to pass the activity without visible time on the screen.

Once the child finished each activity specific to the sequence defined by the therapist, and depending on the day of the week, an Output Parameter register was filled in with the following fields (along with the previous input parameters):

- Successes (Suc): number of correct answers.
- Errors (Err): number of wrong answers.
- Success rate (SucR): a formula that shows the success rate depending on the correct answers, wrong answers, and missing answers.
- Time remaining (TRem): remaining time until the activity ends.
- Repetitions (Rep): number of times an activity was played in a week; so if it was programmed Monday and Thursday then this parameter is equal to 1 for the former, and equal to 2 for the latter.

Figure 5.5 shows all the registers involved in the configuration of the activities and Figure 5.7 shows an example based on Figure 5.4 where a therapist defined an activity for a kindergartener with an easy level, with 75% of correct stimuli, and 2 minutes of visible time. The child obtained the following results: 300 correct answers, 0 failures, 100% of success rate, 23 seconds of remaining time until 2 minute mark, and with repetition equal to 1 since it is the first time the child executed this activity.

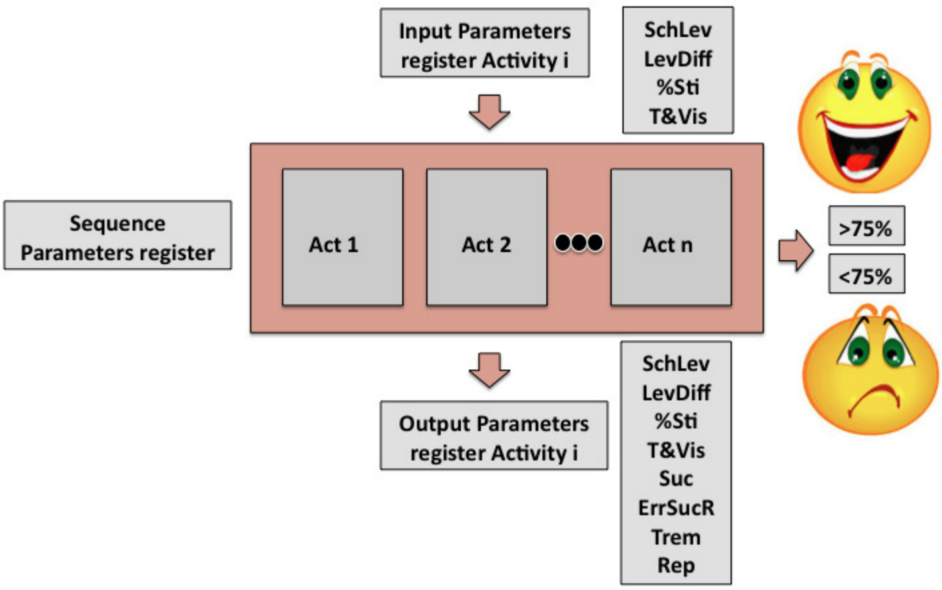


Figure 5.5: Registers involved in the activities.

The sequence of these activities was based on the flow chart shown in Figure 5.6:

When the child began these activities there was a 'test robot' view where the bidirectional communication between the LEGO® MINDSTORMS® NXT 2.0 and the iPod was tested. A button labeled *Move me* appeared on the screen. After pressing it, the robot would have to make a little movement in order to check the communication from the iPod to the LEGO® MINDSTORMS® NXT 2.0; otherwise, the iPod would have to be rebooted. Furthermore a touch sensor had to be pressed to check the communication from the LEGO® MINDSTORMS® NXT 2.0 to the iPod. If everything worked well, then a success message would have appeared on the iPod's screen, otherwise, it would have to be rebooted.

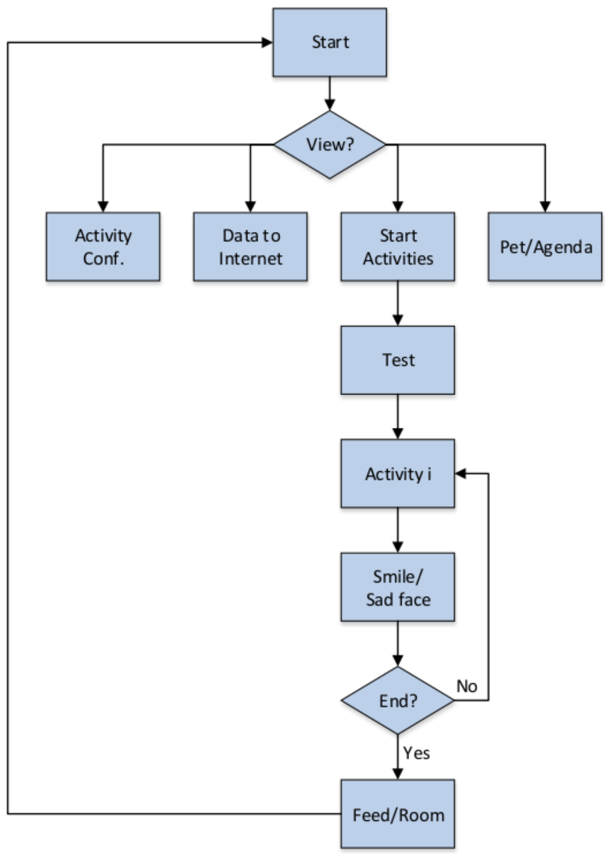


Figure 5.6: Flow of the activities.

Later on, the code would flow to a *Robot behavior status* view where the result obtained appeared as either a smiley face or a sad face. The child must have scored more than 75% in order to see the happy face. Furthermore a command was sent to the LEGO® MINDSTORMS® NXT 2.0 via Teensy to make the robot move with a cheering action.

If another activity had to be done, the process was repeated. Otherwise, the process went to the *Feed the robot* view where different dishes of food were shown (pasta, vegetables, fast food, etc.). The child must feed the robot and see afterwards how it was done. This facilitated healthy eating habits. Finally, the process went to a view asking the child to take a picture of his/her room in order to show the therapist the maintenance of the room. This facilitated the child's responsibility.

Due to some requirements from the therapists, there was no ability to change the sequence of the activities once the week was started. The sequence needed to be completed, and could not be repeated.

Finally, as the therapist reprogrammed the sequence of activities based on the evolution of each patient, they were required to know how well the child performed these activities. This feedback was implemented by sending the results to the Internet. All the data that was saved in the Output parameter register was sent to a Google spreadsheet only available for the clinician with a password. In any case, no data about the identity of the children was stored to guarantee anonymous information. The data shown in the spreadsheet could be downloaded as an excel file to help the therapist with data logging.

Two type of activities were conducted by the robot:, on the one hand activities with a rehabilitation purpose and on the other hand activities with a social purpose:

- Activities designed together with a group of neuropsychologist, with the purpose to recover those functionalities most affected by TBI which are the executive functions. They are a series of interrelated processes responsible for obtaining behaviour aimed at completing goals **Gioia *et al.*** [**2001**]. The executive processes play an important role in cognitive functions: behavioural, emotional and social states **Anderson** [**2002**]. The latter are correlated with mood and the initiative. Deficits in these functions affect learning, emotional control and social adaptation and pose a significant risk of disorders in adulthood. All of these activities not only focus on one cognitive function, each activity has a main objective to work with, but at the same time is working with the others; so it is not possible to correlate directly the activities with the robot with a specific executive function. In the following lines we explain the activities:
  - Activity 1: the child has to recognize a target among a group of similar images like the example shown in Figure 5.7.
  - Activity 2: the child has to repeat a sequence of pointing arrows to the right or left in reverse order that has previously been presented on the screen.

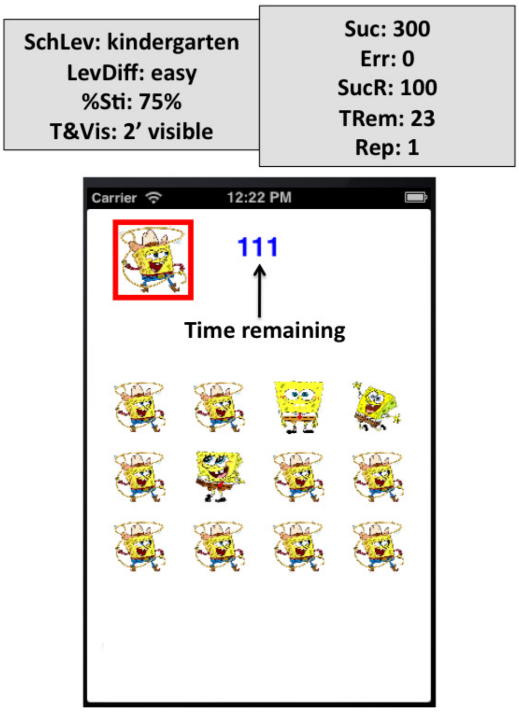


Figure 5.7: Example of an activity view and input-output parameters.

- Activity 3: when the robot whistles the child has to push the touch sensors in a certain order, but if the robot whistles twice then the child has to push the touch sensors in a different order.
- Activity 4: the child has to choose the correct dialog depending on the scenario for each cartoon character. There are several optional dialogs or and explanations, but only one is appropriate depending on the facial and body expressions (see example in Figure 5.8).
- Activity 5: there is a set of pieces made with cardboard that allows the child build a maze. They are required to organize all the pieces in order to build it. After it is built they have to solve it by driving the robot to an exit. A similar activity that can be done with these pieces is the game called Sokoban where they have to build the maze with an obstacle in the way. The obstacle needs to be moved in order to find the exit.
- Activity 6: the child has to organize the objects that are disordered.

Figure 5.8: Activity where the child has to choose the correct dialog.

For example, in Figure 5.9 a circus and a jungle are presented and the child has to drag the gorilla to the jungle.

Figure 5.9: Activity where the child has to drag different items to the corresponding scenario.

– Activity 7: where the child has to search for a specific word which is named at the beginning. There is a similar activity where the child has to build words with different letters. For this type of activity we used external electronic devices such as a connected RF (radiofrequency) transmitter to a RF receiver attached to a LEGO® MINDSTORMS® NXT 2.0 (see Figure 5.10).

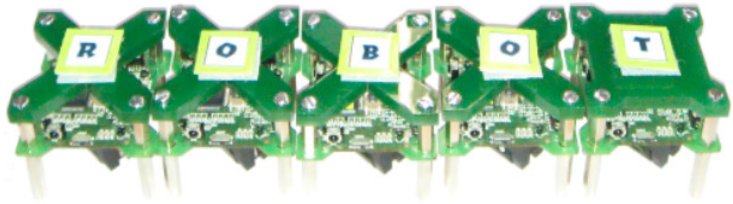


Figure 5.10: Electronic cubilets.

All these activities focused on learning skills and classified with three levels and themes in order to be appropriate to the child's profile. A profile, in which is in terms of realization time, difficulty, and engagement. Many of the activities were designed to simulate a real life situation (ecological activities).

- Activities with a social set was based on imitating pet behaviour and a food habit functionality. The pet functionality sets up an emotional state **Fellous [2004]** for the robot depending on the battery level of the iPod and the scores from the activities (see Figure 5.11):

  - Sad state (blue face): iPod battery level more than 30%, and a success rate of less than 75% in the average of the all activities.
  - Happy state (yellow face): iPod battery level more than 30%, and a success rate of more than 75% in the average of the all activities.
  - Sick state (green face): iPod battery level less than 30%, and a success rate of less than 75% in the average of the all activities.
  - Angry state (red face): iPod battery level less than 30%, and a success rate of more than 75% in the average of the all activities.

Every time they played with the robot the state could vary depending on how they performed with the activities (scoring) and depending on the battery level. Children could identify the different emotional states due to the

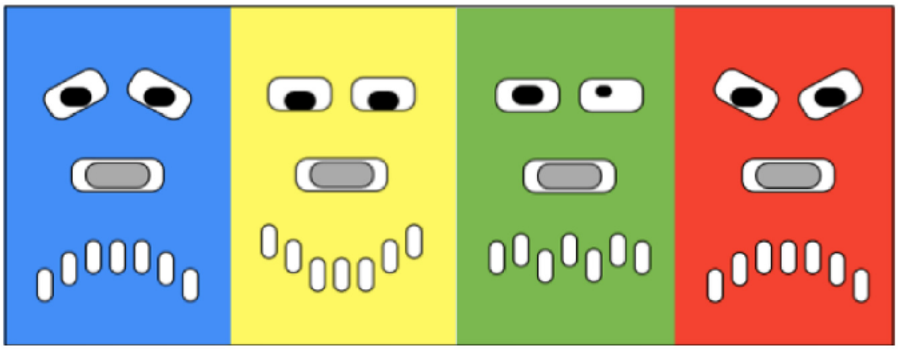


Figure 5.11: Four different emotional faces.

different colours of the faces and due to the basic manual that they received during the training sessions, which showed each face with its correspondence emotional state. This functionality worked the child's responsibility, planning and perseverance.

On the other hand, the food habit functionality was based on a view with different dishes of food (pasta, vegetables, hamburgers, etc.), to let the child feed the robot and later see how the behaviour and health of the robot changed in a fat or slim character or in the speed of the robot's movements. For instance, if a child was feeding the robot with French fries, hamburgers and ice cream the robot's movements were very slow, on the other hand if a child was feeding the robot with a salad, fish and fruit, the robot's movements were much faster. It is all about trying out healthy habits (see Figure 5.18).

Besides these previously mentioned activities, there was another activity that was always running:

- A virtual agenda where the children had to note down their homework and their school timetable. This functionality worked the child's planning and organization skills.

5.3.3 Results and discussion

Finally, we present differences between the control group (13 children), and the group with robots (13 children) that confirm our hypothesis. Each group con-

Figure 5.12: Two different menus and the consequences with a slim character or a fat one.

sisted of children between 8 and 13 years old, each group encountered different neuropsychological tests and questionnaires of conduct after 6 months of rehabilitation. To assess the effectiveness of treatment, therapists compared the differences between pre and post time of each group from the 4 neuropsychological tests that we introduced previously: Direct Digits (DD), Inverse Digits (ID), Total of movement of Tower of London test (TOL), and Speed Naming tests (Naming). We analyzed all the data using SPSS for Windows, version 19.0. Due to a small sample size (n=13 children) therapists used non-parametric tests in the statistical analysis. Generally it is considered significant if the statistical test has a p-value less than 0.05 (alpha significance level of 5%); therapists also took into account those tests that were close to being significant ($p<0.07$). In table 5.5 we can see how the robot group improved in all tests that were administered. This improvement is significant for the Tower of London test (TOL), and the trend tends to be significant in the Inverse Digits Test of WISC-IV and in the index of externalizing behaviors of the Child Behavior Checklist. However, the control group revealed a very homogeneous profile during pre and post treatment. There is only an improvement in the Tower of London test; without being statistically significant (see table 5.6).

These results indicate that the group with the robot has improved goal setting, cognitive flexibility, and behavioural problems. In contrast, the control group showed no significant changes in performance over the last six months.

ROBOT GROUP	N	Mean	Standard Deviation	Sig (p-value)
DD pre	13	96.62	10.774	0.162
DD post	13	101.85	7.679	
ID pre	13	91	11.972	0.069
ID post	13	100.38	10.381	
TOL pre	11	88.09	14.082	0.050
TOL post	13	95.46	19.376	
Naming pre	11	85	16.733	0.085
Naming post	11	100.45	15.883	
CBCL Intern pre	13	57.38	10.587	0.456
CBCL Intern post	12	60.17	9.282	
CBCL Extern pre	13	62.46	11.787	0.065
CBCL Extern post	12	56.5	14.305	

Table 5.5: Results from the rehabilitation program through robotics.

CONTROL GROUP	N	Mean	Standard Deviation	Sig (p-value)
DD pre	13	101	14.036	0.754
DD post	12	98.92	20.079	
ID pre	13	94.54	14.321	0.929
ID post	12	95.42	12.588	
TOL pre	12	75.92	15.791	0.062
TOL post	12	85.08	18.466	
Naming pre	13	95	20.207	0.341
Naming post	12	100.42	12.873	
CBCL Intern pre	11	56.55	14.801	1
CBCL Intern post	12	55.08	9.821	
CBCL Extern pre	11	53.36	9.973	0.065
CBCL Extern post	12	53.42	11.229	

Table 5.6: Results from the control group.

5.3.4 Conclusions

Clinical results suggest effectiveness in long-term neuropsychological treatment through our social robotic platform; it acts as a helpful tool in areas affected by TBI. It is not possible to correlate directly the activities with the robot with a specific executive function. Every activity has a main objective to work with, but at the same time is working with the others. For instance, the activity in Figure 5.8 is testing cognitive flexibility, but during the activity the child also has to pay attention, read, and work other skills. The results are not a direct effect from the activities either. It is a conjunction of many different things, such as: the activities themselves, pet functionality where the child has to demonstrate responsibility, planning, and consistency. Lastly the group dynamic also plays a role, where children and their parents were meeting therapists once per week, getting to know each other, becoming aware of their situation, needing emotional support, etc.

5.4 Pain and Anxiety Treatment based on social Robot Interaction with Children to Improve pAtient experience (PATRICIA)

5.4.1 Introduction

Hospitalization is a serious event that affects children and their families' lives. Hospitalized children are confronted with stressful conditions including physical pain and fear **Díaz Boladeras *et al.*** [**2011**]; **Jeong *et al.*** [**2015a**]. Social support becomes almost limited to hospital staff and relatives, who often are affected themselves by feelings of sorrow and concern. Social engaging robots capable of establishing satisfactory interaction and eventually long-term relationship with children have already been proposed as supplementary tool in pediatric hospitals for rehabilitation **Plaisant *et al.*** [**2000**], autism therapy **Davis *et al.*** [**2005**]; **Kozima *et al.*** [**2005**] treatment, adherence and compliance and even provide entertainment, enjoyment and comfort **Okamura *et al.*** [**2010**]; **Saldien *et al.*** [**2006**]; **Shibata *et al.*** [**2001**]. Focusing on long-term relationship the two main functions a social robot has developed in pediatric services are coaching and companionship. Consistent with their role, coaches and companion robots require different embodiments and behaviour to engage children to fulfil their goals beyond the novelty effect (for a more complete comparison between coach and companion robots for pediatric service see **Díaz Boladeras *et al.*** [**2011**]).

The funded project Pain and Anxiety Treatment based on social Robot Interaction with Children to Improve pAtient experience (PATRICIA) addresses several issues on effective social-robot based therapeutic intervention. The main objectives were:

- Design and develop robot's social behaviour to undertake a useful role in the multi-agent collaborative system that takes care of hospitalized children and therefore improve the effectiveness of their treatment.

- Design and deploy the pet-robots' based intervention to enhance a successful adoption by the organization.

From this objectives we could state the following hypothesis:

- (1st) hypothesis declared that a pet robot can be effective and successfully adopted during the study.
- (2nd) hypothesis declared that a pet robot (PLEO) could be a robust platform to perform a study "in the wild".

Before starting the study we did some assumptions:

- Interacting with PLEO robots would be engaging and enjoyable for a wide array of children profiles and situations during short-terms hospitalization.
- Successful repeated interactions with the robot- would result in children's affective involvement and perceived social support that would affect positively their quality of life.
- The effect on children's quality of life could be measured through subjective perceived health, experienced pain, anxiety and objective data - reduction in analgesics administration, changes in daily activity.
- The robot could be adopted by the organization sustainably and play a valuable role in the caring system.

Before starting the study we also run some preliminary studies:

- Exploratory studies in the laboratory. Children interactive behaviour with PLEO during free-play under different social short-term situations: playing alone with the pet robot, playing in the presence of an adult, playing in pairs.

- Workshop with PLEO Two groups of 18 and 25 children respectively from two different elementary schools. The children played with the robot during a workshop on robotics. Observe preferences: children were presented with 4 different platforms-, expectancies, and interactive behaviour from observed behaviour, group interview and questionnaires **Díaz Boladeras *et al.*** [**2011**].

- Free play with PLEO in pairs: 20 episodes observed in similar conditions of pairs free plays with the robot from 6 to 12 years old. Exploring interactive behaviour from observed behaviour and social presence from questionnaires **Heerink *et al.*** [**2012**].

  As a result of these preliminary studies we gathered observational and self-reporting data of 71 children interacting with PLEO under research conditions: 45 girls and 26 boys, aged from 2 to 13 years all, 5 of them studied in the lab, 66 at school.

We also pointed out some research problems:

- Provide PLEO with a smart interactive behaviour that optimize engagement and bond building.

- Provide PLEO with cognitive skills to support the psycho-social process of engagement and bonding and to gather data to adjust behaviour and to monitor clinical-related parameters.

- Design a robot-based program compatible and consistent with the hospital care system to enhance the effective and sustainable adoption.

In his experiment we used a pet robot called PLEO rb. It is a commercial robot platform distributed by Innovo Labs with appealing baby-likeness, expressiveness, and an array of different behaviour and mood modes. It is equipped with different tactile sensors beneath its skin, ground sensors in the foot, speakers and microphones. It also features a creature like personality which develops internal drives like hunger or sleep, and several mood modes: happy, extremely scared, or excited. **Fernaeus *et al.*** [**2010**] conducted a long-term studio with 6 families, which were given a robot for a minimum of 2 months and a maximum of 10. Similarly, **Jacobsson** [**2009**] carried out a study based on the opinions of a blog users about PLEO. The main results are related to initial engagement due to the novelty effect, the care behaviours and the long-term disappointment effect. Even so, most of the studies identified the development of a social bond with the robot.

5.4.2 Development

From January to May in 2014 and from February to April in 2015 two ethnographic studies were carried out in Sant Joan de Dééu hospital to investigate:

- How children interact with the robotic-pet in different situations and services.
- Attitudes, perceptions of children, bystanders and hospital staff towards the robot and the deployment process.
- Which Which is the robot role -or roles- in the process of caring inpatient children.
- How the deployment processes have an impact on the organization and how the personnel involved themselves in this deployment **Sabelli *et al.*** [**2011**].

From our perspective, the process of caring is understood as an actor-network in which a network of relations between heterogeneous elements of different materiality are involved **Cejas** [**2014**]; **Llobet** [**2014**]. The in-field work was carried out by a mixed team of engineers and graduated and undergraduate students of the Faculty of Psychology at the Universitat Autónoma of Barcelona. The technique was participant observation and the researchers' camp diaries and the group discussions were analyzed in terms of thick description **Cejas** [**2014**].

In the first study, the team deployed 5 PLEO units in a daily basis in external consultation halls, pre-ambulatory rooms, surgery rooms, waiting rooms, oncology ward and play rooms. The main aim of this exploratory study was observe as much as different situations and contexts as possible to draw guidelines for a systematic intervention.

As a consequence of this first deployment, the volunteers received a donation of 4 PLEOs for the oncology ward and the the robots officially joined the team. The second study was conceived to observe how volunteers personnel used pet robots in their regular assistance to children e.g. the technology appropriation process. However, through the designed technique of observation, shadowing the personal in the situation and the expectancies of the personnel, the research team adopted an active role in the intervention. In this second study robots were deployed in two more services: Day Care Hospital, where chronic disease out-patients receive treatment, and the Ambulatory Surgery Unit.

From the literature and preliminary studies, PLEO's ability to engage children over time like a real pet would benefit from some kind of augmentation (augmented naturalness) to the autonomously displayed behaviour.

Some studies on people-robots relationships reports some drawbacks on PLEO's interactive behaviour such as lack of responsiveness to social requests, lack of contingency to events, changes in behaviour too subtle to be be noticed by non-trained users.

Four degrees of PLEO's autonomy can be deployed when interacting with children in the real scenario of the hospital:

- Full autonomous behaviour according to implicit opaque to users' internal states. PLEO's behaviour is not totally predictable by the user at any time but may be inferred, anticipated or understood by the user according to previous experience in interaction, expectations and social comprehension of PLEOs drives and situation awareness.

- Full autonomous behaviour according to observable internal states: a graphical interface externalize PLEO's internal states that facilitates the understanding and management of the interaction.

- External control of PLEO's states: The coordinator is enabled to modify or control the robot changing the internal states and letting the robot perform the correlative activity.

- External control of PLEO's behaviour: Fully tele-operated control of the movements and actions of the robot. Children's behaviour monitoring.

5.4.3 Results and discussion

Robotic-pets have had the effect of mediators and facilitators of interaction and relationships between the different agents involved in the caring process: inpatients, relatives, bystanders, volunteers and clinical staff, and have to some extent reconfigured the existing pediatric care **Cejas** [**2014**]; **Llobet** [**2014**].

Different roles have been observed along the field work:

- The robot as a distractor: the novelty effect, the compelling appearance and performance of the robot has an effect of absorbing children and bystanders-attention what, as is well known in pediatric emergencies literature- ameliorates 'per se' the management of a stressful situation. **Beran** ***et al.*** [**2013**].

- The robot as an outstanding toy: PLEO's unpredictable behaviour added to its responsiveness to social bids, easily engage children in individual or group play.

- The robot as a companion: PLEO's expressiveness and responsiveness to affection elicits feelings of warmth and concern.

Wireless communication with PLEO rb was implemented via Bluetooth. The proposed solution for this hardware challenge, shown in figure 5.13, is to switch PLEO's battery for a battery-bluetooth package. Distinguishable components are listed below.

- PCB: Its main function is to act as the conductive element between the batteries and the springs that feed the robot. Based on the base of the battery, it must fix the 4 pins that establish contact to the bluetooth output of PLEO.

- Connector pogo pins: Catch the signal that PLEO sends to be processed in the bluetooth module. Bluetooth module: Receives the data signal from the robot and sends it to the connected device. The JY-MCU and HC-05 are two of the cheapest Bluetooth serial port modules in the market, but their provided voltage is not enough. A more sophisticated module is needed, such as the RN-41 microchip.

- Battery pack: PLEO's battery requites a 7.4 V, a charge of 2800 mAh, 20.72 Wh power and can withstand a max temperature of 60 ∞C.

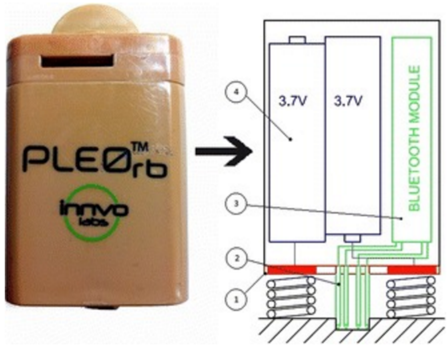


Figure 5.13: Layout of the proposed assembly. Battery pack with bluetooth embedded.

This communication allowed through a graphic interface (Android app) to obtain any state of the robot without stopping its interaction with the patient (see Figure 5.14). Moreover, to sent information to a cloud, so that robot moods, states and interactions can be shared among different robots (more detailed description of the application in **Larriba *et al.* [2015]**).

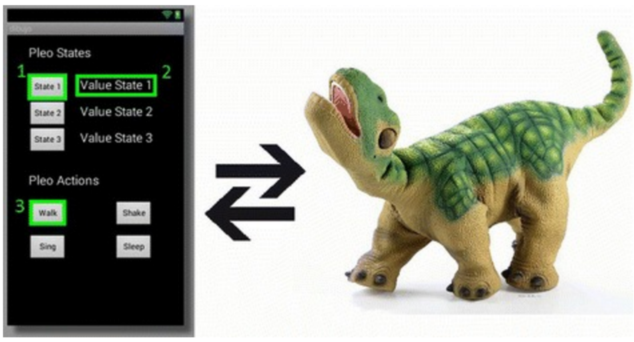


Figure 5.14: First sketch of the interface. First sketch of the Android app.

5.4.4 Conclusions

After deploying the PLEO robot in different rooms within the hospital we were able to understand the best places of deployment. We observed that in consultation halls and waiting rooms was not the appropriate location for deployment due to the large amount of people present. Families and their children had to share the robot and it appeared difficult. On the other hand, in pre-ambulatory rooms, surgery rooms, oncology ward and play rooms were perfect places to have the dinosaur in order to distract the children and give them to have a better experience in the hospital for a short-term interaction. After the study in these last rooms we observed a successful adoption of the robot by the organization of the hospital validating our first hypothesis.

From the technological side we can conclude (not validating our second hypothesis) that after many hours working with PLEO:

- PLEO is not a robust platform. It is common with PLEO that it may during some days not turn on. If PLEO survives for more than 1 month without these boot up issues it should be considered economical since it is affordable.
- PLEO is unable to react to a child's laugh or cry. This is a very important issue because it leads to a child losing interest, and is known that the progress of the therapy is directly proportional to the motivation of the patient. If PLEO does not seem to care for the child, the child will not care of PLEO and the therapy could fail.
- In the future it is desired for the cloud to be able to collect the states of these children (the continuation is the CASPER project) and see how is the interaction in long-term periods.

5.5 Effect of a social robot personalization in terms of interaction with children for educational purposes

5.5.1 Introduction

Academic homework has changed in recent years. It has evolved from written exercises on paper to on-line platforms. These platforms allow continuous communication between the students and the educators; providing useful tools that help routine tasks such as correcting tests or collecting assignments. The idea of this study is part of a bigger project called Robotics@School **Sans-Cope *et al.* [2014]** that aims to introduce the wide spectrum of robotics into schools and homes, from kindergarten to high school levels.

In the past few years, personalization has become a relevant topic because of its ability to provide a better user experience in this era of mass-technology **Jørstad *et al.* [2005]; Sunikka & Bragge [2008]**. In this section we present a study of 20 primary school children (6-7 years old) to verify how personalization, understood as a process that increases personal relevance to a system by altering the distinctiveness of its nature **Blom & Monk [2003]**, combined with social behaviour, increases interaction in child-robot interactions in comparison with robots which did not have these features. In order to personalize the robots we studied the interests of the children and we customized the robots according to these interests. In the following sections more details are given.

We show the results in terms of the interaction time spent on different activities between children with a social behaviour and personalized robots, and those robots without these features, and how the interaction is maintained over time.

5.5.2 Development

We planned a study in a school with 60 primary school children (aged 6-7 years old) carrying out educational activities with the same robotic platform for at least two weeks. In order to personalize the robot we sent a letter to all parents to explain the study, to ask permission for their children to participate in it, and to ask about their children's interests. 46 of 60 families agreed to participate so we randomly split their children into two different groups: 23 children with 23 robots personalized with a social behaviour and 23 children with 23 identical robots without those features. Thus, the following are our hypothesis:

- (1st) hypothesis declared that a social behaviour manipulation and a personalization of a robot could establish a different interaction, in terms of time, in comparison with those robots where a social behaviour and a personalization was not applied over two weeks.

- (2nd) hypothesis declared that a social behaviour manipulation and a personalization of a robot could establish a different maintained interaction, in terms of different total amount of time between the first and the second week, in comparison with those robots where a social behaviour and a personalization was not applied over two weeks.

All these children's interests were collected from a single survey completed by their parents (hidden from children's knowledge in order to make it more surprising for them when they interacted with the robot) who were asked about hobbies, preferences of cartoons, sportsmen, food, animals, favourite places for vacations, etc. **Reeves & Nass** [**1996**]. In addition, the interaction was reinforced with different strategies, increasing the level of social behaviour of the robot, to create complicity such as social dialogue, self-expression, emphasizing commonalities, talking about the past and future together, continuity behaviours (appropriate greetings and farewells), and reference to mutual knowledge, as well as explicit messages to boost confidence **Bickmore** [**2003**], and also secret-telling **Kanda *et al.*** [**2007**] through a recorded female voice and shown on a screen from the information from the surveys. Each personalization was reviewed and renewed once per week.

Children received training sessions on how to use the robot. They also received a basic manual on how to proceed to start and stop the robot and to solve the common unexpected issues that could occur just before bringing the robot home, where they would be interacting with it in a non-guided situation. We had a total of 12 robots so we decided to split the children in 4 groups of 12 (6 with social behaviour and personalization and 6 without anything). The study took 8 weeks and each one of the 4 groups did the activities with their robots for a long-term interaction of 2 weeks (see Figure 5.15). Each group created a common set of activities at home with their robots during the weekdays (the robot was programmed not to be used for the weekend), starting on Monday. The following Monday the technician and the teacher set up another weekly set of activities for everybody and they also reviewed personalization for half of the children. Every Monday the technician downloaded data on the use of robot to monitor the duration of their interaction and to draw some conclusions. Exceptionally the last group were allowed to keep the robot for a few more days.

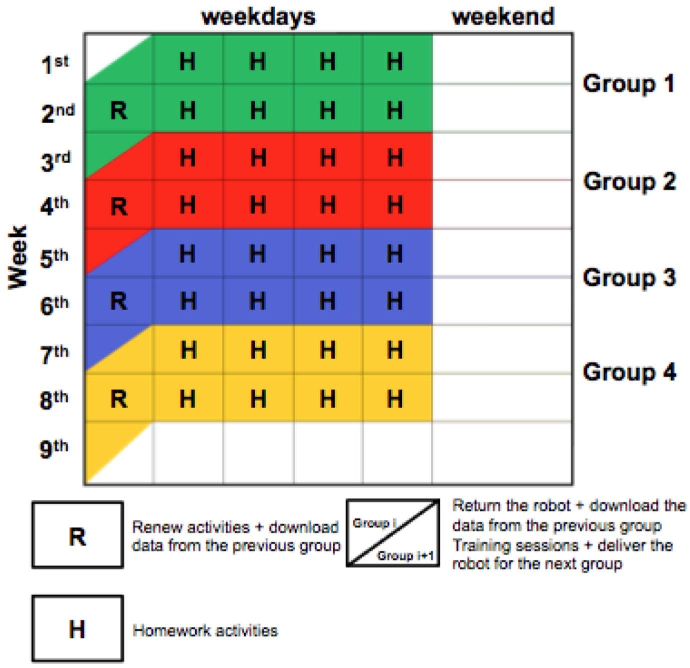


Figure 5.15: Schedule of the study.

The main structure of the robotic platform is the same we presented in Section 4.2. It consisted in a LEGO Mindstorms®. LEGO®, which has lengthy experience in children's toys, turns out to be a multidisciplinary tool that enhances child' motivation. The robot is composed of a LEGO Mindstorms® NXT 2.0 attached to an iPod, plus extra hardware that enhances the connectivity of the robot. The architecture of the robotic platform and its appearance is presented in Figure 5.2. The design idea of the robot comes from a previous work **Barco *et al.*** [**2013**] (see Section 4.2) where this platform was used in a rehabilitation program for children with TBI under a project to compare a rehabilitation program through robotics (1) with a conventional rehabilitation program directed to parents (2) and a control group where no specific intervention was done (3). Children from the school did the same type of activities as the children with a brain trauma based on the idea of **Doman** [**1963**] who began to extend his teaching to help the parents of normal children stimulate their child's' brain and help them reach their potential as human beings, in the same way as brain-injured children.

Two type of activities were conducted by the robot: a basic set for academic purposes, habits and caring skills, and a social behaviour and personalization set only available for half of the children.

Basic set

Academic activities these activities were designed together with a group of neuropsychologists based on the original goal of the robot **Barco *et al.* [2013]** and reviewed by the teachers of the school. They were composed of exercises focused on language, problem solving, maths problems, or memory exercises such as the one shown in Figure 5.16, and classified into three levels of difficulty in order to suit the children profile. To perform some of these activities the children had to use the touch sensors (see Figure 5.2) as a way to interact with the robot. For instance, Figure 5.16 shows the screen for an activity consisting of a sequence of pointing arrows that the child had to repeat to the right or to the left in reverse order that had previously been presented on the screen, therefore the touch sensors were the buttons the child had to press. In another activity when the robot whistled once the child had to push the touch sensors in a certain order, but if the robot whistled twice then the child had to push the touch sensors in a different order.

Figure 5.16: Memory activity.

There were other types of activities with complementary material; a set of pieces made with cardboard that allowed the child to build a maze. Thus, they had to organize all the pieces in order to build it. Once they had built it, they had to solve it by driving the robot as if ti were a haptic device to the exit (see example in Figure 5.17). A similar activity that could be done with these pieces was the game called Sokoban where they had to build the maze but with an obstacle in one of the paths that they had to move in order to find the exit. In both groups the same academic activities were assigned in the same order. In both groups the same academic activities were assigned in the same order.

Figure 5.17: Robot used as a haptic in order to solve a maze.

Many of the activities were designed as real-life situations, the so-called ecological activities. Depending on how they performed the activities the robot moved in a different way. If they obtained high scores the robot would make a cheering action followed by a funny song, on the other hand if the score was low the robot would not move and would play disappointing sounds. Therefore, it was not only an interaction with a display, it was also an interaction with the physical robot with the strengths mentioned before **Piaget & Inhelder** [**1969**].

Caring skills and good habit activities these activities were based on imitating pet behaviour and a food habit functionality. The pet functionality sets up an emotional state **Fellous** [**2004**] for the robot depending on the battery level of the iPod and the scores from the activities (see Figure 5.11):

- Sad state (blue face): iPod battery level more than 30%, and a success rate of less than 75% in the average of the all activities.

- Happy state (yellow face): iPod battery level more than 30%, and a success rate of more than 75% in the average of the all activities.
- Sick state (green face): iPod battery level less than 30%, and a success rate of less than 75% in the average of the all activities.
- Angry state (red face): iPod battery level less than 30%, and a success rate of more than 75% in the average of the all activities.

Every time they played with the robot the state could vary depending on how they performed with the activities (scoring) and depending on the battery level. Children could identify the different emotional states due to the different colours of the faces and with the basic manual that they had received during the training sessions, which showed each face with its correspondence emotional state. This functionality worked the child's responsibility so they had to be aware of the robot's emotional state and take care of it, and this improved the sense of engagement.

On the other hand, the food habit functionality was based on a view with different dishes of food (pasta, vegetables, hamburgers, etc.), to let the child feed the robot and later see how the behaviour and health of the robot changed in a fat or slim character or in the speed of the robot's movements. For instance, if a child was feeding the robot with French fries, hamburgers and ice cream the robot's movements were very slow, on the other hand if a child was feeding the robot with a salad, fish and fruit, the robot's movements were much faster. It is all about trying out healthy habits (see Figure 5.18).

Personalization and social behaviour set

Half of the children of the study had a personalized robot with social behaviour. The personalization was based on the information we obtained from their parents through surveys, on the other hand children without the personalization did not have this programming and they only had the basic set. We took advantage of that to create more complicity with the robot by giving it the same interests as the child. For instance, if the child liked Sponge Bob, the robot told him secrets about his favourite cartoon which was also Sponge Bob. These personalized aspects appeared through opening views, before starting the

Figure 5.18: Two different menus and the consequences with a slim character or a fat one.

academic activities and right after finishing them with short written messages readable by a 6-7 years old child since in this school they teach reading at the age of 5, therefore children were able to read without any problems. These messages appeared every time the child wanted to play the activities and also with a female voice from the speaker of the iPod increasing the social behaviour. The personalization was not only based on messages but also on images to increase interaction over time. For instance, in Figure 5.19 the personalization was based on the Barcelona football team as we can see on the left of the image with a message before academic activities encouraging the child to play, the central image is about either finishing the activities or repeating them, and the image on the right was based on the Doraemon character for the post-activity message right after finishing the academic activities with farewell messages and waiting to see him/her the following day. All these strategic tricks were different every day and renewed every week.

Apart from personalized messages or images, the personalized robots had amusing greetings which indreased the robot's social behaviour before beginning the activities **Bickmore** [**2003**] including the name of the children such as: "Come on Jordi, you'll do it great!, Wanna play, Jordi? Have fun!". And at the end of the activities: "How was the game, Jordi?, Hope you had fun!". The robot also said confidence-building sentences like "I love the way you play!, You are the best!", sentences about past and future together like "Looking forward to playing

Figure 5.19: Personalized views where all messages were in Catalan.

with you tomorrow!, Have a nice weekend, Jordi! See you on Monday! How was your weekend? I hope it was fun!", and sentences to emphasize commonalities like "I love Bob Sponge like you do, and I am also a fan of Barça!".

During the weekdays (the robot was programmed not to be used at the weekend) the child was able to play with the robot when s/he was back home after school. Through counters programmed in the robot we could see how long the child was playing with the academic set of activities. There were two types of procedures depending on the group:

Group without social behaviour and personalization

as we can see on the left of Figure 5.20 the child could choose between the option of the academic activities (e.g. math, language, memory, etc.) or caring skills and good habit activities to start with. If the child chose the academic activities the time counter started. Once all the activities programmed ended there was an option to repeat them. If the child wanted to repeat, they had to do the activities again, if not, the counter stopped and everything was finished. However, they could start again by choosing the academic activities and the playing time was added to the previously counted time. On the other hand they could choose the caring skills and good habits activities where they could interact with the functionalities mentioned before.

Group with social behaviour and personalization

as we can see on the right of Figure 5.20 the child could choose between the academic activities (e.g. math, language, memory, etc.) or caring skills and good habit activities. If the child chose the learning skills activities a personalized view was prompted with all the social behaviour and personalized messages we mentioned before. After that, the activities and the counter started. Once all the activities programmed had ended there was an option to repeat them. If the child wanted to play more, s/he had to do the activities again, if not the time counted stopped and was followed by a social behaviour and personalization view, and everything was finished. However, they could start choosing the academic activities again. On the other hand they could choose the caring skills and good habit activities where they could interact with the functionalities mentioned before.

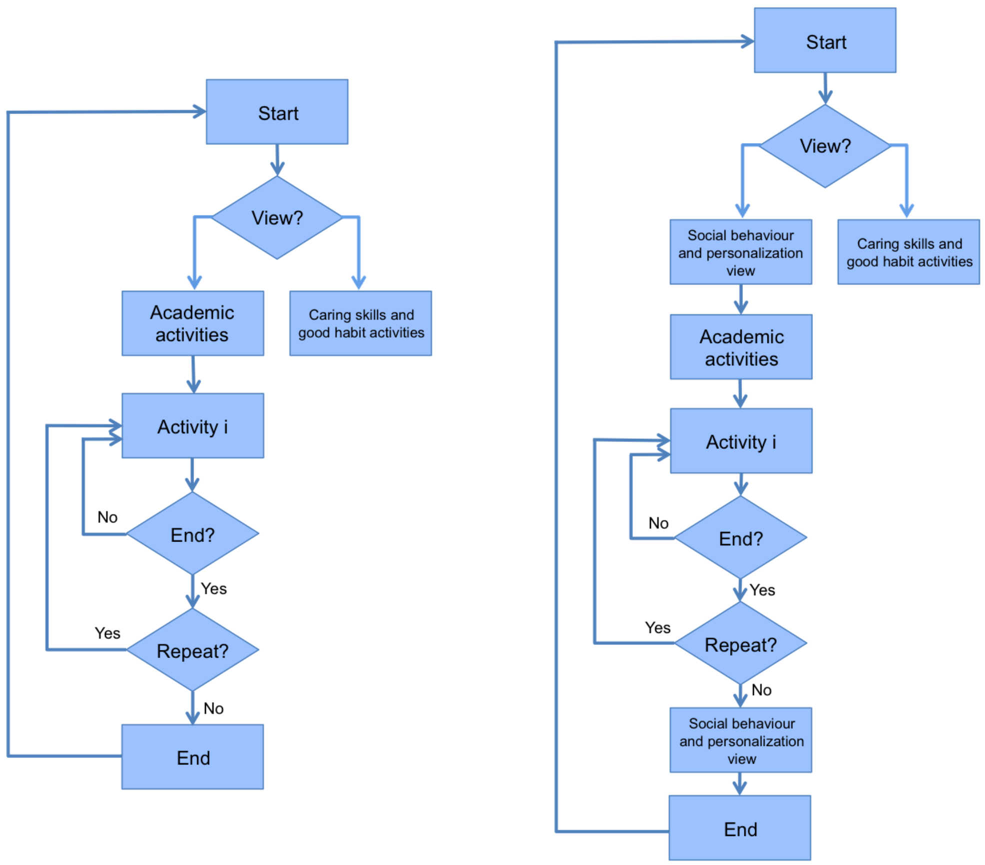


Figure 5.20: The procedure with and without the social behaviour and personalization.

	Gender	Average minutes/day of use Week 1	Week 2	Total average minutes/day of use
With social behaviour and personalization	boy 1	10.48	12.47	11.90
	boy 2	7.68	24.85	16.27
	boy 3	17.43	10.21	14.33
	boy 4	25.12	23.60	24.51
	girl 1	28.53	14.13	19.89
	girl 2	28.33	12.40	24.35
	girl 3	27.17	15.25	21.21
	girl 4	17.94	10.17	14.49
	girl 5	15.16	18.87	15.90
	girl 6	5.43	11.57	8.50
	girl 7	22.86	13.46	18.16

Table 5.7: Individual time of use with social behaviour and personalization.

5.5.3 Results and discussion

We started the study with 46 participants but only 20 children completed it successfully because in some cases there were problems downloading the data from the robot, or problems with the robot, or children who did not play with it in either first week or second week.

In the end the group with social behaviour and personalization had 11 participants (4 boys and 7 girls) and the group without anything had 9 participants (8 boys and 1 girl). We treated all data anonymously. We analyzed both groups considering the average time per day of use for the first week and the second week, and the average total of time in both weeks (see table 5.7 and table 5.8). We obtained all this information from the counters programmed in the code of the robot. Every time the child played we registered it and when the child brought the robot to the school the technician downloaded all the data.

First we applied the Modified Thomson Tau Test **Cimbala [2011]** to find outliers in our data set and we observed how the boy 5 was clearly an outlier during the first week (with $\alpha = 0.05$ or even lower up to $\alpha = 0.008$), which was the reason why we removed him from the study leaving 19 participants in total.

The group with social behaviour and personalization (GSB&P) used the robot during an average time of $\overline{x} = 18.74$ minutes per day the first week with a standard deviation of s = 8.36 minutes, and $\overline{x} = 15.18$ minutes per day the second week with s = 5.09 minutes. On the other hand, the group without social behaviour

	Gender	Average minutes/day of use Week 1	Week 2	Total average minutes/day of use
Without social behaviour and personalization	**boy 5**	**42.38**	**7.97**	**19.44**
	boy 6	21.39	9.03	18.30
	boy 7	5.83	11.08	7.58
	boy 8	23.47	10.56	17.01
	boy 9	19.84	13.32	16.58
	boy 10	6.83	3.58	5.38
	boy 11	7.04	7.45	7.26
	boy 12	12.27	23.23	17.75
	girl 8	7.30	14.65	8.52

Table 5.8: Individual time of use without social behaviour and personalization.

and personalization (GwSB&P) used the robot during an average time of $\overline{x}$ = 12.99 minutes per day the first week with s = 7.41 minutes, and $\overline{x}$ = 11.61 minutes per day the second week with s = 5.82 minutes. If we do the same with the total average minutes per day in both weeks GSB&P scored an average of time of $\overline{x}$ = 17.22 minutes with s = 5 minutes, and GwSB&P scored an average time of $\overline{x}$ = 12.29 minutes with s = 5.55 minutes. See boxplots in Figure 5.21.

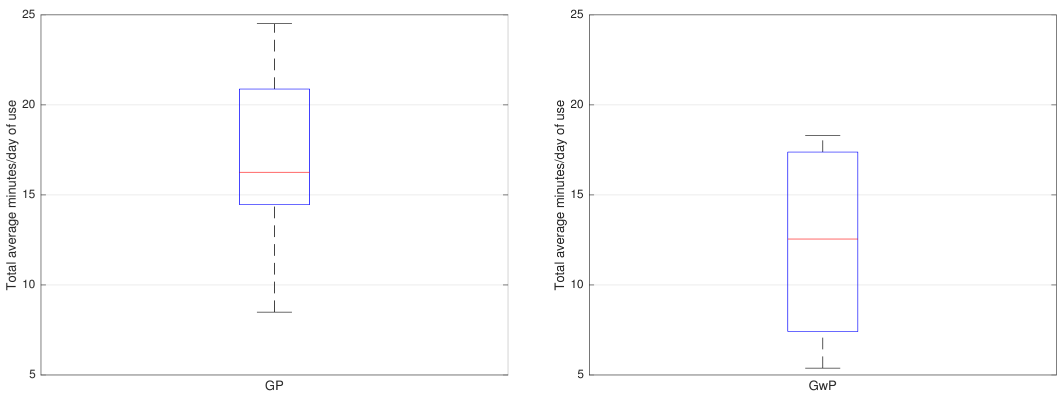


Figure 5.21: Boxplots with the median and the interquartile range of both groups.

We also applied the Shapiro-Wilk test to study the normality of the remaining data. In this sense the p-value for the GwSB&P was only p = 0.044 which was lower than the common $\alpha = 0.05$, although close to it. On the other hand there was no problem with the normality of the GSB&P data. Due to the normality of the data for the GSB&P group and the fact that the data for the GwSB&P are close to the normality, we applied an unpaired t-test. In this case, as we do not have strong criteria to use the one-tailed unpaired t-test and being up to date of the controversy between the use of the two-tailed test and the one-tailed test **Kimmel [1957]; Ruxton & Neuhäuser [2010]**, we chose the former for our study. In this sense the null hypothesis was that the GSB&P and the GwSB&P played the same time in total average minutes per day while the alternative hypothesis was that the GSB&P and the GwSB&P played different.

The test with a pooled estimator of common s2 = 27.45, test statistic (t0) = 2.02 and p(t0> 2.02) +p(t0<-2.02)= 0.059 greater than the common = 0.05 showed that we could not reject the null hypothesis. In fact the confidence interval for the differences between means with inclusion of 95% was [-0.02,10.06]. Furthermore we also ran the Mann-Whitney U test as it does not require the assumption of normal distributions. In this sense the distributions in both groups did not differ significantly (U=26 higher than U=19 for n1=11, n2=8, α=0.05, two-tailed). Although there were no strong evidences from these results to conclude that the GSB&P played more than the GwSB&P, there were slightly evidences showing that there could be some kind of effect there.

In order to validate the (2nd) hypothesis in the study we also ran a two-tailed unpaired-t test where our null hypothesis was that both groups GSB&P and GwSB&P had the same maintained interaction in terms of different time between the first and the second week, and the alternative hypothesis was that the GSB&P had a different maintained interaction in terms of different time between the first and the second week, in comparison with the GwSB&P. For the first week, the test with a pooled estimator of common $s^2 = 63.79$, test statistic (t_0) = 1.55 and p(t_0> 1.55) + p(t_0<-1.55)= 0.14 much greater than the common $\alpha = 0.05$ showed that we could not reject the null hypothesis and conclude that the GSB&P and the GwSB&P had a different maintained interaction. If we do the same for the second week, the test with a pooled estimator of common $s^2 = 29.25$, test statistic (t_0) = 1.42 and p(t_0> 1.42) + p(t_0<-1.42)= 0.17 much greater than the common $\alpha = 0.05$ showed that we could not reject the null hypothesis and conclude that the GSB&P and the GwSB&P had a different maintained interaction. In conclusion, we could not see any significant results after applying the test, so we could not state any conclusion or validate our (2nd) hypothesis.

The important contribution of this study is that the interaction between children with a social behaviour and personalized robots and those ones where a social behaviour and personalization was not applied was slightly different in terms of average time per day of use in both weeks. These findings suggest that participants with the social behaviour and personalized robot may interact more time in both weeks than those without anything. If we look at what happened in the total average time in both weeks we can see how these results, when analyzing the longer interaction in the total average of time in the group with social behaviour and personalization, showed slight evidences towards a different interaction. These results reinforce the idea of the potential of robots in education **Cejka *et al.* [2006]; Danahy *et al.* [2014, 2008]; Kanda & Ishiguro [2005]; Kozima *et al.* [2009]; Tanaka [2014]; Tanaka *et al.* [2007]**. Including social behaviour and personalization in the robots implied more time playing with the activities and possibly increasing interaction to engage the child in homework **Han *et al.* [2008]**. On the other hand we could not validate our (2nd) hypothesis in our study, where a social behaviour manipulation and a personalization of a robot could establish a different maintained interaction, in terms of less decreased time between the first and the second week, in comparison with those ones where a social behaviour and a personalization was not applied over two weeks due to the low significance of the results. According to the results we cannot state whether we are beyond the novelty effect ((A) Acquaintance stage) in Levinger's model **Kelley *et al.* [1983]** but what we could see is that presumably we are moving from stage (A) to stage (B). Perhaps, we are limited by the duration and by the small sample of the study. For further analysis with the data raw we worked with, researchers can take a look on Table 5.9.

Other studies, as we mentioned previously, based the personalization on other strategies **Andrist *et al.* [2015]; Belpaeme *et al.* [2012]**, but we focused on the interests of the children **Henkemans *et al.* [2013]; Janssen *et al.* [2011]** and through this we adapted some of the robots to this. We also used other strategies based on the maintenance of human-human relationships **Stafford & Canary [1991]** providing the robot a social behaviour as the work done by Kanda **Kanda *et al.* [2007]** in human-robot relationships for long-term interactions. All this social behaviour was included within the activities in all robots.

		Week 1					Week 2				
		Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**
With social behaviour and personalization	**boy 1**				10.53	10.43	10.20	20.45	10.1	10.56	11.03
	boy 2					7.68	24.85				
	boy 3	35.55	22.25	6.48		5.41	12.30		9.96	8.34	
	boy 4	51.06		7.09		17.18	12.21				34.98
	girl 1			27.91		29.15		19.28	12.38		10.73
	girl 2			11.08	37.08	36.81	12.40				
	girl 3			28.86	36.25	16.4	13.23			17.58	14.93
	girl 4	21.33	38.91	7.99	14.38	7.06	9.85	10.21	10.45	10.15	
	girl 5	9.05		13.35	31.7	6.53	18.86				
	girl 6		5.61			5.23		11.26		11.86	
	girl 7		17.13	34.25		17.18		23.03	9.8	7.53	
Without social behaviour and personalization	**boy 5**			42.38				6.36	9.58		
	boy 6			5.26	46.81	12.08	9.03				
	boy 7	5.40			6.25		11.08				
	boy 8		22.80	22.5	25.11		10.26	11.08	10.31		
	boy 9		14.58			25.1			8.96	17.68	
	boy 10	8.61	6.31	5.73	8.70	4.76	3.91	3.03	4.35	3	
	boy 11	13.16	5.53	4.90	4.55		9.18	7.46	6.61	7,38	6.58
	boy 12	12.26					23.23				
	girl 8	8.13	5.35	6.76	10.01	6.21	14.65				

Table 5.9: Data raw from each child with minutes played day by day.

All the social behaviour and personalized messages were written on the screen and were also vocalized loudly through a female voice. Our robot did not have a speech recognition therefore the child could not speak back to the robot, however, in any case we were not formulating a question, it was only amusing greetings messages (among others) in order to avoid an answer and a possible corresponding frustration because of that. In addition all these messages were each week manually renewed each week, changing the programming code for each child, a task which took up a lot of our time.

5.5.4 Conclusions

Overall, in this section we presented an educational robotic tool to help children at homework time and to see interaction changes with a social personalized robot in a two-week interaction. These results would help on long-term interactions between children and robots and therefore, it could be useful in the effectiveness of those treatments that use social robots for children with special needs.

Chapter 6

Conclusions and Future Lines

6.1 Conclusions

This thesis was challenged with 4 different studies. Each study is quite different from the others although they all share many common features. All of them use social robots and for all of them the final goal is try to improve the effectiveness in their treatments. We targeted our efforts with children with ASD, with children with a TBI and children who are hospitalized. In our fourth study we tried to study how we can improve the interaction between a social robot and a child and thus, improve the effectiveness of a treatment for future projects.

In this dissertation, working with a multidisciplinary group was also challenging (and very inspiring at the same time) and our team from La Salle, all engineers, had to learn to deal with people with completely different backgrounds: nurses, physicians, psychologists, neuropsychologists, designers, lawyers, mathematicians, school teachers, etc. From this interaction we could design the activities and intervene more effectively with different children's profiles.

We started investigating how the robotics could improve the social skills for children with ASD and we raised the following question: *Is the treatment with a robot-based activities designed in a program of social skills training for children with high and low functioning ASD feasible and effective?* High functioning: We could conclude that the intervention group and comparison group, experienced an improvement in their social skills by the end of the program (e.g. sharing interests between them, engage in conversations more easily, have fun all together).

During robotic activities we observed in children motivation, engagement and commitment to the activity and a participatory and active attitude (e.g. building, programming, and playing with the robot). Low functioning: We could conclude that designing activities for this kind of profile of children is very challenging. This profile is very wide, and from one child to another the feasibility and the effectiveness can be very different. However, the therapists adopted this technology as a very helpful tool for them. In this study we also tried to answer another research question: *Can the preferences of the children help make funnier activities and thus, have a better impact on child's behavior?* High functioning: At the end of each session we were left asking what they wanted to play in the next one, what they preferred. We were taking notes about that and we were playing that game for the next session. As a result, they were more motivated and moreover they felt involved during the sessions. In addition, we tried to answer this final question: *Is the treatment engaging during therapy for those children with high and low functioning ASD?* The response we got from high functioning and low functioning: children was very good. They felt very attracted from the beginning for the different robots we introduced to them. We are still working from videotaped data in order to proof with accuracy the engagement with the activities and also, the feasibility of our interventions.

Later on we performed a long-term study to compare a rehabilitation program through personal robotics and a control group with a sample of 26 children with moderate or severe brain injury. But *Does the designed social robot was enough feasible, appropriate and robust during the neuropsychological treatment for children with TBI?* From the results in section 5.3 we can conclude that the designed platform could accomplish our expectations from the hypothesis. On the other hand, we have still to work in the robustness of the robot due to some broken wires during the interaction. *Can the treatment with a social robot have a better performance on cognitive functions, especially in tasks related to executive functions, after 6 months?* From this study we concluded that results suggested effectiveness in neuropsychological treatment through robotics; it acted as a helpful tool in those areas affected by TBI.

We also did research on a robotic-pet based intervention integrated to the child life program in a pediatric hospital. One of our research questions was: *Was the*

PLEO appropriate and enough interactive for the study?. There is still a lack of interaction in this platform, we need a more engaging tool for the users. Apart from this we need a more robust robot, the life-time is not more than a month when intensive intervention. The other research question on this study was: *Could the PLEO be engaging and enjoyable for a wide array of children profiles and situations during hospitalization and have an effect on children quality life and a good effect on the staff of the hospital?.* After performing the study we could conclude that the PLEO robot could work as a distractor and as a companion, and the robot was a very useful tool due to its unpredictable behaviour added to its responsiveness to social bids, easily engage children in individual or group play. Some of the staff from the hospital easily adopted this technology during their daily tasks in order to distract the children in different stressful and boring situations.

Lastly but not less importantly, we raised another research question: *Could a social behaviour and personalization increase and maintain the interaction between a social robot and a child over time?.* With the same robotic platform used for the rehabilitation of children with TBI and now used for children of a primary school for an educational purpose we concluded that results suggest a different performance in the group with social behaviour and personalization, in terms of continued interaction with the robot. With this result we could improve our robotic tool in order to enhance the interaction between the child and the robot for future projects and thus, maybe increase the efficiency in our treatments. If they spent more time playing with the robot the treatment could be more successful.

The results of this dissertation supports the possibility of using social robots as an agent to help children with special needs in their treatments. Knowing the preferences and likes of the children could allow us to personalize the activities or the robot behaviour in order to have a better interaction and maintain it over time, and maybe increase the effectiveness of the treatment for future studies. However, the number of participants was low, therefore more studies need to be conducted to asses whether the same results apply to other settings or are maintained.

We also used different type of analysis depending on the study. If we are talking about the project of autistic children we can conclude that the qualitative results we used for this kind of experiences are the ones that suit better. In a 6 month period of time with 1 hour intervention every 2 weeks, a quantitative result is not appropriate. Through different behavioural tests it is very difficult to conclude anything, therefore a qualitative study was applied. If we talk about the TBI project we presented quantitative results based on different neuropsychological tests. In our opinion we also think that a qualitative study gathering data from the opinions of the parents and the children could have been very interesting for our study. The study with hospitalized children was very exploratory so we looked for qualitative results. Finally, in the study with neurotypical children we wanted to draw some conclusions on the interaction time, therefore, quantitative methods worked better. In summary, in the different type of analysis that we used we can conclude that when you are in social sciences a qualitative approach can help to better understand what happened. On the other hand, quantitative analysis are very useful when you are trying to measure certain things, those things that are in fact measurable. If we talk about measuring how social skills through tests are changing over time it is very difficult to do this. When you want to study how the interaction time changes in a certain period, a good way to do it is with quantitative analysis and then applying different statistical analysis. Finally, if you want to complement it with a qualitative analysis it can add value to the study.

Children are amused by robots and we have to take that as an advantage to using and enhancing their potentialities in order to help them in those situations that are more difficult when we are talking about a rehabilitation. Robots are examples of systems that are expected to work in an autonomous or semiautonomous way to deliver useful services for the well-being of humans, but also in those situations that can be viewed as boring, such as when they have to do the school homework.

On the other hand, we can see the robots as an advantage when they are seen as tools that can be useful for diagnosis, monitoring, and alerts, as well as treatment suggestions by the physicians. Furthermore, as new medical sensor technology is developed, these medical devices can be integrated with the robot for more versatile care settings. In addition, it can save a lot of time and a lot of resources in hospitals as they can do repetitive tasks on which the physicians do not wish to waste their time.

Overall robots are engaging for children and they have an added value when they can provide useful strategies for the physicians, nurses, therapists, psychologists, teachers, parents, etc. and always in a non-intrusive way, where they can use these robots as another tool perfectly compatible with their traditional methodologies. But I think the most important thing we have realized during this 5 years of studies and observing many children is what we learned from one of the therapists (Vanesa Padillo): **children have to have fun**. As roboticists we do not have to lose sight of this lesson, the most important is a good interaction with the final user, in our case, all these projects involved the children. Having fun is the best therapy, the best rehabilitation program a child could have. If they have a great time interacting with the robot, this is the baseline to move forward for the next step in your rehabilitation/therapy/education.

6.2 Future Lines

There are some open issues that demand further research that could improve the ideas presented herein. These future work directions are presented thereafter following the studies shown in dissertation.

- Design, implementation and evaluation of a social skills group program of robot-based activities for children with ASD

  Future research lines could include:

  - A documentation of activities so that practitioners could have a guide that allows them to use resources in a completely autonomous and independent mode, making unnecessary the technician/engineer intervention during the activity. We want to adapt this new technology to their needs and profiles in order to make them feel comfortable in the use during the therapy.
  - Parent Training Courses, which are offered information, resources and strategies on using technological supports to implement specific ap-

plications at home to improve learning, communication and leisure opportunities and relationship of the children with ASD.

- Develop social interaction with non-disabled peers. This would lead to more insight as to how social skills can be improved in a more natural environment with a mix of children with and without ASD.

- Effectiveness of a long-term rehabilitation program through robotics in children with Traumatic Brain Injury

  This cognitive rehabilitation program can be adapted for the treatment of different brain pathologies in the future. While TBI was the focus here, we believe this layout can be implemented in other ways. The long term cost savings of neuropsychological rehabilitation suggests that it may be helpful to implement in other public hospitals. It is capable of halting the deficit of skills of these children, as well as future economic, and social costs for the families. The application of rehabilitation treatments based on new technologies, like robotics solutions in this study, may allow treatment of more patients simultaneously in rehabilitation settings, always supervised by a therapist. It may also reduce hospital waiting lists, help with further facilitation of cognitive rehabilitation at home (not only limited to weekly sessions in the hospital/centre), and minimize short and long-term cognitive impairment; all of which is necessary for improving functional prognosis of these patients.

  From a technological perspective, the use of the robot presented minor problems. Furthermore, parents of children had a permanent contact with the engineers via email and telephone call in order to solve problems with the robot. Nevertheless, a few problems occurred with the communication between the iPod and the LEGO, reason why in a near future we will implement a communication via bluetooth, avoiding electronic issues such as broken wires. In addition, we will program more activities and we will work on different ways to improve the engagement between the children and the robot.

- Pain and Anxiety Treatment based on social Robot Interaction with Children to Improve pAtient experience (PATRICIA)

Based on the ethnographic studies and the technical developments our next challenge is to carry out a study in the hospital to:

- Observe systematically the interactive behaviour with PLEO and the dynamics of bond forming.
- Assess the effect on children in terms of therapy related outcomes such as well-being, anxiety, perception of support, optimism.
- Design internal states and PLEO interactive behaviour to enhance the beneficial effects of PLEO's company.
- Increasing and maintaing a child-robot interaction through personalization for an educational purpose

From the mentioned above and from the results and the problematics of the PLEO robot we have started the project called CASPER (Cognitive Assistive Social PEt Robots for hospitalized children). This project is conformed for a team of multidisciplinary professionals having as main objective to add value to the research results and experiences on cognitive assistance for hospitalized children using social pet robots. CASPER is a Cognitive Assistive Social PEt Robot. It is cognitive in the sense that it is able to capture information from the interaction with the environment; assistive because it will be assisting children; in fact, socially assisting children because it will be working on social aspects of the intervention; and a pet robot since this is the shape that it will take. It will be primarily a robot designed for hospitalized children, having in mind a broader scope of scenarios, including caring environments, pedagogical units, educational institutions and home, for engaging particular parents-children interactions.

- Effect of a social robot personalization in terms of interaction with children for educational purposes

  This study is limited by the generalisability of the results. The sample size is 20 children between 6-7 years old therefore the results may not translate to an older population in the community where these educational robots may be useful in the future.

Further effort will be dedicated to developing a personalized software on the interests of the children and renewing the views, the voices, and everything to keep the personalization going along the interaction between the child and the robot. Future studies could be conducted with a larger sample over a longer period of time, and taking into an account the possible differences between genders.

If we mention a general future line we can talk about the analysis. We have to find somehow the right balance between quantitative and qualitative results. Our methodology has to become very rigorous combining both of them. A big part of the community is demanding quantitative results but our studies which involve social sciences are very qualitative. For this reason it is very important a trade off between quantitative and qualitative methods.

List of publications

1. Díaz, Marta, Alex Barco, Judit Casacuberta, Jordi Albo-Canals, Cecilio Angulo, and Carles Garriga-Berga. "Robot Assisted Play with a Mobile Robot in a Training Group of Children with Autism", paper presented in iHAI Workshop IROS, 2012.

2. Heerink, Marcel, Marta Díaz, Jordi Albo-Canals, Cecilio Angulo, Alex Barco, Judit Casacuberta, and Carles Garriga. "A field study on perception of social presence and interactive behavior with a pet-robot with primary school children", paper presented at the IEEE RO-MAN: The 22nd IEEE International Symposium on Robot and Human Interactive Communication, 2012.

3. Barco, Alex, Jordi Albo-Canals, Miguel Kaouk Ng, Carles Garriga, Laura Callejón, Marc Turón, Claudia Gómez, and Anna López-Sala. "A robotic therapy for children with TBI", paper presented in Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction, pp. 75-76, 2013.

4. Albo-Canals, Jordi, Marcel Heerink, Marta Díaz-Boladeras, Vanesa Padillo, Marta Maristany, Alex Barco, Cecilio Angulo, Ariana Riccio, Lauren Brodsky, Simone Dufresne, Samuel Heilbron, Elissa Milto, Roula Choueiri, Daniel Hannon, and Chris B. Rogers,. "Comparing Two Studies with LEGO Robotics-Based Activities in a Social Skills Training Program for Children

with ASD", paper presented at the IEEE RO-MAN: The 22nd IEEE International Symposium on Robot and Human Interactive Communication, 2013.

5. Angulo, Cecilio, Cristóbal Raya, Carles Garriga-Berga, Marta Díaz, Jordi Albo-Canals, Alex Barco, Jaume Campistol, and Vanesa Padillo. "Social Skills Training With Robots For Children´ s Education", paper presented in Workshop on Ambient Intelligence for Telemedicine and Automotive., pp. 29-30, 2013

6. Barco, Alex, Jordi Albo-Canals, and Carles Garriga-Berga. "Engagement based on a customization of an iPod-LEGO robot for a long-term interaction for an educational purpose", paper presented in Proceedings 9th ACM/IEEE International Conference on Human-Robot Interaction, pp. 124-125, 2014.

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Appendix A

Appendix

Some information is included from the work done in Hospital Sant Joan de DÈu with children with high functioning autism and CASPAN with children with low functioning autism.

Actividades con robots LEGO en un programa de habilidades sociales para niños con TEA.

Investigador principal: Marta Maristany
Investigadores colaboradores: Jordi Albó; Alex Barco; Marta Díaz; Vanesa Padillo y Lina Rosa.

INTRODUCCIÓN

La Unidad Especializada en Trastornos del Desarrollo (UETD) del *Hospital Sant Joan de Déu* está dedicada de forma específica al diagnóstico, al asesoramiento a personas y familias afectadas de Trastornos del Espectro del Autismo (TEA), a la formación de profesionales y a la investigación en el ámbito del autismo.

El término de Trastornos Generalizados del Desarrollo-TGD utilizado en el DSM-IV (*Diagnostic and Statistical Manual of Mental Disorders, American Psychiatric Association, 1994*) y CIE 10 (*International Statistical Classification of Diseases and Related Health Problems, OMS, 1992*) ha evolucionado hacia una comprensión dimensional de los problemas de comunicación, socialización y simbolismo bajo el nombre de Trastornos del Espectro del Autismo (www.**dsm5**.org).

El aumento gradual de la prevalencia de personas con dificultades dentro del Trastorno del Espectro del Autismo, actualmente estimado en 1/88 (*Centres for Disease Control and Prevention*, 2012), junto con la aparición de nuevas tecnologías en nuestra sociedad, convierte en prioritaria la investigación en el uso de las mismas en el tratamiento de personas con TEA.

En el área de la adquisición de habilidades sociales, existen investigaciones pioneras que indican que los robots pueden actuar como facilitador social (Dautenhahn, K. 2002).

Objetivo
Desarrollar un programa para ayudar a los niños con Trastornos del Espectro del autismo basado en actividades con un robot LEGO.

Supuestos

- Jugar con un robot – LEGO puede ser beneficioso para niños con TEA, puede facilitar la adquisición y el entrenamiento de habilidades sociales.
- Para que el uso de robots sea efectivo debe ser un facilitador de la participación (engagement*) de los niños en las actividades propuestas en el grupo.
- Algunas características y conductas del robot le hace adecuado para provocar conductas sociales apropiadas en niños con TEA.

* Se puede definir este constructo en dos dimensiones: i) Adhesión a alguien o algo como un estado psicológico o social relacionado con emociones (sentimientos de pertenencia, preocupación por el bienestar del otro, empatía y voluntad de estar con otros) implica cierto nivel de percepción social /capacidad de atribución de estados mentales y ii) Engagement más relacionado con actividad (Voluntad de mantener interacción, disfrute, satisfacción, inmersión). Ambos pueden ser medidos y/o identificados gracias a técnicas subjetivas (autoregistros) u objetivas (conducta observada) o con una combinación (Altamente recomendado).

OBJETIVOS

1. **Objetivos terapéuticos.**
2. **Objetivos metodológicos.**

- Observar, describir y medir las conductas de los niños durante las actividades del grupo para evaluar como se van desarrollando las habilidades y competencias que se pretenden enseñar en el programa así como estados psicológicos tales como la atención, el disfrute y la interacción entre los niños.

- Diseñar actividades y juegos basados en la evidencia (escenarios sociales, roles, etc.) para optimizar la participación de los niños en cada actividad y facilitar la emergencia de conductas que se quieren favorecer (conductas diana/objetivo).

- Estudiar qué características o variables individuales afectan en la participación de los niños en las actividades con contenido social diseñadas con un robot LEGO.

- Inferir estados psicológicos significativamente fiables tales como participación o disfrute a través de micro conductas observadas.

HIPÓTESIS

Aunque este estudio es **exploratorio** (no demostrativo) las hipótesis son:

- **Hip. 1** El programa basado en el robot de LEGO dará como resultado una mejoraría de las habilidades sociales de los niños con TEA.
    - Comparación de las medidas Pre test/ Post test (Ej. Escala de habilidades sociales, opinión de los padres y de los profesores y observación).

- **Hip. 2** El programa basado en el robot de LEGO dará como resultado una mejoraría de las habilidades sociales de los niños con TEA de forma más efectiva que otros programas que utilizan métodos tradicionales.
    - Comparación de los resultados entre el grupo con tratamiento con robot y el grupo control (sin robot) después de finalizar el tratamiento (Post test).

- **Hip. 3** El tipo de programa que incluye el robot LEGO facilita varias conductas y estados psicológicos relevantes para la terapia.
    - Relación entre la modalidad de juego (competitiva, cooperativa) y las conductas y estados psicológicos de los niños.
    - Descripción de cómo fluye la actividad y la relación con las diferentes conductas.

MATERIAL Y MÉTODOS

Se trata de un estudio clínico aleatorio que pretende estudiar cómo influye el uso de robots LEGO en grupos de habilidades sociales de 13 sesiones. La duración de las sesiones será de una hora y se realizarán con una frecuencia quincenal.

Los pacientes que participan en el estudio son niños con Trastorno del Espectro del Autismo con capacidad dentro de la normalidad de 8 a 12 años de edad.

Se realizará el estudio en una muestra de 16 niños (n=16) distribuidos en 4 grupos. Dos grupos realizaran la intervención con robots y los otros dos grupos serán grupos control.

Se incluirán todos los pacientes interesados en participar que cumplan todos los criterios de inclusión/exclusión y firmen el consentimiento informado.

Criterios de inclusión:

- Niños que hayan sido diagnosticados en la UETD.
- Capacidad cognitiva dentro de la normalidad.

Criterios de exclusión:

- Niños que estén realizando paralelamente intervención grupal de habilidades sociales.

Material:

- Robot Lego NXT:
  El equipo Lego NXT es una plataforma de construcción. El equipo NXT contiene varias piezas de hardware que incluye una unidad de microcontrolador reprogramable referido como el ladrillo NXT, sensores de ultrasonidos, sensores de sonido, sensores de luz y de color, y de contacto. Dichos componentes se pueden montar de diversas formas con piezas estructurales que vienen con el equipo.
  Además, el equipo incluye algunas herramientas adicionales como una pantalla LCD que puede mostrar información visual al usuario, un altavoz para la reproducción de sonido y Bluetooth que permite que el Lego NXT se comunique con otros dispositivos de forma inalámbrica (Información más detallada en Apéndice 4)

- Materiales que apoyen las actividades impresas en papel, presentaciones powerpoint o vídeos (modelado o automodelado).

- Ordenador para mostrar las presentaciones ppt o los vídeos.

- Dos videocámaras para realizar la filmación de las sesiones de intervención.

VARIABLES

1. Variables epidemiológicas: La muestra será seleccionada entre pacientes que han sido diagnosticados en la UETD, de manera que nos permite asegurar que han seguido el mismo protocolo clínico para obtener el diagnóstico. Se entrevistará a las familias y a los pacientes previamente al inicio de la intervención para conocer diversos aspectos que tendremos en consideración para la formación de los grupos:

- **Datos demográficos:** edad, sexo, etnia, procedencia y nivel educativo de los padres.
- **Datos clínicos:** Diagnóstico específico; Preocupación de los padres: Terapias psicológicas y tratamiento farmacológico; Intereses de los participantes; Percepción de dificultades; Aspectos que les producen malestar o detestan; Grado de familiaridad con las nuevas tecnologías (robots, tabletas, móviles, ordenador, Internet…).

2. Tests:

2.1. Cuestionarios de conducta Achembach forma para padres y profesores.
2.2. The Social Skills Rating System (SSRS). Forma para padres y profesores.
2.3. Autism Treatment Evaluation Checklist (ATEC).
2.4. The ABC: Aberrant Behaviour Checklist – Community.
2.5. Vineland Adaptative Behavior Scales (VABS).

3. Control de la patología:

Se realizará la filmación de las 13 sesiones de intervención tanto en las que se utilizarán robots como en los grupos control. Se pretende realizar un análisis pormenorizado de comportamientos relacionados con los déficits en habilidades sociales que presentan las personas con TEA (Tabla de observación - ver apéndice 2)

DISEÑO EXPERIMENTAL

Cuasiexperimental, pre-post, con grupo cuasi control (Grupo de comparación o grupo de control no equivalente).

PLAN DE TRABAJO

1. Reclutamiento de los pacientes:

Los pacientes se asignarán a los grupos en función de criterios clínicos (Edad, características de temperamento, intereses, tipología de dificultades en las habilidades sociales, etc.) para garantizar la eficacia de las dinámicas de grupo.

Los 4 grupos se asignarán aleatoriamente para ser grupo de intervención (Grupo A1 y A2) que siguen las actividades diseñadas con robot y grupo de control (Grupo B1 y B2) que siguen un programa de Habilidades Sociales convencional.

Se realizará un pre – test (Pruebas estandarizadas) en ambos grupos para evaluar las habilidades sociales de los participantes previas a la intervención (Línea base de variable dependiente).

A1	O_1	Q	X	X	X	X	X	X	X	X	X	X	X	X	O_2	O_3
A2	O_1	Q	X	X	X	X	X	X	X	X	X	X	X	X	O_2	O_3
B1	O_1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	O_2	O_3
B2	O_1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	O_2	O_3

O: Evaluación
X: Sesión de Intervención con robot.
Q: Sesión de intervención sin robot.

Se realizará un post-test con todos los participantes inmediatamente después de finalizar la intervención y otro más después de 3 meses para evaluar la permanencia de los efectos de la intervención.

2. Calendario de visitas:
Visita 0 (basal)

La psicóloga que hace la visita de seguimiento informará del estudio al paciente, revisará que cumpla todos los criterios de inclusión/exclusión.
En la misma visita se firmará el consentimiento informado para participar en el estudio (**Apéndice 1**). Se recogen datos demográficos y clínicos basales (**Apéndice 3**).

Aleatorización.

Los pacientes se asignan a cada grupo en función de criterios clínicos (Ver apartado de reclutamiento de los pacientes).
Los grupos se asignan aleatoriamente a una condición experimental (A1, A2, B1, B2) de forma aleatoria. Se introducen 4 tarjetas del mismo tamaño con los nombres de los niños que componen cada uno de los 4 grupos en una bolsa opaca y se van extrayendo tarjetas una a una. Se les otorga una condición experimental según el orden en el que van saliendo las tarjetas, las dos primeras serán los grupos con robot.

5. Sesiones de intervención grupal (De la 1ª a la 12ª).

FECHA	GRUPO	SESION
09/10/12	A1	Presentación
10/10/12	A2	Presentación
16/10/12	B1	Presentación
17/10/12	B2	Presentación
23/10/12	A1	1
24/10/12	A2	1
30/10/12	B1	1
31/10/12	B2	1
06/11/12	A1	2

07/11/12	A2	2
13/11/12	B1	2
14/11/12	B2	2
20/11/12	A1	3
21/11/12	A2	3
27/11/12	B1	3
28/11/12	B2	3
04/12/12	A1	4
05/12/12	A2	4
11/12/12	B1	4
12/12/12	B2	4
08/01/13	A1	5
09/01/12	A2	5
15/01/13	B1	5
16/01/13	B2	5
22/01/13	A1	6
23/01/13	A2	6
29/01/13	B1	6
30/01/13	B2	6
05/02/13	A1	7
06/02/13	A2	7
12/02/13	B1	7
13/02/13	B2	7
19/02/13	A1	8
20/02/13	A2	8
26/02/13	B1	8
27/02/13	B2	8

05/03/13	A1	9
06/03/13	A2	9
12/03/13	B1	9
13/03/13	B2	9
19/03/13	A1	10
20/03/13	A2	10
02/04/13	B1	10
03/04/13	B2	10
09/04/13	A1	11
10/04/13	A2	11
16/04/13	B1	11
17/04/13	B2	11
23/04/13	A1	12
24/04/13	A2	12
07/05/13	B1	12
08/05/13	B2	12
14/05/13	A1	13
15/05/13	A2	13
21/05/13	B1	13
22/05/13	B2	13
28/05/13	Padres A1	Val. Post inm.
29/05/13	Padres A2	Val. Post inm.
04/06/13	Padres B1	Val. Post inm.
05/06/13	Padres B2	Val. Post Inm.
17/09/13	Padres A1	Val. Post 3m.
18/09/13	Padres A2	Val Post. 3m
24/09/13	Padres B1	Val. Post 3m.

25/09/13	Padres B2	Val Post. 3m

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Apéndice1. Consentimientos informados.

HOJA DE INFORMACIÓN Y CONSENTIMIENTO INFORMADO
Para Padres / Representantes legales

TÍTULO DEL ESTUDIO: Actividades con robots LEGO en un programa de habilidades sociales para niños con TEA.

Este formulario de consentimiento forma parte del proceso de consentimiento informado. Si desea más detalles sobre algún aspecto, se le invita a que lo solicite al investigador del estudio. Tómese el tiempo necesario para leerlo.

Este estudio pretende explorar como el uso del Robot Lego puede mejorar las habilidades sociales de niños con TEA. Si aceptan participar en el estudio, su hijo será asignado aleatoriamente a un grupo de intervención con robot LEGO o bien, a un grupo de intervención basado en un programa HHSS tradicional (Sin robot).

Actividades del estudio

La duración del estudio es de 13 sesiones de intervención grupal con una frecuencia quincenal y una duración de 1hora por sesión. (De Octubre a Mayo).

En la visita de inicio se realizará una entrevista con padres y pacientes para dar información sobre el estudio y tener un primer contacto entre los niños y la persona que realizará la intervención grupal.

Si necesita más aclaraciones (o su hijo/a o representado/a), respecto a este estudio, por favor contacte con la Sra. Marta Maristany de la UETD del Servicio de Psicología – Neurología del Hospital St. Joan de Déu, teléfono 93 280 40 00 Ext. 4352 o bien con la Sra. Vanesa Padillo, mail: vpadillo@hsjdbcn.org

Se le facilitará una copia de este consentimiento. Se le ruega que conserve esta documentación para futuras referencias.

FULL D' INFORMACIÓ I CONSENTIMENT INFORMAT
Per a pares/ Representants legals

TÍTOL DE L'ESTUDI: Activitats amb robots LEGO en un programa d'Habilitats Socials per a nens amb TEA.

Aquest formulari de consentiment forma part del procés de consentiment informat. Si desitja més detalls sobre algun aspecte, us convidem a que ho sol·liciteu al investigador de l'estudi. Prengueu el temps necessari per llegir-ho.

Aquest estudi pretén explorar com l'ús del Robot LEGO pot millorar les Habilitats Socials de nens amb TEA. Si accepteu participar en aquest estudi, el seu fill serà assignat aleatòriament en un grup d'intervenció amb robot LEGO o bé, a un grup d'intervenció basat en un programa de HHSS tradicional (Sense robot).

Activitats de l'estudi

La duració de l'estudi és de 13 sessions d'Intervenció grupal amb una freqüència quinzenal i una duració d' 1hora per sessió. (D'Octubre a Maig).

A la visita d'inici es realitzarà una entrevista amb pares i pacients per donar informació sobre l'estudi i tenir un primer contacte entre els nens i la persona que realitzarà la intervenció grupal.

Si necessiteu més aclariments (o el seu fill/a o representat/a), respecte a aquest estudi, preguem contacteu con la Sra. Marta Maristany de la UETD del Servei de Psicologia – Neurologia del Hospital St. Joan de Déu, telèfon 93 280 40 00 Ext. 4352 o amb la Sra. Vanesa Padillo, mail: vpadillo@hsjdbcn.org

Es facilitarà una còpia d'aquest consentiment. Es prega que conserveu aquesta documentació per futures referències.

HOJA DE INFORMACIÓN Y CONSENTIMIENTO INFORMADO
Para Padres / Representantes legales

TÍTULO DEL ESTUDIO: Actividades con robots LEGO en un programa de habilidades sociales con TEA.

A RELLENAR SÓLO POR LOS PADRES / REPRESENTANTE (de su puño y letra)

Yo (nombre y apellidos)____ en calidad *de (relación con el participante):* _________________________________de *(nombre del participante) :* ____

He leído y entendido la hoja de información que se me ha entregado.

He podido hacer preguntas sobre el estudio y se han contestado.

He recibido respuestas satisfactorias a mis preguntas.

He recibido suficiente información sobre el estudio.

He hablado con*:*

Vanesa Padillo Marín; Nº colegiado: 17419 y DNI: 53029648-C

Comprendo que la participación es voluntaria.

Comprendo que puede retirarse del estudio:

1.º Cuando quiera.

2.º Sin tener que dar explicaciones.

3.º Sin que esto repercuta en sus cuidados médicos.

En mi presencia se ha dado a *(nombre del participante*): ____ toda la información pertinente adaptada a su nivel de entendimiento y está de acuerdo en participar.

Y presto mi conformidad con que *(nombre del participante)* ____ participe en este estudio.

Fecha: Firma de los padres / representante:

_____________ ____

Fecha: Firma de la persona que llevó la conversación del consentimiento informado

_____________ ____

FULL D'INFORMACIÓ I CONSENTIMENT INFORMAT
Per a Pares / Representants legals

TÍTOL DE L'ESTUDI: Activitats amb robots LEGO en un programa d'Habilitats Socials per a nens amb TEA.

A OMPLIR NOMÉS PER PARES /REPRESENTANTS (amb la seva pròpia lletra)

Jo(nom i cognoms)____ en qualitat de *(relació amb el participant):* ____de *(nom del participant) :* ____

He llegit i entès el full d'informació que se m'ha entregat.

He pogut fer preguntes sobre l'estudi i s'han contestat.

He rebut respostes satisfactòries a les meves preguntes.

He rebut suficient informació sobre l'estudi.

He parlat amb:

Vanesa Padillo Marín; Nº colegiado: 17419 y DNI: 53029648-C

Comprenc que la participació es voluntària.

Comprenc que pot retirar-se de l'estudi:

1r. Quan vulgui.

2n. Sense haver de donar explicacions.

3r. Sense que això repercuteixi en el seu seguiment mèdic.

En la meva presència s'ha donat a *(nom del participant)*:

____

tota la informació pertinent adaptada al seu nivell d'enteniment i està d'acord amb participar.

I Dono la meva conformitat a que *(nom del participant)*

____________________________ ____

participi en aquest estudi.

Data: Signatura dels pares / representant:
(A completar pels pares / representant)

____

Data: Signatura de la persona que va portar a terme la conversa sobre el consentiment informat

____

Apéndice 2. Tablas de Observación y valoración. Puntuaciones: Nada (0); Un poco (1); A veces (2); Bastante (3); Mucho (4)

Fecha: Sesión: NH. Del niño:

Actividad: Grupo: Observador:

CATEGORIA	**SÍNTOMAS**	**PUNTUACIONES**				
Comunicación no verbal	Atención conjunta	0	1	2	3	4
	Contacto ocular	0	1	2	3	4
	Gestos o señalización	0	1	2	3	4
	Sonrisa social	0	1	2	3	4
Lenguaje	Inicia conversación relacionada con la actividad	0	1	2	3	4
	Inicia conversación no relacionada con la actividad	0	1	2	3	4
	Pide ayuda	0	1	2	3	4
	Interrumpe durante una conversación	0	1	2	3	4
	Ignora la pregunta	0	1	2	3	4
	Tono, volumen, ritmo y velocidad adecuada.	0	1	2	3	4
	Tendencia a hacer monólogos	0	1	2	3	4

Atención conjunta: Cuando los niños miran el mismo objeto y se miran entre ellos. Compartiendo la actividad.

CATEGORIA	SÍNTOMA	PUNTUACIONES				
Conducta	No participa del juego o de la actividad	0	1	2	3	4
	No muestra interés por la actividad o por colaborar con el grupo	0	1	2	3	4
	Muestra dificultad para respetar los turnos durante la actividad	0	1	2	3	4
	Le cuestan las transiciones de una actividad a otra	0	1	2	3	4
	Juega solo	0	1	2	3	4
	Agresividad verbal o física	0	1	2	3	4
	Presencia de conductas repetitivas	0	1	2	3	4
	Baja tolerancia a la frustración	0	1	2	3	4

Apéndice 3. Datos demográficos y clínicos basales.

NH – APELLIDOS, NOMBRE
FN.
Edad:
Tel.
Dirección: c/ Nº, piso. localidad. Provincia. CP.
Fecha actual:
Entrevistador: Vanesa Padillo
Nombre de los entrevistados:
Mail:

Nombre de los padres:
Escuela:
Curso: Tutor/a:
Refuerzos escolares:
Disponibilidad horaria:
Preocupación de los padres en el momento actual:
¿Qué otras terapias está recibiendo?
¿Toma medicación?
¿Qué métodos utilizan para modificar conductas?
Intereses (Niño y padres):
- Cosas que le cuestan:
- Cosas que no soporta:
- Grado de familiaridad:
  ¿Qué es un robot?
  ¿Has visto alguno? ¿Has jugado con alguno?
  Y con otras tecnologías: videojuegos, ordenador, smartphone…

Nombre de los amigos y actividades que comparten:
Otros comentarios y observaciones padres:

Apéndice 4. Descripción del robot Lego NXT.

DESCRIPCIÓN DE CONDUCTAS

- **Iniciación Espontánea de Atención Conjunta.**

  Se codifican los intentos por parte del niño de atraer la atención de un adulto o compañero hacia un objeto que ninguno de los dos está tocando y que no es con el propósito de pedir algo.

  * Descripción de la conducta extraída del ADOS.

- **Ofrece Información verbal.**

  Se evalúa el ofrecimiento espontáneo y apropiado por parte del participante de información personal que resulte nueva para el examinador. No tiene que suceder dentro de un contexto determinado ni ser parte de una interacción sostenida. Puede suceder como elaboración o respuesta a alguna pregunta, pero debe incluir información nueva, que no esté especificada en la pregunta. Puede estar relacionada con los intereses del participante pero no puede estar relacionada exclusivamente con sus preocupaciones. Los comentarios acerca de relaciones o posesiones (p.ej., "tengo dos hermanos" o "nuestra familia tiene un barco") se pueden codificar aquí si se refieren a una actividad y no es simplemente una lista de características.

  Es decir, se contabilizan las ocasiones en las que el niño ofrece información espontáneamente sobre sus pensamientos, sentimientos o experiencias.

  * Descripción de la conducta extraída del ADOS.

- **Berrinches, agresiones, comportamientos negativos o disruptivos.**

  Este ítem incluye cualquier forma de enfado (molestia o enojo) o disrupción que va más allá de comunicar una leve frustración o queja.

  (Incluye amenazas verbales, tono de voz deliberadamente alto, provocar, lanzar cosas, pegar, gritar, hacer conductas que molestan a los compañeros en general).

  * Descripción de la conducta extraída del ADOS.

- **Ofrecimientos para compartir: Cantidad de veces que comparte.**

  Ofrecimientos no solicitados ni rutinarios para compartir una variedad de objetos diferentes con otras personas. (Diferenciar los ofrecimientos claros y espontáneos para compartir de aquellos ofrecimientos sugeridos o de cuando renuncia a cosas si otra persona trata de llevársela).

  * Descripción ADI-R

- **Cantidad de gestos y/o expresiones faciales usadas para comunicarse (Comunicación recíproca no verbal: Señalar, asentir, sonreír, encoger hombros).**

  Se refiere a las **expresiones faciales** usadas para comunicarse, no únicamente a aquellas asociadas con la experiencia de emociones. Un rango normal de emociones, hasta en niños pequeños, se esperaría que incluyera varias expresiones faciales más sutiles utilizadas para comunicarse incluyendo (sorpresa, culpa, disgusto, interés, diversión y vergüenza, así como alegría, ira, temor y dolor).

  Se consideran **gestos convencionales/instrumentales** aquellos movimientos intencionados de brazo o mano, espontáneos y culturalmente apropiados, que transmiten un mensaje por su forma como seña social. Se excluyen señas puramente emocionales (tales como taparse la cara con las manos por vergüenza o encogerse de miedo), demostraciones y tocar o tirar de alguien para obtener su atención o mostrarles algo. También se excluyen manierismos tales como tocarse la cara o rascarse. (Ejemplos: soplar un beso, aplaudir por un trabajo bien hecho, llevar un dedo a sus labios para significar silencio, agitar un dedo para significar malo, llama por señas a alguien o extiende la mano para pedir algo…).

  *Descripciones de ADI-R

Trainning Videos:

- **ClipJuegocooperativoTraining.** Se analiza a **B2.2** (justo sentado a la izquierda de Vanesa) – Niño con Prosodia alterada (robotizada).
- **ClipConversaciónTraining.** Se analiza a **B1.3** (Sentado a la derecha de Vanesa) muy inquieto y simpático con “acento” extranjero y **B1.1** (sentado a la izquierda de Vanesa) muy inhibido y callado.
- **ClipProgramaciónTraining.** Se analiza a **A2.4** (Niño sentado junto y dando un poco la espalda a la pizarra – aula 20).

ANALISIS VIDEOS TRAINNING
María Ángeles Mairena
Psicóloga Clínica experta en TEA de la UETD – HSJD

Juego Cooperativo (B2.2)

	Conducta	Cantidad de Veces
I. Atención Conjunta		3
Ofrecimiento información	"Ya no tengo mas"	1
Berrinches/C. disruptivas		11
Gestos/E. Faciales	Mira, Sonríe	6
Compartir/Dar		0

Conversación (B1.3)

	Conducta	Cantidad de Veces
I. Atención Conjunta		0
Ofrecimiento información		7
Berrinches/C. disruptivas		0
Gestos/E. Faciales		12
Compartir/Dar		0

Conversación (B1.1)

	Conducta	Cantidad de Veces
I. Atención Conjunta		0
Ofrecimiento información		2
Berrinches/C. disruptivas		0
Gestos/E. Faciales		5
Compartir/Dar		0

Programación (A2.4)

	Conducta	Cantidad de Veces
I. Atención Conjunta		10
Ofrecimiento información		2
Berrinches/C. disruptivas		1
Gestos/E. Faciales	Señalar, asentir, sonreír	22
Compartir/Dar		2

DETALLES DEL ESTUDIO:

TIPO DE CONSENTIMIENTO: ESCRITO ESTANDARD

LOCALIZACIÓN: Centro CASPAN en Panamá

PARTICIPANTES: Niños/as entre 7 y 14 años, Padres y/o Tutores Legales, y profesor/a / observador/a.

COMPENSACIÓN: NINGUNA

FORMULARIO DE CONSENTIMIENTO DE PADRES/TUTOR LEGAL PARA LA PARTICIPACIÓN DE NIÑOS/AS EN UN ESTUDIO DE INVESTIGACIÓN

TITULO DEL ESTUDIO: Using Pet Robots to Positively Affect Social and Emotional Development in Children with Autism

INVESTIGADOR PRINCIPAL: Jordi AlboCanals,Ph.D.

ANTECEDENTES: Somos un grupo de investigación del departamento Ingeniería de la Universidad de La Salle Campus Barcelona - Universidad Ramon Llull que, junto con investigadores de otras Universidades, estamos interesados en examinar cómo las actividades con PLEO RB Y CASPER pueden ayudar a los alumnos con trastorno del espectro autista (TEA) a interaccionar socialmente con otros. Al trabajar con la robótica PLEO RB Y CASPER, esta interacción crea un contexto en el que se requieren habilidades sociales. Varios estudios realizados anteriormente por la mayoría de los investigadores involucrados en este proyecto han demostrado que los alumnos con autismo disfrutan enormemente las sesiones de construcción con robótica en grupo y que sus habilidades sociales mejoran a lo largo de sesiones de terapia repetidas.

PROPÓSITO Y DURACIÓN: El proyecto consta de 2 semanas de enseñanza diaria y formación del plan de estudios de la robótica PLEO RB Y CASPER. Los maestros capacitados durante estas sesiones en CASPAN seguirán el plan de estudios PLEO RB Y CASPER durante varias semanas posteriores después de que los investigadores dejan el Centro CASPAN. La duración de las sesiones es de aproximadamente 1 hora, donde los estudiantes pueden interactuar con el robot PLEO RB Y CASPER. Esta interacción fomentará estímulo, mantener a los niños centrados en el aprendizaje, y facilitar la interacción social entre los estudiantes.

PROCEDIMIENTOS: Todas las sesiones tendrán lugar en el Centro CASPAN en Panamá. Usted tendrá que llevar a su hijo al centro donde su hijo va a participar en cada una de las 8 sesiones de estudio. Todas las sesiones se llevarán a cabo después de la escuela. Su hijo no está obligado a asistir a todos los talleres con el fin de participar en nuestra investigación, aunque se recomienda su asistencia.
Durante cada sesión, vamos a presentar a los alumnos una nueva actividad y romperlas en pequeños grupos para completar la actividad.
Después de cada sesión, el profesor que participa en la sesión llenará un cuestionario del estudio profesor para cada estudiante con respecto a su / sus observaciones de los cambios en el comportamiento del niño y su / sus sentimientos acerca de la eficacia del curso de robótica.
Investigadores del proyecto evaluarán el comportamiento de los estudiantes con varias herramientas de evaluación que son los cuestionarios, la codificación de vídeo, y la interacción entre los niños y el robot.
Durante cada sesión, se grabara con videocámara la interacción del equipo y sus creaciones con el robot PLEO RB Y CASPER.

RIESGO Y MOLESTIAS: La participación en el estudio tiene un mínimo riesgo para los participantes ya que la probabilidad y magnitud de daño o molestia anticipada en la investigación no es mayor que lo que se encuentran normalmente en la vida cotidiana durante la realización de exámenes o pruebas físicas o psicológicas de rutina. Existe un riesgo emocional menor relacionado con el compromiso social con sus compañeros, instructores, o familiares. Sin embargo, el objetivo del taller es mejorar las relaciones y habilidades sociales y, a largo plazo, aumentar la disponibilidad de las futuras oportunidades de empleo para los participantes lo que el riesgo emocional en realidad debería disminuir y esperamos sea eliminado.

La experiencia previa del equipo de investigación debe ayudar a minimizar el riesgo potencial: El PI del proyecto ha estado involucrado en proyectos relacionados con los niños con TDA durante los últimos 5 años, y el resto de los investigadores tienen publicaciones y experiencia en el campo del autismo.

COSTES Y BENEFICIOS: No hay coste por participar en el estudio. Por otra parte, como beneficio las herramientas tecnológicas educativas que mejoran el funcionamiento social y ocupacional podrían ayudar a los estudiantes con autismo a cumplir su potencial académico y aumentar las habilidades sociales.

DISEMINACIÓN: Las conclusiones y resultados del estudio de investigación serán publicados en conferencias internacionales y en revistas internacionales a sí como en la página web del proyecto. Los videos, fotografías o cualquier información identificable bajo ninguna circunstancia será mostrada en reuniones, conferencias u otras actividades profesionales.

CONFIDENCIALIDAD: Los formularios de consentimiento de los padres y la información de Diagnosis y Tratamiento del Estudiante serán escaneados a un ordenador protegido por contraseña y después serán eliminados. Todos los datos del proyecto serán digitales y guardados en un servidor seguro situado en la Universidad de La Salle Campus Barcelona - Universidad Ramon Llull (Sant Joan de la Salle 42, 08022, Barcelona – España) protegido por un usuario y contraseña individual. Los datos relacionados con cada participante serán codificados con un identificador (será una letra) que el PI del proyecto asignará durante el proceso de matriculación.

ABANDONO DE PARTICIPACIÓN: Pueden abandonar el estudio en cualquier momento sin consecuencia alguna. Ustedes tienen el derecho para que alguna o toda la información de su hijo/a recogida hasta el momento sea retirada del estudio.

SOLICITUD PARA MÁS INFORMACIÓN: Si ustedes tienen alguna pregunta al respecto, no duden en ponerse en contacto con el coordinador de investigación, Jordi Albo-Canals, en el +34 629424807 ó (507) 225-7419 [Estudio en Panamá] o enviar un email a jalbo@salleurl.edu.

FIRMA DE LOS PADRES/TUTORES LEGALES: Al firmar este documento, Ustedes están de acuerdo con la participación de su hijo/a y su propia participación en nuestro proyecto de investigación así como en rellenar los cuestionarios de los Padres. Ustedes pueden estar de acuerdo con todos, algunos o ningunos de los datos recogidos a continuación. Si su respuesta es no, su hijo podrá participar en el taller, pero la imagen de su hijo y la voz será borrada del video inmediatamente después de la sesión, y su hijo no rellenará los cuestionarios. Si ustedes tienen alguna pregunta, por favor no duden en hacérnosla.

Por favor firme el formulario de padres adjunto y haga que su hijo/a firme la parte de estudiante. Por favor devuelva los formularios y la Información de Diagnosis y Tratamiento al PI del proyecto (Dr. Jordi Albo-Canals) antes del inicio del estudio.

Sinceramente,
Jordi Albo-Canals

Estoy de acuerdo en que mi hijo/a sea grabado y sus creaciones con el robot PLEO RB Y CASPER también durante cada sesión del proyecto. ____SI ____NO

Estoy de acuerdo en que las interacciones de mi hijo/a con otros compañeros sean analizadas y cuantificadas durante cada sesión por los investigadores. ____SI ____NO

Estoy de acuerdo en que las interacciones de mi hijo/a con el robot compañero sean analizadas y cuantificadas durante cada sesión por los investigadores. ____SI ____NO

Estoy de acuerdo en que mi hijo/a rellene los cuestionarios sobre sus sentimientos en relación con las actividades de construcción del robot. ____SI ____NO

Estoy de acuerdo en rellenar el cuestionario en cuanto a mis sentimientos y observaciones en los cambios de comportamiento y sentimientos de mi hijo/a sobre la efectividad del curso de robótica. ____SI ____NO

____

Nombre del Participante

__________________________________ ____________

Firma de los Padres/Tutor Legal **Fecha**

____

Nombre de los Padres/Tutor Legal

____

Nombre del Investigador

__________________________________ ____________

Firma **Fecha**

Positive Technological Development (PTD) Engagement Checklist

What is the Checklist?

The PTD Engagement Checklist is based on the theoretical foundation of Positive Technological Development (PTD). The PTD framework guides the development, implementation and evaluation of educational programs that use new technologies to promote learning as an aspect of positive youth development. The PTD framework is a natural extension of the computer literacy and the technological fluency movements that have influenced the world of education but adds psychosocial and ethical components to the cognitive ones. From a theoretical perspective, PTD is an interdisciplinary approach that integrates ideas from the fields of computer-mediated communication, computer-supported collaborative learning, and the Constructionist theory of learning developed by Seymour Papert (1993), and views them in light of research in applied development science and positive youth development.

As a theoretical framework, PTD proposes six positive behaviors (six C's) that should be supported by educational programs that use new educational technologies, such as KIBO robotics. These are: communication, collaboration, community building, content creation, creativity, and choice of conduct.

More information about PTD can be found in Marina Umachi Bers' book <u>Designing Digital Experiences for Positive Youth Development: From Playpen to Playground</u> (2012).

How is the Checklist used?

The PTD Engagement Checklist is intended to be used in a variety of settings where children are engaging with technology. It is divided into six sections (each one representing a behavior described in the PTD framework) and measured using a 5-point Likert scale. The checklist is meant to evaluate a group of children and their environment as they use the technology but can be adapted to observe an individual child's behaviors. Adults my use the checklist as often as during every lesson, or as infrequently as once per unit. The goal of the PTD checklist is to provide a lens into how children are engaging with the technology and experimenting with the behaviors described by the PTD framework.

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following? Please select one.	1 Never	2 Almost Never	3 Some-times	4 Often	5 Always	N/A or Not Observable
Communication						
Students are exchanging ideas with others.						
Students feel comfortable seeking help and asking questions with adults.						
Students feel comfortable seeking help and asking questions with peers.						
Collaboration						
Students are helping each other to understand materials.						
Students are receiving help from others and are appreciating it.						
Students are borrowing or lending materials from/to one another.						
Students are working together towards a common goal.						
On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	**1 Never**	**2 Almost Never**	**3 Some-times**	**4 Often**	**5 Always**	**N/A or Not Observable**
Community Building						
Student are participating in community-related tasks (ex. helping with clean-up, set up, etc.).						
Content Creation						
Students know how to use the technology to make an activity.						
Students are interested and enthusiastic about their activities.						

On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	**1 Never**	**2 Almost Never**	**3 Some-times**	**4 Often**	**5 Always**	**N/A or Not Observable**
Creativity						
Student are using technology in an unexpected way.						
Students exhibit confidence and can initiate and complete a task with limited coaching.						
There are a variety of materials available for students to choose from.						
On a scale from 1 to 5 (with 1 = Never and 5 =Always), how often do students do the following?	**1 Never**	**2 Almost**	**3 Some-times**	**4 Often**	**5 Always**	**N/A or Not Observable**
Choice of Conduct						
Students are focused on the activity and choose to engage with it.						
Student are following classroom rules.						
Students are aware that their actions with the technology will have an impact on others.						
Student are using materials and resources responsibly.						
Student are showing respectful behaviors to peers and teachers.						

VIDEO CODING

ID:
Session:
Time of observation (Circle): 15mn 45mn 75mn

	How often in 5 minutes	Comments
Non Verbal Communication		occ
Eye gaze / Contact to face / eyes		occ
Gestures / Pointing		occ
Joint Attention back and forth		occ
Groupmates look at the same object		
Conversation		
Meaningful, in relation to activity		period
Non meaningful / tangential		period
Echolalia / Scripting		period
Initiation of		occ
Response to		occ
Interrupts other child		occ
Sharing positive affect		occ
Construction / Dynamics		
Turn Taking		occ
Collaboration: negotiation, sharing, asking for opinion		occ
Proximity (within 100 cm)		period
Ask help / permission from adult		occ
~~Ask help / permission from robot companion~~		~~occ~~
Solves problem with other student		period
Solves problem alone		period

Disengagement		period
LEGO Robot manipulation		period
~~Computer manipulation~~		~~period~~
Behavior		
Self-stimming behaviors		
Hyper/Hypo active		
Decreased affect		
Difficulty with change / transitions		
Other behaviors		
Design Outcome		
Task completed Y/N If No, why?		
Happy about it Y/N		
Sharing to adult Y/N		

Esta Tesis Doctoral ha sido defendida el día ____ d________________ de 201__

En el Centro____

de la Universidad Ramon Llull, ante el Tribunal formado por los Doctores y Doctoras abajo firmantes, habiendo obtenido la calificación:

Presidente/a

____

Vocal

____

Vocal *

____

Vocal *

____

Secretario/a

____

Doctorando/a

(*): Sólo en el caso de tener un tribunal de 5 miembros