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Dr Daniela Conti

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First-Supervisor: *Dott.ssa Elena Commodari*

Second-Supervisor: *Prof. Santo Di Nuovo*

Third-Supervisor: *Prof. Angelo Cangelosi*

Fourth-Supervisor*: Dott. Alessandro Di Nuovo*

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Contents

"Stay Hungry. Stay Foolish!"

The Whole Earth Catalog, 1970 Stewart Brand

Introduction

Recent technology advances and research achievements have boosted the area of robotics and resulted in a fast grow of possible applications, with a concrete impact on the everyday life of the common people. Among the applications in social contexts, those regarding education and care of children have received particular attention thanks to evidence from several studies and more affordable new robotic platforms.

Despite the scientific success and increasing evidence and applications, it seems that the majority of people are still sceptical or even against the use of robots in real contexts like education and care of children. For example, according to a recent survey (European Commission, 2012), European respondents indicated a positive attitude towards robots, but 60% of them said that robots should be banned from the area of care for children, the elderly and the disabled. Furthermore, only 3% said that robots in education are a priority, while 34% specifically stated that they should be banned from education. This is perhaps related to the common perception of robots as technically powerful but *dangerous* machines, which are mainly useful in space exploration, in military applications and in industry where there are no human beings around or just the ones that are employed to control them. I must say that the survey was very general and participants were given only very limited information about the concept of robots and how they could be used. The European study (European Commission, 2012) did not elaborate on the term disability; therefore, it seems reasonable to expect that the negative sentiment is bigger the more the disabled person is seen to be cognitively compromised (Wolbring & Yumakulov, 2014).

Public perception of an emerging scientific and technological product is important for the acceptance of such a product. Ethical studies based on public surveys toward using robots in eldercare and other applications, showed a high acceptance for pet-like therapeutic robot, the human-like care robot, and a surveillance care robot (Moon, Danielson, & van der Loos, 2012). However, it also reported a rejection in the case of a bathing robot because of the judgment that the robot-based action would be inferior to the human-based action and that it would take away jobs from human workers. However at the same time, social robots are seen as a possible way to address the human resource and economic pressures on health care systems, but several studies stressed that care workers assisting the elderly should not be replaced by robots (Coeckelbergh et al., 2015; R. Sparrow & Sparrow, 2006).

A Swedish study (Ray, Mondada, & Siegwart, 2008) concluded that "people were globally positive towards the idea of intelligent service robots, which were seen as "domestic machines" that can be "controlled" and do mainly household tasks". In fact, Dautenhahn et al., (2005) found that people would want a companion robot more as a servant (e.g., 96.4% wanted the robot to be able to do household jobs), but not a friend whereby young people were more inclined toward the friend role (i.e. 10.7 % of participants wanted the robot to be able to look after their children).

However, this negative attitude is one of the biggest challenges that scientific research must address. To fill this gap, there have been many studies on the factors that can influence the acceptance by potential users and on how it can be increased. Among the objectives of current robotics research is the adaptation of the robot appearance and behaviours in order to improve the acceptance by the user (Broadbent, Stafford, & MacDonald, 2009; Kanda, Miyashita, Osada, Haikawa, & Ishiguro, 2008).

Research about robotics acceptance have often seen older people in assisted living scenarios as the main focus (e.g., Broekens, Heerink, & Rosendal, 2009; Chen & Chan, 2011; Klamer & Ben Allouch, 2010; Smarr et al., 2012), but relatively few studies have been conducted with other participants such as children or their educators (Baroni et al., 2014) and caregiver.

Taking into account this scenario, chapter IV (4.1) focus on the acceptance by practitioners that work on a daily basis with children with intellectual disabilities, and on a group of university students from two classes concerned with social professions: education and psychology.

Moreover, the purpose of the other study in the chapter IV (4.2) is to examine the acceptance and willingness to use robots among psychology students with Italian (ITA) and British (UK) background cultures in order to evaluate cultural differences in the acceptance of robotics by future psychology practitioners.

Both studies were conducted using a platform for Socially Assistive Robotics (SAR) and a questionnaire based on the Unified Theory of Acceptance and Use of Technology (UTAUT) model. The objectives of the research are to confirm the reliability of the UTAUT model and its applicability in the context of education and care of children, and to evaluate the acceptance of robotics by individuals who are currently working in, or will work in the future, in the education of children with developmental disabilities, also considering the cultural influence. In fact, only few studies have attempted to test the UTAUT model in other countries and most of them include the US where the model was originally developed and tested (Simeonova, Bogolyubov, Blagov, Kharabsheh, & Administration, 2010). In this case, the aim was to identify the capability of items in UTAUT questionnaire to reveal cultural differences, and, thus, the main factors that may influence each group in the use of robots in their future practice. This negative attitude is one of the biggest challenges that scientific research must address to be completely successful in giving actual benefits in the field of education and care.

However, robots have been used in a variety of service, educational, entertainment or therapeutic applications, some projects focusing on the robot's functionalities, others on the social aspects using human–robot interaction studies to evaluate human responses to the appearance and behaviour of robots for different contexts (e.g., Falcone, Gockley, Porter, & Nourbakhsh, 2003; Goetz, Kiesler, & Powers, 2003; Kahn Jr, Friedman, Perez-Granados, & Freier, 2004; Severinson-Eklundh, Green, & Hüttenrauch, 2003; Thrun, Burgard, & Fox, 2000).

This rapid progress in technology, especially in the area of robotics, offers numerous possibilities for innovation in the education and care of individuals (Tapus, Mataric, & Scasselati, 2007). This has enabled robots to provide assistance to a variety of human-like functions, as well as to aid with the goal of improving social skills in individuals with disability (Diehl, Schmitt, Villano, & Crowell, 2012). Studies have considered the therapeutic use of robots such as aids for the elderly at home performing tasks they are unable to carry out, and providing socialising opportunities for the elderly who may be lonely and unable to leave the house (Monk & Baxter, 2002).

Starting from these findings, in the chapter V my on-going research aims to identify effective modalities for treatment of Autism Spectrum Disorder (ASD) through interaction with a robot, and to integrate them into existing therapeutic protocols to improve their efficacy. I detail the methodology and give the results of a pilot clinical trial, focused on imitation skills, with three children affected by ASD and Intellectual Disability (ID) under treatment in a research centre specialized in the care of children with disabilities. Analysis of these initial results encourages the development of effective protocols in which the robot becomes a mediator between the child with ASD and humans and suggests some research avenues for focus in the future.

However, the robotics is not only social. For this reason the aim of chapter VI, is artificial life where the ‘models derived from the data’, implement artificial organisms that replicate experimental observations. The purpose of this approach, as proposed by the Palmer’s book (Palmer, 2001), is to create new realities, reproducing (or simulating) the mechanisms of adaptation, learning and development, underlying the life of a biological system. Specific skills or behaviours are not directly imitated or reproduced, as schematic ‘photographs’ of a part of reality, but emerge as a result of adaptation processes put in place by the new reality built artificially.

Traditionally, artificial life realizes models that *simulate* psychophysical activities. In fact, in the chapter VI I will present the experimental results of a cognitive robotic approach for modelling the human cognitive deficit known as Unilateral Spatial Neglect (USN), where I replicated a previous experiment with human patients affected by the USN and *iCub* robotic platform. The numerical results show that the robot simulate the behaviours previously exhibited by humans and this last work of dissertation highlights some possible advantages of the use of robotic platforms to model and study cognitive dysfunctions of the human brain.

Chapter I

Developmental of robotics in human history

In 1921, when K. Capek coined the name "robot" for machines designed for slave labour in the play RUR (the title is an acronym for "*Rossum's Universal Robots"* the company that produces robots in the play), robots were thought as ideal workers (Čapek & Jarý, 1973). Emotions were given to the robots in the drama, in order to increase their productivity. The robots after turned on their creators and destroyed them, much like "the creature" in M. Shelley' s Frankenstein, written in 1818. Robot couples have also been presented as successors for humans. Various science fiction writers have dealt with robots as slaves for humans, and a common theme has been for the robots to acquire minds and some degree of consciousness and to become enemies of their human masters (Asimov & Dawson, 1950; Aylett, 2002; Rosheim, 1994). These stories present the duality of technology, i.e., threat versus promise, through the concept of the perfect worker. If humans feel threatened by interacting with robots, subsequently they would evaluate robots to be of very low value in terms of subjective evaluation (Shibata, 2004).

The market for industrial robots grew quickly during the 1970s and 1980s, with a peak demand in 1991. Though, due to the subsequent recession in the world economy, the market for industrial robots has been slow or stagnant over the last decade. The price of industrial robots fall during the 1990s, while at the same time their performance, measured both in terms of mechanical and electronic characteristics, was improving continuously (Čapek & Jarý, 1973).

However, there are two categories of robots that are usually recognized in the robotics industry: industrial robots and service robots (Europe, 2002).

Industrial robots have been used widely in manufacturing factories since the early 1960s and work very fast and accurately at their tasks though they have to be taught by a human operator and their environment has to be specially prepared so that they can accomplish their tasks. Typical tasks for industrial robots are assembly, welding, packaging, painting, and palletizing in automotive manufacturing and other industries. For this reason, most industrial robots are considered as a potential danger to humans, so people are kept isolated from them (Shibata, 2004).

On the other hand, service robots are a new development in the robotics industry and include several different kinds of robot. These can be classified into two subcategories: service robots for professional use and service robots for personal and private use (Europe, 2002). Service robots for professional use include cleaning robots, sewer robots, inspection robots, demolition robots, underwater robots, medical robots, robots for disabled persons such as assistive robots and wheelchair robots, courier robots, guide robots, refuelling robots at gas stations, fire- and bomb-fighting robots, construction robots, agricultural robots, and so on. Instead, service robots for personal and private use have been developed to interact with human being and include domestic (home) robots for vacuum cleaning, lawn-mowing, and so on, as well as entertainment robots, educational robots, and the like.

In the health care, the first and pioneering effort of using robots for autism therapy was made in 1976 by paediatrician Sylvia Weir and psychotherapist Ricky Emanuel with a mobile turtle-like robot with a seven-year old autistic child (Emanuel & Weir, 1976) and no other important innovations have been identified in similar context until the late 1990s.

Other early work conducted by Werry et al. (Werry, Dautenhahn, Ogden, & Harwin, 2001) showed the potential for robotic use by initially studying whether children diagnosed with Autism Spectrum Disorder (ASD) would enjoy interacting with a robot. Other mobile robots specifically designed to help with the therapy of those with ASD also appeared about the same time (Michaud, Clavet, Lachiver, & Lucas, 2000; Michaud & Clavet, 2001; Michaud et al., 1999; Michaud, Lepage, et al., 2000).

Since then the use of robotic devices for children with autism has developed substantially (Michaud & Théberge-Turmel, 2002; Salter & Michaud, 2010).

Children with ASD have been known to be attracted to inanimate; technological objects namely computers, gadgets and robots. At the same time, the robot itself is much simpler in appearance compared to real life objects, its behaviour can be custom-made to suit various scenarios and it has the ability to offer expected and simpler interaction with the children. These two complementing factors make robots the ideal medium to be used in autism therapy.

In the surgery, the use of robots began in 2001 with the introduction of a specialized robot arm to perform surgery on patients at Children's Hospital Boston. Robots have also been used to dispense and transport medication and materials in hospitals (Challacombe, Khan, Murphy, & Dasgupta, 2006). Mobile robot systems are also being tested as a means for physicians to communicate remotely with their patients and for lifting patients.

Several robots are uniquely programmed to work with people, capable of both verbal and nonverbal communication. With emerging research suggesting that mobile robot systems and robot arms improve patient care (Rozet, Harmon, Cathelineau, Barret, & Vallancien, 2006; Satava, 1999), it seemed timely to examine whether a humanoid robot could reduce paediatric pain and distress.

A number of research projects in the field of embodied interaction have developed robots explicitly for interaction with children. For example, a pioneering example of a "sociable robot" is *Kismet* (Breazeal & Scassellati, 2000). This robot engaged people in natural and intuitive face-to-face interaction by exchanging a multiplicity of social cues, such as facial expression, vocalization, and gaze direction. Kismet's elicitation of caretaking behaviour from people (including children) enabled a form of socially situated learning with its human caregivers.

Another pioneer is the *AuRoRa* project (Dautenhahn, 1999), which reported that even simple mobile robots provided autistic children with a relatively repetitive and predictable environment that encouraged spontaneous and relaxed interactions. Furthermore, *Robota* is a doll-like anthropomorphic robot, Billard (2002), developed for mutual imitative play with autistic children; Robins (Robins, Dickerson, Stribling, & Dautenhahn, 2004) analysed two children playing with *Robota* and observed mutual monitoring and cooperative behaviour to draw desirable responses from it. Michaud (Michaud & Théberge-Turmel, 2002) has developed a number of mobile and interactive robots (e.g., *Roball* and *Tito)*, and has observed interaction with autistic children in order to explore the design space of child-robot interaction for fostering children's self-esteem. Creature like robot *Muu* was developed by Okada (Okada & Goan, 2005) to observe how autistic children collaborate with the robot in shared activities (e.g., arranging colored blocks).

In another work Scassellati (2005a), observed autistic children interacting with a robot with an expressive face and found that they showed positive proto-social behaviours (e.g., touching, vocalizing, and smiling at the robot) that were generally rare in their everyday life.

Enthusiasm for developing robotic technologies to assist the elderly is linked with the belief that there is a societal need (an aging society with few human caregivers available to care for the elderly) to be met by these technological innovations, which could save costs for public services or care-assurance budgets (Blackman, 2013).

Robot study in the eldercare field includes two kinds of assistive robots: rehabilitation robots and social robots (Broekens et al., 2009). The first emphasize physical assistive technology, while the second refer systems that can be perceived as social entities with communication capacities. There are two categories of assistive social robots in eldercare: 1) pet-like companionship robots, whose main function is to enhance health and psychological well being; and 2) service-type robots, whose main function is to support daily activities so that independent living is possible (Wu & Rigaud, 2014).

Kozima et al. (Kozima, Michalowski, & Nakagawa, 2009) highlight that some basic traits common to people and animals (e.g., lateral symmetry and two eyes) are important cues to the potential for social agency. In fact, keeping the appearance simple—so that it is aligned with the robot's behavioural capabilities—is important for helping people understand and feel comfortable with the robot's behaviour.

Social robots, in fact, have been also used as reasonable substitutes for animals in therapy for people suffering from dementia (Shibata, 2012; Kazuyoshi Wada, Shibata, Musha, & Kimura, 2008) and have been proposed as one form of assistive technology likely to have much potential to support older adults, maintain their independence, and enhance their well-being (Broadbent et al., 2009; Ezer, Fisk, & Rogers, 2009; Seelye et al., 2012; Smarr et al., 2012).

In a study by Valentí Soler et al., (2015) on robot therapy sessions for patients with moderate/severe dementia cared for at a day care centre, showed improvements in irritability and global neuropsychiatric symptoms after participating in sessions with the humanoid robot, but not after sessions with the animal shaped robot. In fact, the alternative of replacing real animals with animal-shaped objects became an object of investigation (Nakajim et al., 2001).

The use of animals in therapy intervention (Animal-Assisted Therapy - AAT), is one such non-pharmacological tool currently under investigation. The effect of animal therapy seems to calm agitated behaviour and has positive effects on the quality of social interaction and mood disturbances, although no effect was observed on cognitive performance (Bernabei et al., 2013). The presence of an animal involves an increase in the duration and frequency of visual contact and smiles. AAT was independent of the severity of dementia (Filan & Llewellyn-Jones, 2006), but is not always possible. Animals are often not allowed in nursing homes or day care centres, due to the risk of injury to patients, staff or visitors, the possibility of allergic reactions, and the potential nuisance of cleaning up after the animals. Patients or staff may have undesired reactions to animals, both negative and overly positive. The cost of animal care (e.g., space, time and money) might exceed the benefits of a few hours of therapy per day. Instead robots have fewer needs for space, time, or care and their sensors can respond to environmental changes simulating interaction with the patient. The robot can monitor patients or be used in the therapy. Other potential benefits of therapy with robots are that there are no known adverse effects, specially trained personnel are not required and they can repeat the script in the same way as many times as it is required (Valentí Soler et al., 2015).

Various studies have shown the importance of the duration of the interaction. For this reason can be considered two categories in terms of duration of interaction between human–robot: short-term interactions and long-term interactions (Shibata & Tanie, 2001).

In the case of short-term interaction a human interacts with a robot during a demonstration at an exhibition, a museum, or a similar event, he acquires his first impressions of the robot in a very short timescale. The appearance of the robot influences the subjective interpretation of the behaviour of the robot and in subjective evaluations of the short-term interaction (Sciutti, Rea, & Sandini, 2014).

The long-term interaction is when a human can interact with a robot over a prolonged period or even live together if the robot shares his home or is stationed for example in a school, in a nursing home and in a hospital. The human interacting with the robot gradually acquires some knowledge of the robot by his learning ability. If the robot always displayed the same reaction or behaviour during these interactions, the human would soon become bored with the robot and would quickly discontinue his relation with it. For this reason is important that the robot has some learning function to avoid the human becoming bored by the interaction.

Anyhow, the robot should be robust, durable safe and easy for long-term use for to maintain the relation between human and robot (Shibata, 2004).

1.1 Human-Robot Interaction

The term “robotics” encompasses a variety of research subareas. One subarea is termed *Social robotics* and involves robots that engage in some form of social interaction with humans, through speech, gestures, or other means of communication (Fong, Nourbakhsh, & Dautenhahn, 2003). Another subarea of robotics is *Assistive robotics*, which generally involves robots that aid people with disabilities, mainly for the physical and neurodevelopmental disabilities (Kwakkel, Kollen, & Krebs, 2007). *Socially Assistive Robotics* (SAR) is a fast emerging field that develops from the intersection of these two and involves robots that are designed to help through advanced interaction driven by user needs (e.g., tutoring, physical therapy, daily life assistance, emotional expression) via multimodal interfaces (speech, gestures, and input devices) (Feil-Seifer & Mataric, 2005). SAR arises from connection between social robotics and assistive robotics, and involves robots that are designed to help through social, rather than physical, interaction (Feil-Seifer & Mataric, 2005; Tapus, Mataric, et al., 2007). SAR systems face challenges different from those faced by other social or assistive robots. In fact, SAR design emphasizes emotional expressiveness, user engagement, physical appearance, and robustness during interaction whereas assistive robot design typically focuses on reliability, precision of motion, and repeatability. The social features of SAR systems must aid the user and must coach, motivate, and influence behaviour change, unlike in typical social robotics applications (Scassellati, Admoni, & Matarić, 2012).

Increasingly, research supports the design process by identifying the needs and expectations of the end user-group, be it adults, children, experts, or therapeutic client groups. Although, still not clear to what extent the physical appearance of a robot and the associated psychological impression it may evoke determine whether it will be accepted by the user (Woods, 2006).

However, the appearance of robots is important as it influences the expectations that humans might have when interacting with a robot. For example, a robot that has an overall animal appearance will be perceived differently to a robot, which has a humanlike appearance, and thus may be perceived more as a person rather than a machine. This has important implications for the accompanying behaviour a human user would expect for a machine-like robot compared to a human-like robot. For instance, a human user might expect a human-like robot to have language capabilities and personality characteristics, but might not expect a machine-like robot to have any language communication abilities at all (Woods, 2006).

Robotic appearance will no doubt impact on people's overall perceptions in terms of likeability, whether they would approach the robot and feel comfortable with it, trust, and overall willingness to engage with the robot (Fong et al., 2003).

There is little consistency in physical appearance of robots; the appearance of these robots has ranged across many levels of anthropomorphism, including humanoid, animal-like, and machine-like (non-biomimetic) systems, and across the fidelity of the reproduction from stylized features to a realistic, complex appearance (Scassellati et al., 2012).

Anthropomorphism is the tendency to attribute human characteristics to objects in order to facilitate understanding and interpretation of their actions and if robots should be structurally and functionally similar to a human is still an open research question (Breazeal, 2003). However, this hypothesis was evaluate thanks a study of gaze behaviour, where the eye motion of people during a conversation with an android and human girl were compared and recorded (Minato, Shimada, Ishiguro, & Itakura, 2004). Friedman et al. (Friedman, Kahn Jr, & Hagman, 2003) confirm that the tendency to attribute human-like characteristics to robots with a human appearance is an important design consideration as this facilitates human–robot interaction.

Anthropomorphism in robots takes many forms: It can mean a robot that is built precisely to a child's physical dimensions (Kozima & Yano, 2001); a robot with highly realistic silicone-based skin and expressive facial features (Dautenhahn et al., 2009); a robot built on a doll's body that has typical, although stylized, human features (Billard, 2002); or a robot that is child-sized and -shaped but with simple stylized features and limited expressive abilities (Duquette, Michaud, & Mercier, 2008; Feil-Seifer & Matarić, 2008). To create evocative but visually simple robots, designers often use a cartoon-like style, with oversized and exaggerated primary features, such as eyes, and an absence of secondary features, such as lower eyelids (Kozima, Nakagawa, & Yasuda, 2007; Matsumoto, Fujii, & Okada, 2006). Robots with machine-like bodies and cartoon faces displayed on a screen are another option for providing socially simplified stimuli (Ferrari, Robins, & Dautenhahn, 2009).

Other robots are non anthropomorphic by design. *Zoomorphic* robots are designed to imitate living non-human creatures to allow owner–pet relationships, (e.g., Sony Entertainment Robot, 2004), and caricatured robots primarily focus on developing exaggerated features such as the eyes or mouth (e.g., Cañamero, 2002). Some robots are modelled after animals — for instance, commercial robots Pleo (E. Kim, Paul, Shic, & Scassellati, 2012) and AIBO (Stanton, Kahn Jr, Severson, Ruckert, & Gill, 2008) — and appear social but nonthreatening. These animal-like robots often allow for the expression of social cues that are simpler than those provided by anthropomorphic robots but that are still appropriate to the physical form and easy to interpret. Finally, some robots are not designed to match any biological form. These non-biomimetic robots have a range of appearances based on their intended use, but they tend to be simple, easy to operate, and toy-like. Because a non-biomimetic robot does not possess typical social features, it is usually used as a social mediator that aims to engage children in a task or game with adults and other children (Feil-Seifer & Matarić, 2009; Michaud et al., 2005) rather than used to socially engage with children directly.

In addition to physical appearance, realism can be established or limited through varying levels of biological motion.

The mode of locomotion it is important, because a robot that has two legs is more likely to be perceived by children as having anthropomorphic qualities compared to a robot, which moves using tracks. A robot using tracks for locomotion would usually be considered as being machine-like and, therefore, having industrious functions (Woods, 2006). For instance, a robot that moves its arm with multiple Degrees Of Freedom (DOF) in the shoulder seems more human-like than a robot that can move its arms only up and down in a single plane of motion. Once again, the level of realistic biological motion for a particular robot is dictated by the goals of the interaction. Extensive actuation (typically achieved with multiple motors) induces the perception of anthropomorphism and allows for more complex expression. Minimizing actuation, perhaps to as few as one to three motions, reduces the cost of development and limits the range of behaviours expected from the robot, thus simplifying the interaction. Additionally, having fewer motors reduces the chances of hardware failures on the robot, which is particularly important for devices like these that must survive extended periods of interactive play with children.

Highly realistic biological motion is difficult to generate using robotic systems. Facial expression alone demands large numbers of motors to replicate the effect of more than 30 muscles involved in generating human facial expressions. Because actuating a robot with many motors is expensive, delicate, and time-consuming, few robots for autism therapy are highly actuated. One example of a highly actuated robot is the Facial Automaton for Conveying Emotions, or FACE, which is designed on the basis of biological principles to be a realistic facial display system (Pioggia et al., 2007). FACE has servomotors to control facial movement, as well as a biomimetic proprioceptive system composed of an elastic sensing layer within its artificial skin. Motors can be adjusted to achieve realistic expressions on the basis of feedback from the sensing layer. Using this system, FACE can express six basic emotions.

Most robots have less complex actuation systems. For instance, Bandit (Feil-Seifer & Matarić, 2008) has two DOF in the mouth and one in each of the eyebrows, allowing limited facial emotion expression without being biologically faithful. It can also turn its head side to side (to indicate "no," for example) and has six DOF in each arm, for deixis (pointing) and gestures. Similarly, a remote-control robot named *Kaspar* has a realistic face with significantly less actuation (Dautenhahn et al., 2009). It has two DOF in the mouth (open/close and smile/frown) and three DOF in the eyes (up/down, left/right, and open/close the eyelids). According to its designers, *Kaspar's* minimally expressive face reduces its complexity as a social stimulus. Similarly, Tito (Duquette et al., 2008) and *Robota* (Robins, Dautenhahn, Boekhorst, & Billard, 2005) have few DOF in their arms and heads, so they can perform simple actions such as "dancing" and participate in imitation games while maintaining simplicity in design. *Keepon* was also designed to be simple but expressive (Kozima et al., 2007); it has four motors powering four DOF enabling its body to lean side to side and front to back, bob up and down, and pan or rotate on its base. The researchers determined that these four actions are sufficient to express attention by orienting toward an object or a person as well as happiness (rocking back and forth), excitement (bobbing up and down), and fear (shaking).

Along with actuation of limbs and facial features, robot designers must decide whether to instrument a robot with the ability to locomote within an environment. All robots used in autism therapy research have some movement capability, frequently involving manipulation of body parts.

Social robots are complex machines that are envisioned to engage in meaningful social interaction with humans and with each other (Carlos, Albo, & Dıaz, 2012; Dautenhahn, 2002; Dautenhahn et al., 2005; Duffy, 2003; Flandorfer, 2012; Fong et al., 2003; Giron-Sierra, Halawa, Rodriguez-Sanchez, & Alcaide, 2000; Heylen, van Dijk, & Nijholt, 2012; Leite et al., 2012; Louie, McColl, & Nejat, 2012; Mordoch, Osterreicher, Guse, Roger, & Thompson, 2013; Sekiyama, 1999; Shaw-Garlock, 2011; Tapus, Mataric, et al., 2007; Yumakulov, Yergens, & Wolbring, 2012) and are also seen to have great potential for long-term care and daily care provisions (Gelderblom, Bemelmans, Spierts, Jonker, & De Witte, 2010). Also, social robots are a possible way to address the human resource and economic pressures on health care systems (e.g., created by growing elderly populations) (R. Sparrow & Sparrow, 2006), because being a companion for the elderly is seen as another main application (Gelderblom et al., 2010; Vardoulakis, Ring, Barry, Sidner, & Bickmore, 2012). For example a socially interactive, *Philos,* is a robot designed for use in homes of those who need continual care and capable of daily health monitoring as well as emotional stimulation (HRSI) (Hornfeck, Zhang, & Lee, 2012).

As health care robots they are envisioned to be involved in post-stroke motivation to do exercises (rehabilitation) (Ang et al., 2010), to motivate and enable movement in people with physical disabilities, for supporting self-management in children with diabetes (Blanson et al., 2012), teaching people with Autism to recognize eye contact, facial expressions, social cues, etc. (Arendsen, Janssen, Begeer, & Stekelenburg, 2010; Boccanfuso & O'Kane, 2010, 2011; Damm et al., 2013; Dautenhahn, 2002; Fujimoto, Matsumoto, De Silva, Kobayashi, & Higashi, 2010; Y.-D. Kim et al., 2010; Kozima et al., 2009, 2007; Welch, Lahiri, Warren, & Sarkar, 2010), and to perform tasks otherwise performed by health care staff such as taking blood pressure, carrying and moving patients, bathing patients and easing vaccinations for youth (Arendsen et al., 2010; Boccanfuso & O'Kane, 2010; Damm et al., 2013; Dautenhahn, 2002; Fujimoto et al., 2010; Y.-D. Kim et al., 2010; Kozima et al., 2009, 2007; Welch et al., 2010).

Motivation is a fundamental tool in establishing adherence to a therapy regimen or task scenario and in promoting behaviour change. If a task is below the optimal challenge level, it is too easy for the user and results in boredom. Otherwise, if the task is above the optimal challenge level, it is too hard and causes the user to get anxious or frustrated. Therefore, an instructor that oversees user performance in a task scenario must be able to continually adjust the task to meet the appropriate needs of the user in order to increase or maintain intrinsic motivation to perform the task (Fasola & Matarić, 2012).

There are two forms of motivation: intrinsic motivation, which comes from within a person, and extrinsic motivation, which comes from sources external to a person. Extrinsic motivation, though effective for short-term task compliance, has been shown to be less effective than intrinsic motivation for long-term task compliance and behaviour change (Dienstbier & Leak, 1976; Fasola & Mataric, 2012). Intrinsic motivation, however, can be affected by external factors. In a task scenario, the instructor (a SAR, for example) can impact the user's intrinsic motivation through verbal feedback. In fact, verbal feedback provided to the user by the instructor certainly plays an important role in task-based motivation, but the task itself and how it is presented to the user perhaps plays an even more significant role.

Self-determination, represented in the task in the form of choice of activity (Zuckerman, Porac, Lathin, & Deci, 1978), choice of difficulty level (Fisher, 1978), and choice of rewards (Margolis & Mynatt, 1979), has been shown to either increase or be less detrimental to intrinsic motivation than similar task conditions that do not involve choice (Fasola & Matarić, 2012).

The primary focus of the study by Fasola & Mataric (2012), was on eliminating the perceived repetitiveness of the robot's verbal instructions/comments, because if the robot is perceived by the user as repetitive and hence predictable, this can lead to a decrease in the perception of the robot's intelligence by the user, and ultimately to a loss of trust in the robot's helpfulness in motivating exercise. In fact, the robot always drew from a list of phrases that emphasized the same point when speaking to the user, choosing randomly at run time. Adding the user's name to the interaction dialog was an important part of our system design, not only to add variability, but also for its relationship building effect (Bickmore & Picard, 2005). Having the robot refer to the user by name is an important part of personalizing the interaction, along with providing direct feedback specific to the individual user's performance level and performance history during the games, and referencing mutual knowledge.

In the study by Fasola & Mataric (2012), the SAR exercise system was very well received, with high participant evaluations regarding the enjoyableness and usefulness of the interaction, companionship, social presence, intelligence, and helpfulness of the robot coach, and the positive mood and attributed importance of the exercise sessions. The system was also found to be effective in motivating consistent physical exercise throughout the interaction, according to various objective measures, including average gesture completion time, seconds per exercise, and feedback percentage.

In conclusion, the overall acceptance of the SAR exercise system by elderly users is very encouraging and illustrates the potential of the system to help the elderly population to engage in physical exercise to achieve beneficial health outcomes, to facilitate independent living, and ultimately to improve quality of life (Fasola & Matarić, 2012).

Chapter II

Socially Assistive Robotics

The use of Socially Assistive Robotics (SAR) within the acceptance paradigm is even more complex and essential, than the acceptance of other robotic technology. This is due to the increased value of the psychological, communicational, and emotional factors, in addition to the common ergonomics, safety, and previous experience factors that are found in the interactions with SAR robots (Heerink, Kröse, Wielinga, & Evers, 2009; Heerink, 2011; Picard & Daily, 2005; Picard, 1997).

SAR cover a wide range of design solutions: *machine-like robots*, which have an unequivocal mechanical and computer-like aspect; *human-like robots*, whose form resembles a human body and/or have human facial features (e.g., eyes, nose, mouth, eyelids, etc.); *androids* or very realistic human-like robots; *mechanical human-like robots* which combine human-like and machine features; *animal-like robots* that simulate animal behaviour and morphology; and *mechanical animal-like robots* which combine animal-like and machine features. These categories were defined by DiSalvo et al., (2002), MacDorman & Ishiguro (2006), and Walters et al., (Walters, Koay, Syrdal, Dautenhahn, & Te Boekhorst, 2009).

Robots create opportunities not only to learn from a non-threatening, three-dimensional inanimate object, but also to learn through interaction with other human beings, thus encouraging autonomous social behaviour (Fridin, 2014b). This has enabled robots to help with a variety of human-like functions, as well as to aid with the goal of improving social skills in individuals with disability (Houwen, van der Putten, & Vlaskamp, 2014).

Because of the multifaceted expertise required to develop socially assistive systems, the field of SAR is naturally interdisciplinary and shares its challenges with robotics, physiology, psychology, and sociology, among other fields (Tapus, Mataric, et al., 2007). Also from a technological point of view, SAR merges various topics, such as mechatronics, artificial intelligence, and real-time control issues (Feil-Seifer & Matarić, 2011; McColl & Nejat, 2014). Indeed, SAR is currently tested in many fields of application with three primary roles: companion, coach, and play partner. One of the more commonly employed functions of SAR in mental health care has focused on robots in the role of a companion. In much work, SAR systems function in a way that is analogous to a trained therapy animal (e.g., a therapy dog). Although a review on the use of animals in mental healthcare interventions is beyond the scope of this discussion, a growing literature documents the therapeutic value of interactions with animals (e.g., Nimer & Lundahl, 2007).

Another line of research on SAR applications to mental health care has focused on robots as play partners who aid children in practicing or building clinically relevant skills. Socially assistive robots can serve many different clinically relevant functions, including engaging children in task, modelling appropriate social cues (e.g., making eye contact), facilitating joint attention tasks, and serving as partners for practicing critical social skills (e.g., taking turns in play; (Scassellati et al., 2012; Scassellati, 2007).

Socially assistive robots is used along with human providers (e.g., therapists, research assistants) to increase engagement and offer additional opportunities for social interaction and skill building within an interaction (e.g., Atherton & Goodrich, 2011). These socially assistive robots elicit positive social responses from children and are generally experienced as a novel and engaging addition to treatment (Scassellati, 2007). However, the treatment potential for SAR in Autism Spectrum Disorder (ASD) surpasses simple novelty effects (Rabbitt, Kazdin, & Scassellati, 2014).

Indeed, an important goal of SAR research is understanding how interactions with robots and skills learned or rehearsed with an SAR system can be translated into real-world situations and in interactions with other people. In fact, the greatest value in these systems may be understanding benefits from interactions with SAR after the robot is no longer physically present (Rabbitt et al., 2014).

A third role that socially assistive robots have occupied in mental health research is that of a coach or instructor. Much like the examples provided previously of *Autom* the weight loss coach, and *Bandit,* the exercise instructor, socially assistive robots can provide direct instruction and supervision to patients or clients engaged in relevant treatment activities (Fasola & Matarić, 2013; Kidd & Breazeal, 2008). These robots can describe and model tasks, monitor patient performance, provide corrective feedback, and offer encouragement and support. Even so, the idea of a coach of instructor helps to convey the spirit of a robot guiding users through tasks.

However, the robots can also be used outside of treatment sessions. In this way, the robots can serve to engage and encourage patients in performing treatment relevant activities outside of the therapy room, essentially helping to extend a therapist's reach into a patient's home (Rabbitt et al., 2014).

Socially assistive robots have been shown to have promise as potential assessment and therapeutic tools, because children with ASD express an interest in interacting socially with such machines (Grynszpan, Martin, & Nadel, 2007; Scassellati, 2005; Werry et al., 2001).

In the field of education and care of children, SAR research mainly focuses on the therapeutic applications for children with developmental disabilities, like those affected by ASD (Diehl et al., 2012; Feil-Seifer & Matarić, 2009; Robins et al., 2005; Scassellati et al., 2012).

Results have shown that children with autism proactively interact with simple robots and that such robots can mediate joint attention (Robins et al., 2005). Studies have also shown that a simple robot can have a positive effect on gaze and physical contact behaviour when acting as a social mediator (Michaud et al., 2005; Werry et al., 2001). Storytelling robots have been used for therapeutic applications as well (Lathan, Boser, Safos, Frentz, & Powers, 2007). Finally, a cartoon-like robot is being used as part of a long-term study in a day care centre (Kozima et al., 2007; Kozima & Nakagawa, 2006). Most encouraging about these efforts is that children with ASD are often motivated to exhibit proactive social interaction such as joint attention when a robot is present (Robins et al., 2005).

The "WikiTherapist Project" is a very ambitious project which used the humanoid robot NAO (Gillesen, Boere, & Barakova, 2010). This project aims to empower health researchers/practitioners with robot assistants or mediators in behavioural therapies for children with ASD. The goal of the project is to create a web-based community of therapists and robot practitioners who co-create robot behaviours and scenarios with different complexity. The expected result is a robotic environment that is easy to control by non-specialists, which is equipped with a library of behaviours, and scenarios that are found useful for behavioural training of people with ASD (Thill, Pop, Belpaeme, Ziemke, & Vanderborght, 2012).

Also, a small humanoid robot is used in a paediatric hospital to implement cognitive-behavioural strategies (distraction and blowing) while children received a flu vaccination from practitioners (Beran, Ramirez-Serrano, Vanderkooi, & Kuhn, 2013). A humanoid robot provides a highly engaging and entertaining distraction that is able to divert children's attention away from their worry of fear and pain of the vaccination. Thus, it was hypothesized that children who were distracted by a robot during their flu vaccination would experience lower levels of pain and distress than children without such distraction (Taddio et al., 2010; Uman, Chambers, McGrath, & Kisely, 2008). This study demonstrates how human–robot interaction can be used as a medium for paediatric care and shows the following conclusions *"First, as a pain coach, humanoid robots can be designed to use cognitive-behavioural, distraction, and coaching strategies to support children during various types of medical procedures such as tissue repair and intravenous starts. Second, research can explore how a humanoid robot can educate children about health. Perhaps children's propensity to engage with a robot makes them willing to listen to general information and instructions about health presented by one. Third, with considerable time spent in waiting rooms, a humanoid robot can be tested for interacting as a companion with children and their parents to entertain and ease their anxiety while waiting. Finally, a humanoid robot can serve in a coordinating capacity to greet families and collect demographic and health-related information from them to assist with* *administrative duties."* (Beran et al., 2013).

In the field of education and care of children, *Socially Assistive Robotics* (SAR) was also successfully applied to personalise health education for children with diabetes (Belpaeme et al., 2012; Blanson et al., 2013; Looije et al., 2006) to assist either teachers in telling pre-recorded stories to preschool children (Fridin, 2014b) or parents in home education (Han, Jo, Park, & Kim, 2005).

An important goal of SAR research is the production of permanent benefits that last after the robot is no longer physically present. It is fundamental to understand how interactions with robots and skills learned or rehearsed with an SAR system can be translated into real-world situations and to interactions with other people (Rabbitt et al., 2014).

Recently, Benitti (2012) reviewed the scientific literature on the use of robotics in schools and suggested that educational robotics can act as an element that enhances learning, if appropriately used.

Robots have also the advantage of overcoming concerns regarding physical inactivity and isolation of children that is typically associated with the use of computers (Dockrell, Earle, & Galvin, 2010) because they engage them in interactions and encourage movement (Tanaka, Movellan, Fortenberry, & Aisaka, 2006). Recent studies also show that a humanoid robot can be successfully used in physical rehabilitation. In fact, it is essential to motivate children during rehabilitation, since physical therapy sessions include repetitive tasks (Brooks & Howard, 2012). Monotonous actions cause a reduction in performance of behaviour of children due to decreased attention. Furthermore, repetition decreases attention on the current activity and motivation for repetitive exercise. Playing a game is therefore a concrete way for children to communicate and express themselves more naturally (Landreth, 2012), children's motivation to participate in activities can be improved by game-like child-robot interaction.

In particular, robotic assistants have the potential to overcome concerns about the physical effects of children's use of computer-based tools (Dockrell et al., 2010), because they encourage children to be mobile during a game (e.g.

Tanaka et al., 2006). As an example, Fridin et al. (Fridin & Belokopytov, 2014b) show that preschool children are more involved in a motor task when they interact with a robot rather than with a virtual agent. The robot can be a practical learning partner that motivates students in learning and elicits learning performance naturally (Chang, Lee, Wang, & Chen, 2010).

Researchers have shown that a robot companion can help to improve engagement and elicit novel social behaviours in children with developmental disabilities, for instance with ASD (Scassellati et al., 2012) and Down-Syndrome (DS) (Lehmann, Iacono, Dautenhahn, Marti, & Robins, 2014). Lehmann et al. (Lancioni, Basili, & O'Reilly, 2001) have also worked to combine behavioural intervention approaches with assistive technology, where established teaching methods are employed to elicit skills using a robot.

Social robots have been used in the common areas of nursing homes, aiming to increase socialization among residents (Baltus et al., 2000; Jung et al., 2005; K. Wada, Shibata, Saito, & Tanie, 2003). SAR has also been used in rehabilitation robotics, where it has been shown that assistance primarily through social interaction may have therapeutic benefit.

Regular physical exercise has been shown to be effective at maintaining and improving the overall health of elderly individuals (Baum, Jarjoura, Polen, Faur, & Rutecki, 2003; Dawe & Moore‐Orr, 1995; McMurdo & Rennie, 1993; Thomas & Hageman, 2003). Physical fitness is associated with higher functioning in the executive control processes (Colcombe & Kramer, 2003), correlated with less atrophy of frontal cortex regions (Colcombe et al., 2004), and with improved reaction times (Spirduso & Clifford, 1978) compared with the sedentary. Social interaction, and specifically high perceived interpersonal social support, has also been shown to have a positive impact on general mental and physical wellbeing (Moak & Agrawal, 2010), in addition to reducing the likelihood of depression (George, Blazer, Hughes, & Fowler, 1989; Paykel, 1994; Stansfeld, Rael, Head, Shipley, & Marmot, 1997; Stice, Ragan, & Randall, 2004).

For example, in the care for post-stroke (Eriksson, Mataric, & Winstein, 2005; Matarić, Eriksson, Feil-Seifer, & Winstein, 2007), a robot verbally encourages a user to keep to a therapy regimen consisting of functional arm exercises, and post-operative cardiac care (Kang, Freedman, Matarić, Cunningham, & Lopez, 2005), where a robot reminds a patient to perform spirometry breathing exercises, and exercise therapy for elderly residents of a nursing home (Tapus, Fasola, & Mataric, 2008) as part of a preventative care regimen for elders with Alzheimer's. Other rehabilitation projects have explored using a robot as a means of motivating rehabilitation through mutual storytelling that involves expressive movements as a means to keep a repetitive exercise regimen appealing to children (Lathan et al., 2007; Plaisant et al., 2000).

2.1 SAR and Autism Spectrum Disorder

One of the main fields of application for current SAR research is in clinical settings for children with developmental disabilities, like those affected by Autism Spectrum Disorder (Diehl et al., 2012).

The Autism Spectrum Disorder (ASD) is part of a larger group of Neurodevelopmental Disorders (including also Intellectual Disability, ID) and it usually manifests in the first three years of the developmental period. According to the DSM-5 (American Psychiatric Association, 2013), ASD is defined as persistent deficits in social communication and interaction in different contexts, as well as restricted, repetitive patterns of behaviours, interests or activities.

As implied by the term spectrum, every child has different characteristics, including levels of autistic tendencies and existing abilities. This implies that the appropriate intervention approach, such as a robot's behaviour and the interaction scenario, should also be different for each individual.

It has been shown that those with autism are attracted to mechanical and electronic devices (Gabriels, Ivers, Hill, Agnew, & McNeill, 2007; Robins & Dautenhahn, 2004). Consequently, it would seem that a robotic device could be a useful tool when a therapist is trying to help, teach, communicate, or interact with those with autism.

A study by Belpaeme et al., (2012) indicated that physical robots can effectively engage the attention of young users and that adaptation to user characteristics can be a useful tool in supporting sustained interaction.

Related to their deficit in social and communication skills, children with ASD often experience depression and anxiety when interacting with fellow peers due to the complexity and unpredictability of human behaviours. Furthermore, in play scenarios, ordinary toys are often unable to prompt responses and engagement with children with ASD (Shamsuddin, Yussof, Ismail, Mohamed, et al., 2012). Accordingly, the controllable autonomy of robots offers the best of both worlds; resulting in robots being propitious social partners for these children (Adams & Robinson, 2011; Scassellati et al., 2012).

The application of robotics in the treatment of children with ASD aims to teach children basic social skills, communication and interaction (E. S. Kim et al., 2013; Tapus, Member, & Scassellati, 2007).

Scassellati (2005a) indicates that robotic devices can provide quantitative data that could be of use by physicians in diagnosis, tracking the progress of patients, and for the comparison of patients. For example, (Scassellati, 2002) shows that robots generate a high degree of motivation and engagement in subjects, including subjects who are unlikely or unwilling to interact socially with human therapists. Also, Scassellati (2007), has been attempting to give robots a ‘theory of mind’, an area in which children with autism are known to have deficits; in fact, autism has been the inspiration for the design of a robot in his work.

Several studies have shown that some individuals with ASD prefer robots to humans. For example, in Vanderborght et al., (2012) has been shown that the social robot *Probo,* in specific situations, could help the social performance of autistic children. Robins et al. (Robins et al., 2005) showed this preference in children with ASD and limited verbal skills. Humanoid robots, which look like a human being but are much less complex compared to the human, could allow a child with ASD to facilitate the transfer of skills learned through models of imitative human-robot interaction to child-human interaction.

Imitation as a means of communication is related to positive social behaviour and therefore is a good predictor of social skills (Brooks & Howard, 2012). Children with ASD often find it difficult to imitate the behaviour of other people (Williams, Whiten, & Singh, 2004) and imitation is used in therapy to promote better body awareness, sense of self, creativity, leadership and ability to initiate interaction. In Vivanti et al. (Vivanti, Nadig, Ozonoff, & Rogers, 2008), results of eye-tracking analyses indicated that children with autism showed decreased attention to the demonstrator’s face when observing a model to be imitated. Attention to the face is essential to pick up extensive cues from the demonstrator’s intentions. Some experimental studies have controlled for motivation and demonstrated that children with autism engage well with imitation tasks (Meyer & Hobson, 2004).

Sometimes imitation is structured, as children are encouraged by adults or by the same robot actions that mimic the child (Duquette et al., 2008). In other cases, imitation develops spontaneously as part of a game with a child that mimics the behaviour of the robot and vice versa (Robins, Dautenhahn, & Dickerson, 2009). This game also extends to triadic interactions between a child with autism, an adult or child, and a robot.

It has been reported that a higher number of adults with ASD mimic movements of a robot's hand than an actual human's hand (Bird, Leighton, Press, & Heyes, 2007). In addition, children with ASD have faster movements in grasping a ball when they see the robotic arm that performs the movement than the vision of the human arm, while typically developing children showed the opposite effect (Pierno, Mari, Lusher, & Castiello, 2008).

These studies, while not without limitations, suggest that people with ASD can benefit from activities involving imitation of a robot and can then develop human imitation, at least in the initial phase of treatment. However, despite the empirical evidence of the many potential advantages, it must be stated that most of the findings are exploratory and have methodological limitations that make it difficult to draw firm conclusions about the clinical utility of robots (Diehl et al., 2012).

Review of past studies has identified Human Robot Interaction (HRI) as part of the intervention for children with ASD. However, most explored robotic systems in the earlier works are mainly in the form of toys, not humanoid-form social partners (Weir & Emanuel, 1976). As human-like robots pose greater potential in ASD therapy for skills generalization (Ricks & Colton, 2010), the application of intelligent robotic system in the form of humanoid begun to gain its momentum. An emotional humanoid robot with expressive skin called *Zeno* (Ranatunga, Rajruangrabin, Popa, & Makedon, 2011), at the University of Texas at Arlington, is studied for its potential to aid ASD subjects to undergo therapy in a realistic and engaging manner. The minimally expressive humanoid robot *KASPAR* that has been shown to be an important object in encouraging interaction in children with ASD (Robins et al., 2009) and *Robota*, a humanoid robotic doll that encourages human-human interaction (Robins, Dautenhahn, Te Boekhorst, & Billard, 2004) are past studies that explores the usage of robots in human form as part of ASD therapy (Shamsuddin, Yussof, Ismail, Mohamed, et al., 2012).

With the introduction of humanoid robot NAO by Aldebaran-Robotics in 2008, a performant biped robot is now available and affordable for research laboratories and the mass market (Shamsuddin et al., 2011).

A growing number of studies have investigated the application of advanced interactive technologies to ASD intervention, including computer technology (Goodwin, 2008), virtual reality (VR) environments (Bellani, Fornasari, Chittaro, & Brambilla, 2011), and more recently, robotic systems (Diehl et al., 2012).

Specifically, data from several research groups have demonstrated that many individuals with ASD show a preference for robot-like characteristics over non-robotic toys and humans (Dautenhahn & Werry, 2004; Robins, Dautenhahn, & Dubowski, 2006) and, in some circumstances, even respond faster when cued by robotic movement than human movement (Bird et al., 2007; Pierno et al., 2008).

In the only identified study in this category to date, Duquette et al., (2008) demonstrated improvements in affect and attention sharing with co-participating partners during a robotic imitation interaction task using a simplistic robotic doll. The study paired two children with robot mediator and another two with human mediator. Shared attention and imitation were measured using visual contact/gaze directed at the mediator, physical proximity, as well as rated facial expressions and gesture imitations. Although this study was conducted using a comparison group, the very small sample size, pre-programmed behaviours, and remote operation were limitations of the system that restricted interactivity and individualization.

In another study, use of *IROMEC* with children with ADHD and some traits of autism seem to be advantageous due to its mobile characteristics, which facilitate the needs of children with this specific disorder more explicitly (Lehmann, Iacono, Robins, Marti, & Dautenhahn, 2011).

One of the important conclusions of research in using robots for autism to date is the need for individualizing such robot systems to the needs of each person, which brings additional challenge to robotics research and to the sets of principles for building training scenarios.

The effectiveness of dyadic interaction with a robot which helps children with ASD to improve the interactions with other people has been shown by Robins et al., (2005).

Given rapid progress and developments in technology, it has been argued that specific computer - and robotic - based applications could be effectively harnessed to provide innovative clinical treatments for individuals with ASD (Goodwin, 2008).

Children with ASD also spent significantly more time looking at the humanoid robot than the human administrator, a finding replicating previous work suggesting attentional preferences for robotic interactions over brief intervals of time (Dautenhahn et al., 2002; Duquette et al., 2008; Kozima & Nakagawa, 2006; Michaud & Théberge-Turmel, 2002; Robins et al., 2009).

A specific issue arose in relation to the expressivity of the face. Although Autistic children do indeed require a very simplified face without too many details that should resemble a cartoon-like “mechanical” face; Moderate Mentally Retarded children (MMR) and Severe Motor Impaired children (SMI) require a more expressive face, able to show basic facial expression, in order to appropriately support imagination in Symbolic games. However, the level of competence and preferences of Autistic children can vary considerably. For example, high-functioning Autistic children can recognize a digital face on a screen, while the Autistic children with a severe impairment are more likely to recognise a physical face. This suggests that a robot characterized by predictable reactions is better able to facilitate autistic children in expression than a human.

Autistic children of listeners and speakers perform less well than neurotypical children in conversation especially when the listener is a human, (human is essentially characterized by a high degree of variability on verbal and nonverbal emotional reactions, i.e., unpredictable reactions (Pierno et al., 2008). Adding the fact that the child is impaired in interpreting the referential statement of other people (Baron-Cohen, 1997), the listener's verbal and nonverbal emotional contributions are not always scrutinized. There are at least two main reasons for this. The first reason is associated with the fact that autistic children have continual comprehension and language expression problems. Even if autistic children acquire language, it is often lacking any depth and is characterized by a paucity of imagination (Pelphrey & Carter, 2008). The second reason is that autistic children experience difficulties in perception and emotion, functions which are linked to language (Giannopulu & Watanabe, 2014; Giannopulu, 2013) o social interaction and metalizing (Frith & Frith, 2003).

During treatment a robot will need to be programmed for different relevant tasks and for practical purposes, it would be ideal for therapists to have the ability to complete this programming themselves. When a robot is used in treatment for ASD, the specific focus that a therapist addresses in given session are likely to change over time for an individual patient (e.g., because a patient makes progress and masters skills, because a patient enters a new environment that possess new challenges) and across different patients (e.g., because of different presenting problems, because of different levels of functioning). Getting technological consultation and programming assistance before every session is not feasible for a variety of reasons (e.g., cost, time). Therefore, therapists and other users must be able to manage and understand how to use the robot for a variety of clinical needs. Apart from the challenges of using robots among practitioners, there will be an inevitable reticence or resistance to their use by professionals and clients alike.

One major shortcoming in all of the studies described here is that the data are qualitatively but not quantitatively rich: Robot experiments tend to involve descriptive case studies of a small number of individuals over a few days or, rarely, a few weeks or months. At the moment, there are no large-scale longitudinal studies with many participants that provide quantitative measures about how people with autism interact with social robots.

In conclusion, although the effects demonstrated by SAR systems are consistently reported across studies that vary in geography, the degree of disability present in participants, the robot appearance and capabilities, and the nature of the interaction, there are no clear conclusions on why these robots succeed in establishing and, in some cases, maintaining social engagement (45).

As summarized by Scassellati, Admoni, et al., (2012), there are many viable hypotheses about why robots generate prosocial behaviours in many children:

- perhaps the simplified social cues that robots present result in less overstimulation of the children;
- perhaps robots offer more predictable and reliable responses than those from a human partner with ever-changing social needs;
- perhaps robots trigger social responses without the learned negative associations that some children have with human-human interactions;
- and perhaps the exaggerated social prompts that robots provide are better triggers for social behaviour than the nuanced and subtle social prompts from a human partner.

Although SAR research studies have documented numerous interesting effects, few of these efforts offer real insight into why many children with ASD tend to respond to robots with positive social behaviours. Understanding the basic causes of these effects represents perhaps the most critical future direction for SAR research (Scassellati et al., 2012).

2.1.2 NAO robot

For most children affected with autism, the complexity of emotions expressed by normal persons may be the reason why they experience difficulty understanding gestures or facial expressions, resulting with them shying away from friends and the world around them. As NAO possess simpler features compared to real humans, it will be more approachable and appealing to these children. In addition, the humanoid robot NAO is also one of the most advanced and commercially available humanoid, providing ease of programming to support HRI architecture for the intervention of autistic children. In other words, 4 out of the 5 children exhibited a decrease in autistic behaviour (communication subscale) when the robot is executing HRI modules during the single session of child-robot interaction.

NAO robot is a humanoid robot produced by Aldebaran Robotics and simpler in appearance compared to real humans. The robot has up to 25 degrees of freedom and is capable to walk in a biped way. NAO robot is built in the size of a two-year old child and this fits the requirements of robot design for autism therapy that requires the robot's size to roughly be the size of a human toddler (Giullian et al., 2010). The embedded low level control processor chest board is mounted in the robots chest and is capable to read all sensors within a cycle time of 8 ms and writes new target values for the controlled actuators. All motors are monitored by the chest-board to ensure no damage through overheating. The higher-level control is realized by an embedded PC board in the robots head on which a Linux operating system runs. A real time kernel patch is applied to the Open Embedded based Linux distribution to ensure the computation time needed for the communication between the chest board and the embedded PC.

Because difficulties in sustaining joint attention are one of the manifestations of autism; helping the children with ASD to focus and give attention is critical to help them in learning and also acknowledge the presence of other people around them (Ricks & Colton, 2010).

These promising results indicate that the basic modules of interaction together with the appealing appearance of the NAO robot were able to attract the children's attention, and hence keep each child engaged with the robot during interaction. This 'engagement' had resulted with a reduction in autistic behaviour of these children compared to their typical environment in class (Shamsuddin et al., 2011).

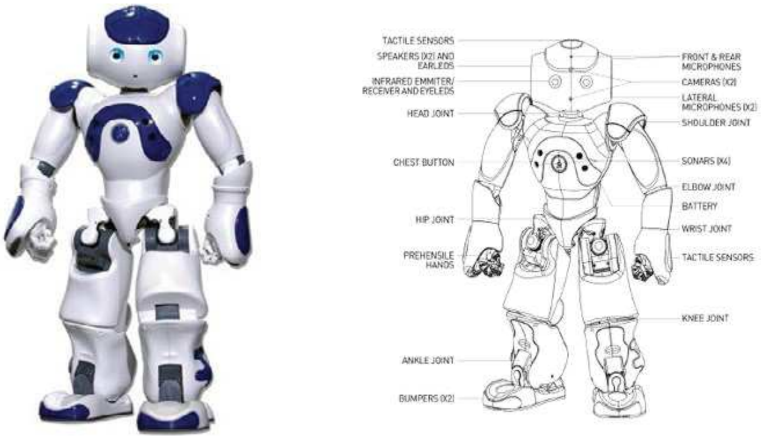


Figure 2.1 *The humanoid robot NAO by Aldebaran Robotics in France.*

Chapter III

Acceptance of robotics

There is no universally accepted definition of ‘personality’ in psychology. However, it is generally agreed that personality comprises a set of characteristics in terms of abilities, beliefs, preferences, dispositions and temperamental features that have consistency across situations and time (Dryer, 1999). The tendency for humans to assign personality qualities to robots may facilitate the user to understand its behaviour, and help to engage with the robot; this may be particularly important for children, cf. (Norman, 1994). Robotics research thus suggests that a robot’s ability to adapt its behaviour to the user’s preferences and personality can improve acceptability (Broadbent et al., 2009). For this reason, the robot personality should match its design purpose (Druin, 1999). The effects of variables as social influence and image on technology acceptance have been widely acknowledged (De Graaf & Ben Allouch, 2013; Y. Lee, Kozar, & Larsen, 2003; Rogers, 2010).

Following this idea, it has been shown that increasing robot human-like resemblance alone is not sufficient to make the device more likable. In fact, although acceptance seems to linearly increase with an increase in robot similarity to humans, at a certain point this relationship abruptly changes (Mori, 1970). An appearance almost human causes an uncanny feeling, while only a perfect imitation of human appearance can actually produce an acceptance level comparable to that measured for fellow humans. Consequently, the researchers suggested that robot designers have two alternatives to avoid this “Uncanny Valley”: either achieving a perfect human resemblance or aiming at a clearly non-human robot, which however shares enough anthropomorphic traits to be likeable. Though, also for robotic devices which are clearly non-human, but have a human inspired face, some traits (e.g., the colour of the skin or its masculine/feminine features) can change the idea the robot is perceived by its users, thus modifying also its likeability and its acceptance in different contexts (Eyssel & Hegel, 2012; Eyssel & Kuchenbrandt, 2012). Robots face the significant challenge of attempting to appear intelligent to provoke users to perceive them as genuine. The intelligence of the robot is defined as the user's evaluation of the robot's level of intelligence (Bartneck, Kulić, Croft, & Zoghbi, 2009). A robot that is evaluated as more intelligent is liked more and viewed as more realistic (Cuijpers, Bruna, Ham, & Torta, 2011) and, for this reason, is important to include this variable when studying the user acceptance of social robots (De Graaf & Ben Allouch, 2013).

Some authors have proposed that the unpleasant feeling described in the "Uncanny Valley" hypothesis can be caused or emphasized by a conflict between a human-like appearance and a not exactly human-like motion, i.e., movements not as smooth and natural as the ones of proper human agents (Chaminade & Cheng, 2009). This shows that also the way an agent moves contributes to determining if the robot will be liked or not (Sciutti et al., 2014). On the other hand, the possibility to implicitly match our own motion capabilities with those of a humanoid robot would allow a covert form of understanding that in turn would cause increased acceptance (Sciutti et al., 2012). This premise derives from human studies which have shown that when such matching is reinforced (e.g., by imitation), the likeability of the partner increases (the chameleon effect, Chartrand & Bargh, 1999). Results demonstrated that negative attitudes toward human–robot interaction affects communication with the robot, suggesting that people with highly negative attitudes toward robots mentally tend to avoid human–robot interactions (Nomura, Kanda, & Suzuki, 2006).

The adaptability of the robot is defined as the perceived ability of the system to be adaptive to the changing needs of the user and influences perceived usefulness, enjoyment, attitude towards use and use intention (Broadbent et al., 2009; Heerink, Kröse, Evers, & Wielinga, 2010, 2009; Shin & Choo, 2011;

Venkatesh & Davis, 2000).

De Graff et al. (De Graaf & Ben Allouch, 2013) has found that gender, age, personal innovativeness, general evaluation of a particular technology and cultural background, influences user acceptance.

1) The results of researches indicate gender differences on the perception of robots. In fact, gender affects how users react to a robot (Forlizzi, 2007), men show higher intention to use them in the future and are more willing to accept these robots in their daily lives compared to females and perceive robots as more useful (Arras & Cerqui, 2005; Kuo et al., 2009). In contrast, earlier finding (Shibata, Wada, Ikeda, & Sabanovic, 2009) report that female are more open to taking care of artificial companions than males (Turkle, 2012). Certainly, gender also affects one's attitude towards robots and anxiety towards robots (Nomura, Kanda, Suzuki, & Kato, 2008).

Concerning to adult perceptions of gender relations in HRI trials (Kiesler, 2005), little is known about whether, or how children attribute gender to robots, and how this may lead to some kind of gender stereotype for robots. However, Bumby & Dautenhahn (1999) found that children tended not to attribute gender to robots although they did tend to give the robot-human facial features and a humanoid shape, when they were asked to draw pictures of a robot.

2) Age differences have been discovered to impact abilities, attitudes, behaviours and willingness to use new technologies (Kuo et al., 2009). In fact, older people, as compared to younger people, are more likely to enjoy using and anthropomorphize a robot, are more susceptible for other people's opinions when using technology, show more negative emotions towards robots, and have lower intentions to use a robot (Broadbent et al., 2009; Lessiter, Freeman, Keogh, & Davidoff, 2001; Libin & Libin, 2004; Venkatesh, Thong, & Xu, 2012).

3) Personal innovativeness is defined as the willingness of users to try out any new technology (Agarwal & Karahanna, 2000) and is conceptualized as a trait, a relatively stable descriptor of an individual that is invariant cross-situational considerations (Agarwal & Prasad, 1998). These traits are generally not

idiosyncratic to a specific configuration of individual or situational factors and they are not affected by any environmental or internal variables (Webster & Martocchio, 1992).

4) Attitude towards robots is defined as the psychological states reflecting opinions that people ordinarily have about robots (Nomura et al., 2008). A study including this measure has discovered that people's attitude towards robots influences the level anxiety when confronted with a robot (Nomura et al., 2008) and the acceptance of assistive robots in people's own homes (Nomura, Kanda, Suzuki, Yamada, & Kato, 2009).

5) In conclusion people with different nationalities tend to rate their experiences with robots differently on enjoyment, usefulness, anthropomorphism, sociability, and perceived behavioural control (European Commission, 2012; Li, Rau, & Li, 2010), because each culture possesses its own level of exposure to robots through either media or personal experiences (Broadbent et al., 2009). For example, the typical ‘‘robots will take over the world’’ scenarios that are often portrayed in Western cultures is less dominant in Japan (Kaplan, 2004).

Culture influences each aspect of people's social behaviour. In one large scale cross-cultural study with more than 50 countries, Hofstede (1980) provided a framework to explain the different social behaviours with the national culture. According to him, the nationality is important for at least 3 reasons. The first is political, because Nations are political units, rooted in history, with their own institutions; the second reason is sociological because we all derive part of our identity from it and it is part of the “who am I”; and the third is psychological because the thinking is partly conditioned by national culture factors.

The results of experiments into cross-cultural differences in the subjective evaluation of a human interactive seal robot *Paro* showed that regardless of differences between countries, cultures, religions, and so on, a human interactive robot has the potential to be accepted by most people. In this study, the citizenship of the sample was Japan, Great Britain, Sweden, Italy, Korea, and Brunei (Shibata, 2004).

Cultural and individual differences such as age and previous exposure to robots could play an important role in explaining possible differences in attitude that emerge (Broadbent et al., 2009). The number of humanoids robots, toy robots, games, and TV shows give Japan the leading role in robotic development and culture (Bartneck, Nomura, Kanda, Suzuki, & Kato, 2005). However, in a large study with 467 participants from seven different countries, the Japanese were not as positive as stereotypically assumed (Bartneck, Suzuki, Kanda, & Nomura, 2007). The participants' cultural background had a significant influence on their attitude and the US participants had the most positive attitude, while participants from Mexico had the most negative attitude.

A comparison of elderly perceptions of social assistive domestic robots between Italian and Swedish user groups is presented in Cortellessa et al., (2008). The results, obtained through a video-based methodology, highlight the variety in level of appreciation of domestic robots for elderly care as it relates to a number of aspects of culture that are not necessarily trivial to identify. The Swedish user group, whom likely has more exposure to ICT (Information and Communication Technology), is less challenged by the prospect of having to program or repair the device.

Furthermore there are substantial differences between the views of children and adults, because there is a perception of the world substantially different.

The hypothesis that the major differences between young children and adults ranking could be due to their a priori expectations seems to be confirmed by the modifications in the relevance scores induced by an actual experience with the robot. For example, in a study with *iCub* robot the youngest participants after the interaction have started giving more importance to robot abilities than to robot shape. The reactions during robot motion presentations are wide and fast motions of the whole body, more common to games and physical activities, excited the children, while dexterous and precise fine hand motions interested the adults. In addition, the goal of an interaction might be quite different between children and adults. In fact, kids want the robot to be a game companion, while adults see the robot as a helper or as a replacement in stressful tasks (Sciutti et al., 2014).

In general robot acceptance by younger children is difficult to assess because it is not possible to reliably administer the common questionnaires, thus acceptance factors are indirectly derived observing the interaction (Salter, Werry, & Michaud, 2008).

In contrast to Bumby & Dautenhahn, (1999), a study based on imagined robots not actual pictures of robots, the current results highlighted that children aged 9–11 years assigned a gender to the robot images, in particular male gender. It was interesting that female gender was associated with positive robot traits such as happiness and friendliness, whereas male gender was not distinguishable for positive and negative robot traits.

School children's perceptions and evaluations of different robot designs were studied by Woods (2006). A large sample (N=159) of children evaluated 40 robot images and judged human-like robots as aggressive, but human-machine robots (i.e. with human-like features in addition to some machine-like traits) as friendly. This result on children's perceptions of the robots' behavioural intentions provided tentative empirical support for the Uncanny Valley, hypothesized by Mori (Mori, MacDorman, & Kageki, 2012).

Projects addressing the development of assistive social robots for experiments in eldercare generally either focus on possibilities and requirements or on measuring the responses to it by performing experiments with specific robots.

Studies investigating robot-acceptance in older adults involve participants interacting with a robot during a period of time (from several minutes to several days). Robot-acceptance is measured by different kinds of questionnaires and/or interviews.

One recent survey of public attitudes toward using robots in eldercare and other applications (Moon et al., 2012) showed, among other things, a high acceptance for the bathing application, the therapeutic robot animal, the human-like care robot, *Ri-Man* (for carrying patients) and a surveillance care robot (Danielson, 2010; Moon et al., 2012). The main reasons for rejection in the case of the bathing robot were based on the judgment that the robot based action would be inferior to the human-based action and that it would take away jobs from human workers (Moon et al., 2012).

The experiments with a seal shaped robot (*Paro*) showed that a robot could have the same beneficial effect on elders that a pet can have, making them feel happier and healthier (Shibata, Wada, & Tanie, 2003; Kazuyoshi Wada & Shibata, 2006). A more recently developed robot with similar pet-like functionalities is the *Huggable* (Stiehl et al., 2006). Another example of a robot developed specifically for eldercare experiments is 'nursebot' *Pearl*. This robot could actually provide advanced assistance to elders, although its functionalities were merely simulated (Montemerlo, Pineau, Roy, Thrun, & Verma, 2002; Pollack et al., 2002). Conversely, *Care-o-bot* robot for eldercare is intended to provide assistance in many ways, varying from being a walking aid to functioning as a butler projects concern an assistive social robot that is developed as an integrated part of an intelligent home (Parlitz, Baum, Reiser, & Hägele, 2007). Examples are the Italian *Robocare* project (Cesta, Cortellessa, Pecora, & Rasconi, 2007; Cesta & Pecora, 2005) and the Intelligent sweet home at *KAIST*, South Korea (H. E. Lee, Kim, Park, & Bien, 2005; Park, Lee, Kim, & Bien, 2008). These type of robots are both socially interactive (Fong et al., 2003) and developed or used as assistive agents and can be assistive by their social interaction, like *Paro* (Feil-Seifer & Mataric, 2005), or by providing monitoring or physical assistance like Care-o-bot and an assistive social robot can be a mixture of those two.

Kuo et al., (2009) used blood pressure monitoring in the service scenario to investigate the differences between two age groups (40–65 years [n=29] versus 65 years [n=28]) in attitudes and reactions before and after their interactions with a mobile robot capable of measuring blood pressure. They found few differences between the two age groups. However, a significant sex effect was found, as males had a more positive attitude toward robots in health care. Although participants of both sexes rated the performance of the robot highly, they expressed desires to have more interactivity and a better voice from the robot.

Research De Ruyter et al. (De Ruyter, Saini, Markopoulos, & Van Breemen, 2005) concerned a robotic interface (the *iCat* made by Philips), which was tested in a Wizard of Oz experiment where the robot was controlled remotely by an experimenter while the adult participants perceived it to be autonomous.

The results showed that the extravert *iCat* was perceived to be more socially intelligent and was also more likely to be accepted by the user than a more introvert version. The same robot was used in an experiment by Looije et al. (Looije, Cnossen, & Neerincx, 2006) where it featured as a personal assistant for a small group of people with diabetes. Results showed that participants appreciated a more socially intelligent agent more and had a higher intention of using it than a less socially intelligent agent.

It seems that perceived social abilities of a robotic system are indeed appreciated as they would be in a human conversational partner and research on screen agents indicates that this is also the case for two-dimensional artificial personalities (Bickmore, Caruso, & Clough-Gorr, 2005; Bickmore & Schulman, 2006).

In another study Broadbent et al., (2010) compared attitudes and reactions of 57 participants aged over 40 years who had their blood pressure taken by a medical student and by a robot. The results showed that there were no significant differences between the participants' blood pressure levels or pulse taken by the robot and the medical student, suggesting that robot use in this kind of health care task is appropriate. In spite of this, the participants felt more comfortable with the medical student, and considered him/her to be more accurate. Neither age nor sex but initial attitudes and emotions toward robots were significant predictors of quality of interaction with the robot.

In the research by Stafford et al. (Stafford, MacDonald, Jayawardena, Wegner, & Broadbent, 2014) a mobile robot was placed in a retirement village, over a 2-week period, where 25 older people were invited to use the robot's several functions (vital-sign measurement, medication reminding, fall detection, entertainment, telephone calling, brain fitness, and games). Of the 25 residents, only eleven used the robot over the 2-week trial period. Age, sex, and education were not related to residents' choice to use the robot. Compared to residents who did not use the robot, those who did had significantly more computer experience, better attitudes toward robots, and perceived robot minds to have less agency (capacity for self-control, morality, memory, emotion, recognition, planning, communication, and thought). Furthermore, among robot users, it was also found that attitudes toward robots improved over time. Overall, this research investigated whether older people's attitudes toward robots and their perceptions of the robot's mind could predict the use of a health care robot in a retirement village.

In another research Seelye et al., (2012) studied the feasibility of use and acceptance of a remotely controlled robot with video-communication capability in independently living, cognitively intact older adults. They received daily calls from the research team and up to two additional calls daily from a family member or friend who was trained in the use of the device. The robot was placed in the homes of eight seniors for 2 complete days. The results showed that participants appreciated the potential of this technology to enhance their physical health and well being, social connectedness, and ability to live independently at home. The older adults also voiced little concern about privacy and expressed the wish to have control over who was able to contact them through the device.

The study compared older adults with Mild Cognitive Impairment (MCI) to Cognitively Intact Healthy (CIH) adults on robot use and robot-acceptance. Older adults with MCI were expected to have more difficulties than CIH older adults in learning to use a robot. The authors explored if MCI subjects would have more negative reactions to a robot, as shown in the study of Seelye et al., (2012).

Participants found the robot easy to use, amusing, and not threatening, but they did not perceive it as useful, in fact showed low intention to use an assistive robot and negative attitudes toward it, as well as negative images of it. Further, social influence was perceived as quite powerful on robot adoption. This suggests that robot uptake in older adults could be facilitated by their children or health professionals who encourage them to use this kind of device (Wu & Rigaud, 2014).

High levels of satisfaction with this experiment contrast sharply with low intention of using a robot. Indeed, a majority of them showed hesitation, and even rejection and none of the participants expressed an intention to use an assistive robot presently, because they did not consider themselves in the situation of needing it. In addition to barriers related to adoption of new technologies in older people, “stigma” embodied by an assistive robot or other assistive devices constitutes an important barrier to their acceptance (Blackman, 2013; Gucher, 2012; Parette & Scherer, 2004; Porter, Benson, & Matsuda, 2011) and the stigma associated with the use of an assistive robot could lead to a decision to hold off using one. In fact, assistive technologies designed to facilitate autonomy are often seen as a sign of decline or handicap because an assistive robot conveys images of dependence and solitude, from which the elderly tend to distance themselves (Neven, 2010).

On the other hand, universal design aimed at increasing the market for and production of products usable by everyone (Mace, 2013) might help to destigmatize assistive devices.

In another study Mutlu & Forlizzi, (2008) observed strong differences in how three units medical, post-partum, and support units used the robot, which affected workflow, perceptions of, attributions to, and interactions with the robot, and acceptance of the organizational and workflow changes engendered by the introduction of the robot.

The result shows difference between the perceptions of the utility of the robot by the medical and post-partum units. Interesting is that while people at the medical units attributed these breakdowns to the limitations of the robot, informants at the post-partum units attributed delays and failures in deliveries to the support units. In the study, nurses who treated cancer patients found the robot “annoying” while nurses at the birth units thought the robot was “delightful.” The authors found that the physical environment that the robot functions in has an impact on use and perceptions of the robot. For example, in busy, cluttered hallways, the robot was mostly perceived as getting in the way of other urgent work and taking precedence over personnel and patients.

In the disability field, Autism is one main focus (Damm et al., 2013; Fujimoto, Matsumoto, De Silva, Kobayashi, & Higashi, 2011; Heylen et al., 2012; Stanton et al., 2008) of social robotics research. In fact, many investigate the acceptance of social robots by users and what we expect from robots (Broadbent et al., 2009; Bumby & Dautenhahn, 1999; Flandorfer, 2012;

Heerink et al., 2010; Qianli et al., 2012; Weiss, Igelsböck, Wurhofer, & Tscheligi, 2011; Weiss & Tscheligi, 2010). The staff were highly sceptical of a robot being ever able to replace them as they felt that the robot will not be able to interact properly with their clients due to lack of various cognitive abilities such as emotions. The participants also felt that a robot should not be used unsupervised as it could break down (European Commission, 2012).

In a recent study for employees of a disability service organization, with an online-delivered exploration without a real robot, the most participants believed that robots cannot replace the human touch, human interaction, or emotional companionship, and that they cannot (should not) replace human workers in the disability setting. Also, many expressed concerns about safety, normality for disabled people, and artificial interactions and had views on whether a social robot can be a bully or could be bullied (Wolbring & Yumakulov, 2014). This suggests that, given the likely high price of robots for some time, the danger of damage to the robot might be seen as too high to leave the robot unsupervised with children period (Wolbring & Yumakulov, 2014).

In conclusion, the robot appearance needs to balance “humanness” and “robotness” in order to both stimulate pleasant social interactions and prevent false beliefs about the robot’s capabilities (DiSalvo, Gemperle, Forlizzi, & Kiesler, 2002).

3.1 The "Uncanny Valley"

When humanoid robots are designed to interact with people, there is a risk of rejection from the users due to the robots similarity with humans. A hypothesis called "the Uncanny Valley," quite popular in Human-Robot Interaction (HRI), tries to explain this phenomenon. The term uncanny is the English translation of the German *Unheimlich*, a word describing something being felt simultaneously as familiar, strange, and scary.

Developed by the Japanese roboticist Masahiro Mori in 1970, the Uncanny Valley phenomenon occurs when the more human-like a thing is (a doll, a robot, etc.,) the more familiar people feel toward that thing (Mori, 1970) and increases until a point is reached at which subtle differences in appearance and/or behaviour create an unnerving effect (MacDorman et al., 2005; Mori, 1970).

However, this relationship is not linear: when human-likeness is close to perfect but some differences still exist, the curve collapses and the feeling, which was familiar, becomes uncanny (Destephe et al., 2015).

Mori's Uncanny Valley hypothesis postulates "*people's familiarity with robots increases the more human-like the machines become, up to a certain point indicated by a sharp drop (the Uncanny Valley) where the robots evoke a repulsive reaction or unpleasant feeling. Robots at this stage appear very human-like, but due to subtle effects will still be clearly distinguishable from humans. This is also called the 'Zombie effect', reflecting our attitude towards moving corpses that very much behave and look like humans, but are distinctively non human"* (Woods, 2006).

Figure 2.1 shows the Uncanny Valley as proposed by Mori, (1970) using different examples for illustrative purposes. However, Mori distinguished between robot appearance and behaviour/movement, and hypothesized that movement would have a stronger impact on the robot's perceived familiarity.

As discussed in MacDorman et al., (2005) and MacDorman (2005) research into how androids, human-like robots, can escape the Uncanny Valley is a scientifically interesting area of research. MacDorman et al., (2005) provide experimental evidence suggesting that robots that fall in the Uncanny Valley elicit in subjects' an innate fear of death and mortality, which might explain why people often experience discomfort in the company of androids.

Also, similar effects can be observed with how people react to very life-like appearing prostheses: they invoke discomfort if they appear 'almost' natural, but only in certain distinct ways suddenly are identified as artificial. In such cases, the appearance of life-likeness does not necessarily add to the acceptability (Dautenhahn, Ogden, & Quick, 2002). The Uncanny Valley, however, can be overcome: as Mori suggests, once robots become more and more realistic and similar to humans, approaching a situation where they appear and behave like humans, familiarity is likely to increase again, up to a point where they are indistinguishable from humans.

However despite its popularity, there is still uncertainty about what would be the cause of this phenomenon. Some studies do not support the existence of the Uncanny valley (Bartneck, Kanda, Ishiguro, & Hagita, 2009; Thompson, Trafton, & McKnight, 2011) as they found little to no evidence of the expected results. On the other hand, other studies (Ho, MacDorman, & Pramono, 2008; Mitchell et al., 2011) support the existence of the phenomenon.

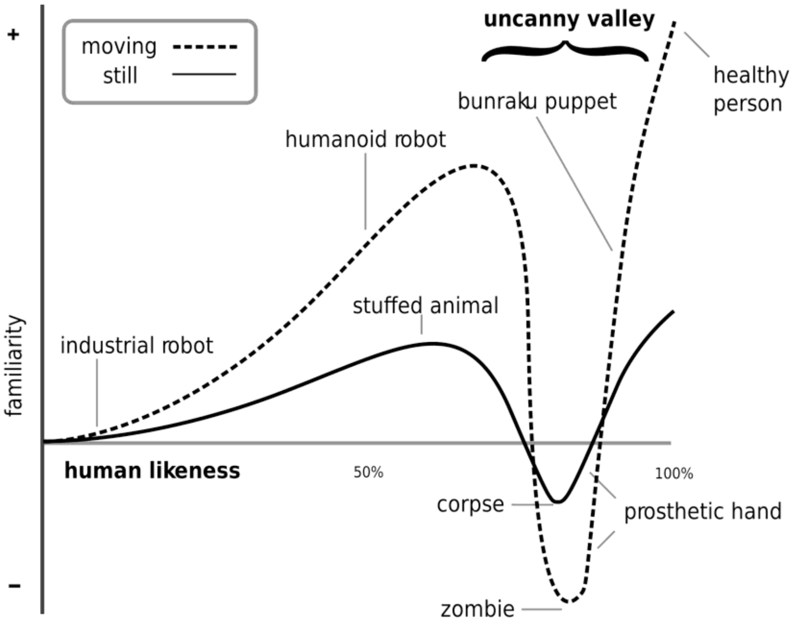


Figure 3.1 *The relationship between human likeness and perceived familiarity.*

3.2 Unified Theory of Acceptance and Use of Technology

With the term “user acceptance” we mean “the demonstrable willingness within a user group to employ technology for the tasks it is designed to support” (Dillon, 2002).

The first studies on technology acceptance modelling usually can be traced back to Davis with the Technology Acceptance Model (TAM) (Davis, 1989). According to this model, which has been used for different types of technology, the user perception of utility and ease of use of a system determines the intention and afterwards the actual use of the system itself. Subsequently Venkatesk et al. (Venkatesh, Morris, Davis, & Davis, 2003) published an inventory of current models and factors and presented a model called Unified Theory of Acceptance and Use of Technology (UTAUT) in which all relevant factors were incorporated. An extensive literature review has been conducted by De Graaf et al. (De Graaf & Ben Allouch, 2013) and they provided an overview of variables influencing the acceptance of social robots categorized by utilitarian variables, hedonic variables, user characteristics, social normative beliefs and control beliefs. In this study, our objective was to evaluate the participant perception, attitude and intention of use a SAR platform in their profession. To this end we adopted the UTAUT model as proposed by Heerink et al. (Heerink, Kröse, Evers, et al., 2009), which has been widely used for the evaluation of SAR platforms and has been found to be highly reliable in several previous studies (among others: De Ruyter et al., 2005; Fridin & Belokopytov, 2014a; Heerink et al., 2010b; Looije et al., 2006). In total, Heerink et al. (2010b) defined seven hypotheses when the entire model is used (Appendix A). The hypotheses considered here are as follows:

- H1: Intention to Use is determined by (a) Perceived Usefulness, (b) Perceived Ease of Use, (c) Attitude, (d) Perceived Enjoyment, (e) Social Influence and (f) Trust.
- H2: Use is determined by (a) Intention to Use and influenced by (b) Social Influence and (c) Facilitating Conditions.

- H3: Perceived Usefulness is influenced by (a) Perceived Ease of Use (b) Perceived Adaptability and (c) Anxiety
- H4: Perceived Ease of Use is influenced by (a) Anxiety, (b) Perceived Enjoyment and (c) Perceived Usefulness
- H5: Perceived Enjoyment is influenced by Social Presence
- H6: Perceived Sociability is influenced by Trust
- H7: Social Presence is influence by Perceived Sociability.

However, H2 and H4 cannot be applied in the studies of chapter IV, because it was not possible to gather data on actual use of the system by the participants.

The technology acceptance literature point to three variables of control beliefs which could be relevant for the user acceptance of social robots: perceived behavioural control, anxiety towards robots and robot related experiences (De Graaf & Ben Allouch, 2013).

Perceived behavioural control is defined as the user's perceived ease or difficulty of using the robot (Bandura, 1977) and is particularly relevant for people who have not yet acquired the necessary skills to successfully perform the behaviour in question (LaRose & Eastin, 2004). Perceived behavioural control has a positive effect on perceived ease of use, intention to use, and actual use (Ajzen, 1991; Heerink et al., 2010; Karahanna & Limayem, 2000; LaRose & Eastin, 2004; Venkatesh & Bala, 2008; Venkatesh, 2000). Emotional arousal is important in the formation of perceived behavioural control (Bandura, 1977). In fact, an important variable to consider when evaluating the acceptance of social robots is anxiety towards robots. This is defined as the user's anxious or emotional reactions evoked in real and imaginary human–robot interaction scenarios (Nomura et al., 2008). We can see that anxiety experienced by users in relation to technology use tends to generate further anxieties (Sarason, 1975). In fact, anxiety has an effect on perceived ease of use (Venkatesh & Davis, 2000; Venkatesh, 2000). In contrast to anxiety, enjoyment in using technology should reduce anxiety and assist people in feeling confident about their ability to successfully execute the needed actions (Mun & Hwang, 2003). These implications point to a correlation between anxiety, enjoyment and perceived behavioural control, which validates their importance for social robot acceptance.

We have seen that people have varying levels of exposure to robots through either media or personal experiences which affects people's familiarity with robots. Being familiar with robots has profound effects on the manner in which people perceive the robot's accessibility, desirability and expressiveness (Fong et al., 2003). In fact, previous experience with specific technology has a positive effect on usefulness, ease of use, attitude towards robots, intention to use, and actual use of that technology (Bartneck et al., 2007; Hackbarth, Grover, & Mun, 2003; Karahanna & Limayem, 2000; Y. Lee et al., 2003). On the other hand, a lack of familiarity can be a reason to feel uncertain when confronted with robots (Broadbent et al., 2009). People's robot related experiences could influence the user experience and are thus important for the user acceptance of social robots (De Graaf & Ben Allouch, 2013).

In conclusion, we have seen that the fields of information systems, human–computer interaction, psychology and communication science realms a long history in technology acceptance research. Social robots are designed to interact socially with humans to simplify communication and, therefore, increase their acceptance by users (Breazeal, 2003). They are expected to increasingly penetrate our everyday lives.

However, if social robots are to be successfully introduced into people's homes, the researchers from various disciplines must understand the underlying reasons whereupon potential users decide to accept these robots and invite them into their domestic environments. To be able to explain social robot acceptance and use, it is essential to understand the determinants of the key acceptance variables (Venkatesh & Morris, 2000).

The research in this field just recently started.

Chapter IV

Acceptance and acceptability of robotics: two field studies

Introduction

Research in the area of robotics has made available numerous possibilities for further innovation in the education of children, especially in the rehabilitation of those with learning difficulties and/or intellectual disabilities. Despite the scientific evidence, there is still a strong scepticism against the use of robots in the fields of education and care of people.

This chapter is divided in two sections. In the first section I will present a study on the acceptance of robots by experienced practitioners (25 participants specialized in the treatment of intellectual disabilities) and 55 university students in psychology and education sciences (as future professionals). The aim is to examine the factors, through the Unified Theory of Acceptance and Use of Technology (UTAUT) model, that may influence the decision to use a robot as an instrument in the practice. The overall results confirm the applicability of the model in the context of education and care of children, and suggest a positive attitude towards the use of the robot. The comparison highlights some scepticism among the practitioners, who perceive the robot as an expensive and limited tool, while students show a positive perception and a significantly higher willingness to use the robot. From this experience, I formulate the hypothesis that robots may be accepted if more integrated with standard rehabilitation protocols in a way that benefits can outweigh the costs.

In the second section, I will present a study on how cultural backgrounds can influence the perception and intention to use a robot as an instrument in the future practice. In this work, I explored the main factors of the Unified Theory of Acceptance and Use of Technology (UTAUT) with the purpose to reveal cultural differences. The instrument used was the UTAUT questionnaire, which was designed and validated to investigate the robot acceptance and use.

The study involved 37 Italian students and 37 English students, as future professionals in the field of psychology; they experienced the actual capabilities of a humanoid robot through a live demo.

The discriminant analysis produced a very high degree of separation between the two groups, confirming that there was a different approach toward the use of robotics between the two cultures. An interesting difference on the intention to use the robot will be reported in results.

The robotic platform used in both experiments is a NAO robot (Gouaillier et al., 2009) that is 58 cm tall humanoid robot that looks like a toy. In the various studies that have used it, this robot was perceived by the participants as a smart, non-threatening educational tool (Nalin, Tabor, Bergamini, & Sanna, 2012) with whom children and the elderly can positively interact (López Recio, Márquez Segura, Márquez Segura, & Waern, 2013; Shamsuddin, Yussof, Ismail, Hanapiah, et al., 2012). The robot speaks with a child's voice, expresses emotions (through verbal and non-verbal communication), and uses proper vocabulary. The NAO robot has 25 degrees of freedom, which allows it to perform a variety of movements. NAO has pioneered the use of robotic toys as therapeutic and educational aides and it is widely used in SAR (e.g., Fridin & Belokopytov, 2014b; K. J. Kim, Park, & Shyam Sundar, 2013; Shamsuddin, Yussof, Ismail, Mohamed, et al., 2012)), particularly in acceptance studies (e.g., De Graaf & Ben Allouch, 2013; A. Kim, Han, Jung, & Lee, 2013).

To program the NAO's behaviours I used *Choreographe*, a development environment provided by the robot manufacturer Aldebaran Robotics (Pot, Monceaux, Gelin, & Maisonnier, 2009). The interface is mainly drag and drop, and allows the programmer to create a sequenced combination of predefined or custom behaviour boxes to manipulate the NAO's joints or attributes, such as its voice or LED colours. Using *Choreographe*, I developed a set of pre-programmed behaviours to allow the robot to interact with the participants and I installed them on the NAO's memory. This way we were able to recall the behaviours during the experiments through a simple application for smartphones/tablets that lists all the available behaviours and allows sending text to speech. I retrieved some complex behaviour from the NAO database, like for instance dancing while playing music and an interactive game of picture recognition. Other custom behaviours were created combining simple actions with text to speech (e.g. waving the hand and say goodbye). All the behaviours originally created in English language and used for the experiment with the English sample (e.g. the image recognition game) were translated into Italian for the Italian sample. In the image recognition game, the robot was programmed to identify a printed image, among the ten stored in its memory (e.g. butterfly, tree, heart, and so on) and recognize if the one shown was correct or not. The recognition is communicated to the participant via speech and gestures. The images were selected to have the highest reliability of the recognition. Indeed, in this experiment the recognition rate was 100%. Images can be rotated, but they must be fully in the robot field of vision to be recognized.

4.1 A study on acceptance of robotics by experienced and future professionals

4.1.1 Materials and Method

4.1.1.1 Participants

The entire research involved 80 participants, all of Italian nationality. All participants had no previous experience of interaction with social robotic platforms. Table 4.1 shows the descriptive statistics of the groups: 25 educations and rehabilitation care practitioners, all of them have obtained at least a university degree equivalent to a master, and 55 university students. Practitioners' professional experience ranges from 2 to 38 years, with an average of 17 years (*SD*=11.2).

Table 4.1 *Descriptive statistics of the sample.*

GROUP	SUB GROUP	Age				Gender	
		Mean	Min	Max	SD	M	F
PRACTITIONERS		41.8	26	63	11.6	5	20
STUDENTS	EDUCATION	22.8	20	37	5.1	6	12
	PSYCHOLOGY	27.1	23	37	3.1	3	34
	ALL	25.7	20	37	4.3	9	46
TOTAL		30.7	20	63	10.5	14	66

The practitioners group was composed of professionals with different specialization (neuro-psychiatrists, clinical psychologist, educators, and nurses) that work daily with people (children and elderly) with mental disabilities at the research and healthcare centre IRCCS Oasi Maria SS of Troina, located in the province of Enna. The students group was composed of two subgroups attending two different degree courses: the bachelor of Education sciences from the University of Enna Kore and the Master in Psychology from University of Catania. The Centre and the Universities are located in two neighbouring provinces of the same region (Sicily), from which the great majority of the students come from.

4.1.1.2 Questionnaire

The UTAUT model uses a structured questionnaire to measure the variables that can influence the acceptance of technology. Each possible influence, named "construct", is represented by a few questions and the scores for the constructs can be mapped and interrelated. For this study, I used the questionnaire proposed in Heerink et al., (2010b), in which we replaced the references to the *iCat* with the general word "robot" (Appendix B). The participants could indicate their level of agreement to 36 statements on a five-point Likert scale including verbal anchors: totally disagree (1) – disagree (2) – neither agree nor disagree (3) – agree (4) – totally agree (5).

The original questionnaire was translated into Italian using a back-translation process employing a bilingual speaker. This procedure ensures that meaning and linguistic nuances are not lost and that the translated version remains as true to the original construct as possible. Prior to the main study, a pilot test (N = 4) for the questionnaire was conducted to confirm the clarity of the wording of the questions and of the instructions. Comments collected during the administration of the pilot format were employed to create the final version of the questionnaire. Only question 6 was significantly modified from the original version of the questionnaire in order to make it more coherent with the two different groups of our sample: the word "life" was replaced by "job" or "future job", according to the group to be interviewed.

4.1.1.3 Experimental setting

The experiment was performed in rooms that had a good light and there was no background noise. Before the beginning of the experiment, the NAO robot was placed on a table to ensure good visibility for all participants. The total time was about thirty minutes and it was divided into two parts. In the first part, participants took part in an interactive demonstration of the NAO robot capabilities. In the second part, all participants anonymously filled the UTAUT questionnaire immediately after the live demonstration. A final discussion was held to allow participants to express their own thoughts and, thus, provide more information for the research. All participants of each group or sub-group attended the demonstration together.

4.1.1.4 Experimental procedure

At the beginning of the first part, the use of robots in the care of children and disabled was briefly presented. The presentation was carried out in two phases: first a familiar authority (the head of the department for practitioners, a teacher for the students) listed some of the possible uses and applications in the education and rehabilitation of children with developmental disabilities; then, the researcher explained the experiment and described the NAO robot functionalities linking them with the possible applications, using the same words for all groups. At the beginning of the demonstration, the robot welcomed the participants and began a dance to give the opportunity to see the harmony of its movements. Next, the robot proposed that the participants played an interactive game of image recognition. Sheets with printed images were placed on the table that a random volunteer selected and showed to the robot when asked (e.g. "I would like to see a butterfly"). In our experiments, the robot was able to recognize all the images presented (Appendix C – D), but some participants spent tens of seconds to find the correct position in the robot field of vision. The game was repeated several times to allow many participants to actually interact with the robot. After the game, the robot was placed down on the floor to demonstrate its walking capability for five minutes. In this phase, participants could verbally indicate the direction (e.g., they can say "forward", "backward", and "turn" "left" or "right") that the robot should go. Finally, the robot thanked the participants for attending and for their participation. The final messages were customized taking into account the different groups of participants. This was to make the interaction with the robot more personalized and friendly.

The robot used informal language and expressed enjoyment through body motion and gestures. Not all participants interacted directly with the robot, but all the spectators were following the demonstration and interaction sessions with great attention and I noted the same emotional involvement as they were playing with the robot in first person. In fact, the Perceived Enjoyment (PENJ) construct was positively scored by the greater majority of the participants. This behaviour was also noted by Fridin et al. (Fridin & Belokopytov, 2014b). In all groups, almost all participants took a picture or a video of the robot with their own mobile phone/tablet (see a Figure 4.1) shows the students playing the image recognition game (see a Figure 4.2).

Figure 4.1 *Students watching the movements of the NAO robot.*

Figure 4.2 *Students playing the picture recognition game.*

The same experimental procedure was used for both students and practitioners.

4.1.1.5 Data analyses

To process the results I employed two sets of analyses. The first set aims to validate the questionnaire and to test the UTAUT model hypotheses in the context of education and care of children with developmental disabilities. The other set of analyses aims to compare the groups and perform qualitative analyses on the acceptance by the practitioners and the students.

The UTAUT data were processed as follows:

- Reliability of the questionnaire was established by calculating Cronbach's Alpha for the items of each construct. I consider an acceptable Alpha value if it is greater than .600, while a solid construct would have an Alpha of at least .700 (for details see Kline, 2000).
- When a construct consisted of more than two statements, I tested what the Alpha score would be if one or more questions are omitted. If a more solid argument is obtained the statement is removed from the calculation of the construct score.
- The scores for each construct were calculated by averaging the scores on the items.
- Hypotheses were tested with correlations (exploratory analysis) and linear regression analysis (confirmative). For each hypothesis, I established the R^2 value, which can be used as an indication of the predictive strength of the model.
- Correlation scores of each construct with age of participants were calculated to evaluate the possible impact of this variable on the results. Age was found to significantly ($p<.05$) correlate to the ITU (Intention to Use) by Heerink (2011).

Group comparisons and qualitative analyses on the acceptance were performed with the following measures:

- A positive perception (POS) of a participant is assumed when the construct score is greater than 3, while a negative perception (NEG) is when average score is lower than 3. Otherwise, the perception is considered neutral.
- Basic descriptive statistics (minimum and maximum scores, mean and variance) and of positive and negative perception (percentage).
- The Mann-Whitney U (a.k.a. Mann-Whitney-Wilcoxon) test was preferred to test the independence of the samples, because it's more general applicability and, thus, reliability when samples have different distribution,

size (i.e. number of subjects) and variance (Mann & Whitney, 1947).

All statistics were calculated using SPSS 21 software.

4.1.2 Results and Discussion

Table 4.2 shows the constructs included in the questionnaire and the Cronbach's Alpha for each of them. Note that, in this research, questionnaire statements are referred to using the construct code to which they belong, and the number corresponding to its position in the list. As an example ITU-10 identifies the 10th statement that belongs to the construct ITU.

Table 4.2 *Constructs Cronbach's Alpha.*

Code	Construct	Num. Items	Cronbach's Alpha	Notes
ANX	Anxiety	4	.872	Alpha is improved by removing questions 1 and 2. Score with all items was .606.
ATT	Attitude	3	.762	
FC	Facilitating conditions	2	.357	Given the low score, this construct is removed from the other analyses. Questions are evaluated individually.
ITU	Intention to use	3	.874	
PAD	Perceived adaptability	3	.741	Alpha is improved by removing question 14. Score with all items was .621.
PENJ	Perceived enjoyment	5	.855	
PS	Perceived sociability	4	.812	
PU	Perceived usefulness	3	.831	
SI	Social influence	2	.629	
SP	Social presence	5	.729	
TR	Trust	2	.933	

According to Alpha values, the reliability of the majority of constructs is solid. As reported in the notes (Table 4.2), I removed question 1, 2 and 14 to improve the reliability of the constructs ANX and PAD. Note that SI is formed by only 2 items so no improvement was possible, but we consider that alpha index of .629 as acceptable. The only construct that we found unreliable is FC, which is lower than .400. This can be due to the limited experience in using the robot and programming its behaviours. A similar result for FC was founded by Fridin et al. (Fridin & Belokopytov, 2014a). For this reason, questions FC-8 and FC-9 are evaluated individually.

The correlation matrix of constructs is reported in Table 4.3. Correlations clearly show that the constructs are related each other, only in a few cases there is not a significant correlation, while in many others we report a strong coefficient. Using the correlation scores to explore the hypotheses, I can conclude that they could be confirmed.

Table 4.3 *Triangular correlation matrix among constructs and age for all participants (N=80).*

	AGE	ANX	ATT	ITU	PAD	PENJ	PS	PU	SI	SP
ANX	-.039	1								
ATT	-.009	**.352****	1							
ITU	-.117	**.282***	**.585****	1						
PAD	-.079	.147	**.587****	**.667****	1					
PENJ	**-.278***	**.327****	**.700****	**.584****	**.598****	1				
PS	**-.336****	.209	**.486****	**.467****	**.526****	**.753****	1			
PU	-.117	**.304****	**.676****	**.712****	**.631****	**.628****	**.545****	1		
SI	-.115	**.224***	**.290****	**.414****	**.294****	**.398****	**.352****	**.523****	1	
SP	-.211	.167	**.231***	**.321****	.212	**.450****	**.612****	**.336****	.178	1
TR	-.041	-.026	.182	.210	**.231***	**.228***	**.384****	**.243***	.180	**.428****

Correlation is significant: *= at the .05 level; **= at the .01 level. Significant scores are in bold.

ANX: Anxiety, **ATT:** Attitude, **FC:** Facilitating Conditions, **ITU:** Intention to Use, **PAD:** Perceived Adaptability, **PENJ:** Perceived Enjoyment, **PEOU**: Perceived Ease of Use, **PS:** Perceived Sociability, **PU:** Perceived Usefulness, **SI:** Social Influence, **SP:** Social Presence, **TR:** Trust.

The correlation with age is low and not statistically significant ($p>.05$) for the majority of constructs, including the ITU, but with the exception of PENJ and PS that seems to be negatively affected by age. Professional experience is highly ($r = .939$, $p<.0001$) correlated with age of participants and it correlates with PENJ and PS too. As regards questions FC-8 and FC-9, considered separately because the unreliability of the FC construct, they don't have any statistically significant correlation with other constructs.

Table 4.4 reports the scores of the regression analyses of the UTAUT hypotheses for the entire sample. All hypotheses are confirmed at least partially.

Table 4.4 *Linear Regression Analyses (Separately for each Hypothesis – N=80).*

Hypothesis	Independent Variables	Dependent Variable	R^2	Beta	t	
H1	ATT	ITU	.544	.111	.903	
	PENJ			.169	1.454	
	PU			.505	**4.154**	**
	SI			.051	.547	
H3	PAD	PU	.444	.217	**2.521**	*
	ANX			.599	**6.976**	**
H5	SP	PENJ	.566	.762	**8.036**	**
	PS			-.016	-.164	
H6	TR	PS	.148	.384	**3.677**	**
H7	PS	SP	.374	.612	**6.826**	**

Significance levels: * =p<.05; ** =p<.01.

ANX: Anxiety, **ATT:** Attitude, **FC:** Facilitating Conditions, **ITU:** Intention to Use, **PAD:** Perceived Adaptability, **PENJ:** Perceived Enjoyment, **PEOU**: Perceived Ease of Use, **PS:** Perceived Sociability, **PU:** Perceived Usefulness, **SI:** Social Influence, **SP:** Social Presence, **TR:** Trust.

Table 4.5 presents the descriptive statistics of the constructs: the minimum (min) and maximum (max) average scores and the percentage of positive (POS) and negative (NEG) perception of the participants.

The main difference between the two groups is on the intention to use (ITU), because it determines the actual use (hypothesis H1). We could say that practitioners were not convinced to actually use the robot in their job, indeed the average is below 3 with a higher number of negative than positive statements: 36% vs 24%. We noted that practitioners' highest average score for ITU is 4, i.e. no one in this group scored a 5. Meanwhile, students show more willingness to use the robot (i.e. 50% of ITU statements are above 3).

Table 4.5 *Comparison between practitioners and students: Constructs analysis.*

Construct	Practitioners						Students						Mean Difference
	Mean	Min	Max	SD	POS	NEG	Mean	Min	Max	SD	POS	NEG	
ANX	4.24	2.50	5.00	0.90	**80%**	8%	4.44	2.00	5.00	0.84	**87%**	7%	-0.20
ATT	3.45	1.00	5.00	0.98	**68%**	12%	3.64	2.00	5.00	0.66	**78%**	11%	-0.19
ITU	2.75	1.00	4.00	0.83	24%	36%	3.18	1.00	5.00	0.82	**51%**	22%	**-0.44** *
PAD	3.14	1.00	4.50	0.84	**52%**	28%	3.38	1.50	5.00	0.76	**65%**	16%	-0.24
PENJ	3.46	1.40	4.80	0.82	**68%**	16%	4.08	2.20	5.00	0.65	**95%**	4%	**-0.62** **
PS	2.45	1.00	4.00	0.78	16%	**72%**	3.20	1.50	5.00	0.82	**51%**	31%	**-0.75** **
PU	3.07	1.00	5.00	0.84	48%	20%	3.38	1.33	5.00	0.79	**64%**	18%	-0.31
SI	2.94	1.00	4.00	0.74	32%	24%	3.30	1.00	5.00	0.73	**53%**	20%	-0.36
SP	2.01	1.00	3.60	0.76	8%	**80%**	2.51	1.00	5.00	0.89	24%	**73%**	**-0.50** *
TR	2.12	1.00	5.00	1.27	24%	**64%**	2.06	1.00	5.00	1.02	7%	**73%**	0.06

Mann-Whitney U significance levels: * =$p<0.05$; ** =$p<0.01$. Highest percentages and significant differences are in bold.

ANX: Anxiety, **ATT:** Attitude, **FC:** Facilitating Conditions, **ITU:** Intention to Use, **PAD:** Perceived Adaptability, **PENJ:** Perceived Enjoyment, **PEOU**: Perceived Ease of Use, **PS:** Perceived Sociability, **PU:** Perceived Usefulness, **SI:** Social Influence, **SP:** Social Presence, **TR:** Trust.

Table 4.6, reports the questions removed from the constructs after the Cronbach's alpha analysis, and those included in the constructs that received the most significantly different answers, in terms of the mean difference between the two groups, statistical significance (p<.01) and impact on the constructs. I analysed the single questions removed from the constructs to avoid losing some information because of the removal. In fact, none had a statistically significant difference, with the only exception of ANX-2. In comparison, practitioners are more self-confident because the majority of them expressed low (4) or no anxiety (5) to damage the robot (ANX-2) and they think that the robot would make their job more interesting (ATT-6). On the other hand, students strongly support the idea to use the robot (ATT-5), while they have no particular opinion on ATT-6, probably because they haven't a concrete work experience yet. Students consider the interaction with the robot pleasant (PS-21/22), indeed practically all of them really enjoyed the demonstration, and they think that the robot is fascinating (PENJ-19). Vice versa the majority of practitioners do not consider the robot as a pleasant conversational partner (PS-21). The factor that has a more negative influence on the practitioner's perception of robot sociability is that they do not think it is actually looking at them (SP-31). Students have an almost neutral perception on SP-31, which is significantly higher than the practitioners. A total of 40% of students perceive that there is a social influence toward using the robot and that they will give a good impression if they should use the robot (SI-29), while practitioners are generally neutral (72%) or slightly negative (20%) about this statement. As a final consideration, 45% of students say that they are planning to use the robot in their job while only 13% are not (ITU-12), while for practitioners percentages are reversed and the maximum score given to this question was 4.

Finally, comparing the student subgroups we can report that there are no statistically significant (p>0.1) differences between the average scores of the constructs according to the Mann-Whitney U test analysis.

Table 4.6 *Comparison between practitioners and students: single answers analysis.*

Question	**Practitioners**						**Students**						Mean	
	Mean	Min	Max	SD	POS	NEG	Mean	Min	Max	SD	POS	NEG	Difference	
Questions removed from constructs after Cronbach’s alpha analysis														
ANX-1	3.48	1	5	1.41	**56%**	28%	3.53	2	5	0.97	49%	16%	-0.05	
ANX-2	3.84	2	5	1.07	**60%**	12%	3.09	1	5	1.13	36%	40%	**+0.75**	**
FC-8	2.52	1	5	1.23	24%	48%	2.60	1	5	1.01	20%	**53%**	-0.08	
FC-9	2.16	1	5	1.43	20%	**68%**	2.27	1	5	1.15	16%	**67%**	-0.11	
PAD-14	3.64	1	5	0.81	**64%**	4%	3.51	1	5	0.92	**60%**	16%	+0.13	
Questions with significant differences between groups														
ATT-5	3.52	1	5	1.08	**56%**	12%	4.11	2	5	0.81	**84%**	5%	**-0.59**	*
ATT-6	3.56	1	5	1.12	**56%**	12%	3.02	1	5	0.93	25%	22%	**+0.54**	*
ITU-12	2.68	1	4	0.90	16%	36%	3.33	1	5	0.96	45%	13%	**-0.65**	**
PENJ-19	3.40	1	5	1.04	48%	12%	4.27	2	5	0.83	**84%**	4%	**-0.87**	**
PS-21	2.36	1	4	1.08	16%	**52%**	3.36	1	5	1.01	47%	16%	**-1.00**	**
PS-22	2.92	1	4	1.00	32%	28%	3.87	2	5	0.75	**76%**	5%	**-0.95**	**
SI-29	2.79	1	4	0.72	8%	20%	3.30	1	5	0.84	40%	11%	**-0.51**	**
SP-31	1.96	1	4	1.10	8%	**60%**	2.91	1	5	1.34	36%	42%	**-0.95**	**

Mann-Whitney U test significance level: * =p<0.05, ** =p<.01. Highest percentages and significant differences are in bold.

ANX: Anxiety, **ATT:** Attitude, **FC:** Facilitating Conditions, **ITU:** Intention to Use, **PAD:** Perceived Adaptability, **PENJ:** Perceived Enjoyment, **PEOU**: Perceived Ease of Use, **PS:** Perceived Sociability, **PU:** Perceived Usefulness, **SI:** Social Influence, **SP:** Social Presence, **TR:** Trust.

Results obtained in this study confirmed the reliability of the UTAUT model and questionnaire in the evaluation of the acceptance and the intention to use a robotic platform by professionals involved in the education and care of children with developmental disabilities.

The correlation and regression analyses confirmed, fully or partially, the hypotheses of the UTAUT model. In particular, the analysis shows that Intention to use (ITU) is influenced by the Perceived usefulness (PU) only. In other words, the desire to use the robot (or not) is mainly predicted by the perception that it will enhance and facilitate the educational and therapeutic process. This is similar to results found by previous studies (Fridin & Belokopytov, 2014a; Hu, Clark, & Ma, 2003) but only partially confirms the hypothesis H1 of Heerink et al. (2010b).

This analysis supports hypothesis H3, because Perceived usefulness (PU) is related to anxiety and perceived adaptability. Indeed, the robot adaptability to different contexts is one of the questions that were asked by some of the participants after the demonstration. Hypothesis H5 is partially confirmed, because Perceived enjoyment (PENJ) is related only to the Social presence (SP), but not to the Perceived sociability (PS). But, given that hypothesis H7 is confirmed and SP is determined by PS, I can conclude that Perceived enjoyment (PENJ) is indirectly determined by Perceived sociability (PS). Finally, hypothesis H6 is confirmed as Perceived sociability (PS) is determined by Trust (TR). In addition, I found also that perceived enjoyment and sociability correlate with age, that was observed in previous work (De Graaf & Ben Allouch, 2013).

The differences in the relationship between the constructs with respect to the hypotheses formulated in Heerink et al. (2010b), can be explained by the fact that they were focused on the elderly and their acceptance of a small robot as a companion, while we are investigating its use as an instrument for professional practice with intellectually disabled.

The Facilitating Conditions (FC) result is clearly limited by the short time spent with the robot. The answers are generally negative and reflect the missing knowledge of the languages and tools to program the robot behaviour. In this case, we can hypothesize the participant derived their answers from previous experience with the technology (Bartneck et al., 2007).

When I compare the two groups in our sample, we can see a more positive Intention to use (ITU) the robot by the students, while this variable is negative for the practitioners. In particular, the majority of the practitioners said that they are not planning to use the robot in the near future.

The main factor of this difference is obviously the professional experience, which has been found to influence the teacher intention to use the technology in the classroom (Baek, Jung, & Kim, 2008). In our sample, professional experience is highly related to age that we found to affect the perceived sociability (PS). Indeed, practitioners considered the experience with the robot less pleasant and, thus, this influenced negatively their acceptance and intention to use the robot (Shin & Choo, 2011). Vice versa, students enjoyed the demonstration and consider the robot pleasant. Moreover, practitioners have a clearer view than students of the educational and therapeutic tools available and their effectiveness. They can easily identify the current technology difficulties and limitations, especially with higher levels of intellectual disabilities and this negatively affects the perceived usefulness. On the other hand, lack of experience leads the students to accept without questioning what they are told by the researchers, i.e. that the robot is a good idea (Attitude ATT-5), it is useful for their future work (Perceived usefulness-PU) and these considerations influences the Intention to use (ITU) the robot.

We can see that students are neutral in ATT-6, while highly positive in Attitude ATT-5 and this is probably because the question was directly asking them to predict the impact of the robot on their future work, so they tend to be neutral.

It should be pointed out that also majority of the practitioners agree that the robot is a good idea, but this does not determine the Intention to use (ITU), because, as this analysis highlight, the only factor that determines the Intention to use (ITU) is the Perceived usefulness (PU), which is negative for them.

As a confirmation of the relation between constructs, we can underline that average score differences are reflected in the single questions of related constructs regardless of the positive or negative perception expressed by the majority of the group participants. For instance, I recall that SP-31 can determine PS-21/22 according to hypothesis H7, while PS-21/22 determines Perceived enjoyment (PENJ) according to hypothesis H5. We see that students scored 0.95 more than practitioners in SP-31, in which we see a negative perception by both groups, then PS-21/22 student average score is respectively 1.00 and 0.95 higher, in which the majority of students are positive, while practitioners are negative, and, finally, student average scores of PENJ-19 are 0.87 higher than practitioners and the majority of both groups have a positive perception.

A factor interrelated with the professional experience is the Social influence (SI). The comparison shows that there is a significant difference in the perception of public recognition achievable by using the robot (question SI-29). This can be explained by the fact that many students perceived the use of the robot as enhancing their self-image or social status in the opinion of significant others, which, in turn, could have consequences for the user's acceptance of that innovation (Rogers, 2010; Venkatesh & Davis, 2000).

Finally, during the open discussion after filling the questionnaire, practitioners expressed concern about the cost of the robot purchase. Similarly, Mutlu & Forlizzi (2008), found that hospital workers have less willingness to use a robot if perceived benefits are outweighed by the costs, in terms of economical expense and workload for workers.

4.1.3 Conclusions

In this section I reported the results of a study on acceptance of robots in the education and care of children by a group of 25 practitioners, specialized in developmental disabilities, and 55 students in psychology and educational disciplines. The study confirmed the reliability of the UTAUT model and its applicability in the context of education and care of children.

All participants showed a global positive attitude toward the use of the robot. The comparison between the two groups highlights the prevailing scepticism of the practitioners, while students show an overall positive perception and significantly higher willingness to use the robot. The result is due not only to differences in age (significant only for few variables), but to the professional experience of the practitioners that allows them to identify practical issues that could be encountered in the use of a robot with children affected by severe intellectual disabilities. I hypothesize that practitioners currently perceive the SAR as just an expensive and limited tool, which may provide a real advancement over other established techniques only if more synergistically integrated with standard protocols, in a way that benefits can outweigh the costs. To this end more evidence from the scientific research and integration with therapeutic protocols are needed to overcome the scepticism and draw firm conclusions about the clinical utility of robots (Diehl et al., 2012).

The study is limited by the short amount of time that the participants spent interacting with the robot; they could be influenced by the limited previous knowledge of the specific technology (Bartneck et al., 2007). On the other hand, in this work I did not want to test a specific platform or the actual use of the robot, but the focus was on their general perception of SAR as a tool for education and care of children with developmental disabilities. Another limitation of the study is that possible applications and different platforms were only described and linked with the functionalities shown in the demonstration. Furthermore, the live experience with only one robotic platform could have biased the participant's perception. In future work, I will investigate the acceptance and usability of practitioners showing the real use of different robots as a therapeutic tool, e.g. with videotaped demonstrations.

I recall that people with different nationalities tend to rate differently their experiences with robots on usefulness, enjoyment, sociability, anthropomorphism, and perceived behavioural control (European Commission, 2012; Li et al., 2010), because each culture possesses its own level of exposure to robots through either media or personal experiences (Broadbent et al., 2009). For this reason in the follow section, another direction for these studies has been to extend the sample with students and practitioners of different nationalities, in order to assess the impact of culture on the results.

4.2 Cross-cultural study and acceptance by future practitioners

4.2.1 Materials and Method

4.2.1.1 Participants

The ITA sample (*n*=37, *M*-age=27.05 years, range= 23-37, *SD*=3.08) was formed of MPsych students of the University of Catania. The UK sample was made of MPsych students at the University of Plymouth, (*n*=37, *M*-age=20.6 years, range=19-40, *SD*=3.86). All ITA and UK participants were native speakers with the exception of 2 UK participants (1 Indian and 1 Polish).

In total, the research involved 74 participants. All participants had no previous experience of interaction with social robotic platforms.

4.2.1.2 Questionnaire

In this study the objective was to compare the participant perception, attitude and intention of use a robotic platform in the future practices. To this end I adopted the UTAUT model as proposed by (Heerink, Kröse, Evers, et al., 2009), which uses a structured questionnaire, in which each construct is represented by multiple questions (from 2 to 5). For this study I used the questionnaire proposed in Heerink et al. (2010b), but modified by the specific robot to a unspecified robot (e.g. "I think I'll use iCat the next few days" change in "I think I'll use robot the next few days" – Appendix B).

Table 4.7 *The UTAUT Questionnaire: Constructs and number of items.*

Code	Construct	Num. Items
ANX	Anxiety	4
ATT	Attitude	3
FC	Facilitating conditions	2
ITU	Intention to use	3
PAD	Perceived adaptability	3
PENJ	Perceived enjoyment	5
PS	Perceived sociability	4
PU	Perceived usefulness	3
SI	Social influence	2
SP	Social presence	5
TR	Trust	2

The participants could indicate their level of agreement to 36 statements on five point Likert scale including verbal anchors: totally disagree (1) – disagree (2) – neither agree nor disagree (3) – agree (4) – totally agree (5).

For the Italian sample the original questionnaire was translated into Italian using the back-translation process employing a bilingual speaker. Prior to the study, a pilot test (N = 4) for the questionnaire was conducted to confirm the clarity of the wording of the questions and of the instructions. Comments collected during the administration of the pilot format were employed to create the final version of the questionnaire. Only question 6 was significantly modified from the original version of the questionnaire in order to make it more coherent with the groups of our sample: the word "life" was replaced with "future job".

Table 4.7 shows the constructs included in the questionnaire and the number of items (statements) for each of them. In this study, the statements of the questionnaire are identified with the code of construct of which they belongs and the number corresponding to its position in the list. As an example ITU-10 identifies the 10th statement that belongs to the construct ITU (*Intention to Use*).

The interrelations between constructs were presented in (Heerink et al., 2010), which suggest also some hypotheses as follows:

H1 Intention to Use is determined by:

(a) Perceived Usefulness, (b) Perceived Ease of Use, (c) Attitude, (d) Perceived Enjoyment, (e) Social Influence.

H3 Perceived Usefulness is influenced by:

(a) Perceived Ease of Use (b) Perceived Adaptability and (c) Anxiety.

H5 Perceived Enjoyment is influenced by:

(a) Social Presence and (b) Perceived Sociability.

H6 Perceived Sociability is influenced by Trust.

H7 Social Presence is influence by Perceived Sociability.

There are therefore seven hypotheses when the entire model is used, but H2 and H4 cannot be applied to the study presented here, because it was not possible to gather data on actual use of the system by the participants.

4.2.1.3 Experimental setting

The experiment was performed with ITA students as part of an academic lecture, while the UK students were invited to attend to an ad-hoc practical session. UK participants were awarded of one credit for the attendance.

The rooms had a good light and there was no noise. The students were able to move freely in the room to watch a NAO robot sitting on a table. Two experimenters were present in the room. One experimenter had always been close to the robot, presenting its features and starting the activities. The other experimenter was checking the robot sensors (e.g. cameras, battery) to verify that all parameters and take action in case of technical problems.

Before the session started, the NAO robot was placed on a table to ensure a good visibility to all participants. The total time was about thirty minutes and it was divided into two parts.

4.2.1.4 Experimental procedure

At the beginning of the first part, the NAO robotic platform was briefly presented along with some of SAR successful case studies, listing some of the possible uses and applications in the practice of psychology. At the beginning of the demonstration the robot welcomed the participants and began a dance to give the opportunity to see the harmony of all of its movements.

Then, the robot proposed to the participants to play an interactive game of image recognition. Sheets, with printed images, were placed on the table that a random volunteer select and show to the robot when asked (e.g. “I would like to see a butterfly”). The robot was trained to recognize the image and say if the one shown was correct or not (Appendix C – D). The game was repeated at least three times to allow numerous participants to actually interact with the robot. This part of the experiment is represented in Figure 4.3.

Figure 4.3 *English students playing the picture recognition game.*

After the game the robot was placed down on the floor in a walking modality for five minutes. In this phase, participants could tell the robot which direction to go (e.g., forward, backward, turn left and right) as to where they want the robot to go. All the observers were at the same distance from the robot during the interaction session and expressed the same involvement during the interactive game. Finally the robot greeted and thanked the participants for attending and for their participation.

In the second part after the live demonstration, all participants filled the UTAUT questionnaire. The questionnaire is anonymous, and apart from some generic details such as age, gender and nationality.

A final discussion was held to allow students to express their own thoughts and, therefore, provide more information for the research.

The research has been subjected to the ethical approval of the relevant university boards.

4.2.1.5 Data analyses

Construct comparisons were performed with the t-test for equality of group means of the average scores and the number of participants with a positive or negative perception (percentage). A positive perception (POS) of a subject for a given construct is assumed when the average score is greater than 3, while a negative perception (NEG) is when the average score is lower than 3. Otherwise the perception is considered neutral.

To better understand the relations and to find possible explanations for cultural differences I also calculated the bivariate correlation between constructs as an exploratory test for the UTAUT hypotheses.

Finally, given that one of the main objectives of this study was to determine cultural differences, I tested the capability of UTAUT items to reveal them thought the stepwise discriminant analysis. The criterion used for controlling the stepwise entry of variables was the Wilks' lambda: variables for entry into the equation were chosen on the basis of how much they lower Wilks' lambda. At each step, the variable that minimizes the overall Wilks' lambda is entered. The Wilks' lambda criterion is a measure of group discrimination.

Statistically significant results are claimed when $p<0.01$.

All statistics were calculated using SPSS 21 software.

4.2.2 Results and Discussion

In the first analysis, I tested the equality of group means of constructing scores and compared the number of positive and negative scores.

Table 4.8 *Result of the t-test and positive/negative perception percentages for each construct.*

Construct	*t*	Sig.	Mean Diff.	ITA		UK	
				POS	NEG	POS	NEG
ANX	1.71	0.09	0.24	**95%**	3%	**86%**	5%
ATT	-1.58	0.12	-0.26	**84%**	8%	**84%**	8%
FC	-0.78	0.44	-0.18	19%	**65%**	30%	**59%**
ITU	**2.84**	**<0.01**	**0.66**	**51%**	22%	32%	**62%**
PAD	-0.86	0.39	-0.13	**70%**	22%	**70%**	19%
PENJ	-0.93	0.36	-0.15	**97%**	0%	**89%**	8%
PS	-1.65	0.10	-0.27	46%	30%	**57%**	19%
PU	1.79	0.08	0.36	**68%**	14%	49%	**51%**
SI	0.21	0.83	0.04	**54%**	19%	**57%**	24%
SP	-1.84	0.07	-0.37	19%	**78%**	35%	**57%**
TR	**-3.05**	**<0.01**	**-0.76**	3%	**78%**	30%	**59%**

Statistically significant ($p<0.01$) differences are highlighted in bold. Positive values for t and difference identify a higher mean score of the ITA; vice versa negative values identify higher means of UK students.

ANX: Anxiety, **ATT:** Attitude, **FC:** Facilitating Conditions, **ITU:** Intention to Use, **PAD:** Perceived Adaptability, **PENJ:** Perceived Enjoyment, **PEOU**: Perceived Ease of Use, **PS:** Perceived Sociability, **PU:** Perceived Usefulness, **SI:** Social Influence, **SP:** Social Presence, **TR:** Trust.

Table 4.8 presents the results of the t-test and the percentages of positive or negative participants within the two groups. The t-test highlights two main differences between the two groups: the British students trust more the robot, but they have less intention to use it in their future profession.

The impact of the difference highlighted by the t-test is evident when comparing the perceptions on Intention to Use (ITU): the majority of Italians are positive while the majority of British are negative. Looking at perceptions, we can see that the PU is positive for Italians (68%) while the British are negative (51%).

The correlation analysis shows that Intention to Use (ITU) is significantly correlated to Perceived Usefulness (PU) and the score is quite high (0.686) as predicted by H1. Moreover, the two groups exhibit a mean difference of 0.36

for that construct, where Italians averaged a positive score of 3.35, while the British were more neutral with 2.99. Intention to Use (ITU) is also significantly related to Attitude (ATT, 0.384), Social Influence (SI, 0.576), but not with Perceived Enjoyment (PENJ). Testing the hypothesis H3, we can see that Perceived Usefulness (PU) is significantly related to Perceived Adaptability (PAD, 0.639), but not with Anxiety (ANX). Regarding H5, Perceived Enjoyment (PENJ) is significantly correlated to Perceived Sociability (PS, 0.558), but not with Social Presence (SP). Finally, as expected by H6 and H7, Social Presence (SP) is significantly related to Perceived Sociability (PS, 0.577), and Perceived Sociability (PS) is significantly related to Trust (TR, 0.356).

In the next step of analysis, I considered all the 36 items of the questionnaire. Seven out of the original 36 items were selected using the discriminant analysis stepwise procedure. The 7 discriminating variables and their relative contributions to the function can be seen in Table 4.9. The strongest contribution is by far given by the ITU-12.

Table 4.9 *Standardized Canonical Discriminant Function Coefficients.*

Item	Statement	Coefficient
ATT-6	The robot would make my life more interesting.	0.855
ITU-12	I'm planning to use the robot in the near future.	-1.21
PAD-13	I think the robot can be adaptive to what I need.	0.49
PS-23	I feel the robot understands me.	0.497
PU-25	I think the robot is useful to me.	-0.643
SP-32	I can imagine the robot to be a living creature.	0.371
TR-35	I would trust the robot if it gave me advice.	0.38

ATT: Attitude, **ITU:** Intention to Use, **PAD:** Perceived Adaptability, **PS:** Perceived Sociability, **PU:** Perceived Usefulness, **SI:** Social Influence, **SP:** Social Presence, **TR:** Trust.

The classification result presented in Table 4.10 confirms that the items included in the discriminant function can effectively separate two different groups.

Table 4.10 *Discriminant analysis classification results.*

Original					**Cross-Validated (leave-one-out)**				
	ITA		UK			ITA		UK	
ITA	35	**94.6%**	2	5.4%	ITA	33	**89.2%**	2	10.8%
UK	2	5.4%	35	**94.6%**	UK	4	5.4%	35	**94.6%**

Considering all participants in the original sample, we can see that 94.6% grouped cases correctly classified and the cross validation is done with the leave-one-out classification. Each case in the analysis is classified by the functions derived from all cases other than that case. In cross validation 91.9% of cross-validated grouped cases correctly classified.

Table 4.11 reports the main statistics to evaluate the discriminant analysis. The key statistic indicating whether or not there is a relationship between the dependent and independent variables is the significance test for Wilks' lambda. Wilks' lambda is the proportion of the total variance in the discriminant scores not explained by differences among the groups. In this case only the 26.8% of the variance is not explained by group differences. The analysis is highly significant (p<.001). The canonical correlation coefficient (0.855) measures the association between the discriminant score and the set of independent variables. Like Wilks' lambda, it is an indicator of the strength of relationship between entities in the solution, but it does not have any necessary relationship to the classification accuracy, which is the ultimate measure of the value of the model.

Table 4.11 *Discriminant analysis statistics.*

Eigenvalue	Canonical Correlation	Wilks' Lambda	Chi-square	Sig.
2.726	0.855	0.268	90.109	<0.001

4.2.3 Conclusions

We can see that the investigation of cultural difference will greatly contribute to the design of robots and their applications.

In this section was reported the results of a study on cultural influence in the acceptance of robotics of 74 psychology students from two universities: Catania (Italy) and Plymouth (UK).

All participants showed a global positive attitude toward the SAR paradigm, but the UTAUT constructs analysis revealed a different approach of the two groups. Italians participants have a positive Intention to Use (ITU), because they have also a positive Perceived Usefulness (PU), while British participants have a negative Intention to Use (ITU), because they have a negative Perceived Usefulness (PU), even though they are more inclined to Trust the robot than Italian participants.

The stepwise discriminant analysis identified seven items among the UTAUT questionnaire statements, which produced a very high degree of separation between the two classification groups as indicated by the final Wilks' lambda (0.268), and the canonical correlation (0.855) for the only one discriminant function identified. Three of the items identified are among the ones of the significantly different constructs (ITU-12, PU-25, TR-35), while the other four items that have an impact are attitude (ATT-6), perceived adaptiveness of robotic (PAD-13) and social abilities (PS-23 and SP-32). These entire items see a more positive attitude and perception by the British with respect to Italians.

This result may suggest a different influence of constructs in the UTAUT hypothesis H1. In fact, it seems that Perceived Usefulness (PU) has a greater impact than Attitude (ATT), Perceived Enjoyment (PENJ), and Social Influence (SI), because in this analysis Intention to Use (ITU) and Perceived Usefulness (PU) are significantly high correlated and different for both groups. The others results are not significantly different and have low Attitude (ATT), and Social Influence (SI) and none Perceived Enjoyment (PENJ) correlation to Intention to Use (ITU).

When comparing British and Italian participants, as pointed out by Hofstede (Hofstede, 1980), the latters will tend to take risks rather easily and they are more open to adopting appliances to reduce their workload. These behaviours may explain the positive Intention to Use (ITU) and Perceived Usefulness (PU) of robots among Italian students.

In brief, this result suggests that more examples of the usefulness of robots in the practice must be given in order to increase the intention to use, and consequently the actual use of the robot by the future British psychologist.

“Culture” in this research means just geographical discrimination, and it was not investigated which cultural characteristics individual respondents were constrained with based on specific determinants such as the ones presented in social science literatures.

However, this study is limited by the brief amount of time that the participants spent interacting with the robot. In fact, these results could be influenced by the limited previous knowledge of the specific technology and also hypothesize that the answers of the participants depend from previous experience with the technology (Bartneck et al., 2007).

However, in this work the focus was on general perception of robots as tool for psychology practice and it was not intended testing a specific platform or the actual use of the robot.

Chapter V

Use of robotics in Autism Spectrum Disorder

Introduction

In the last years, research in robotics has made available numerous possibilities and tools for further innovation in the psychological practice. Indeed recent studies provided many examples of possible applications of robots in the rehabilitation and education of people with learning difficulties and/or intellectual disabilities.

For this reason this chapter is dedicated to application of robotics with children with Autism Spectrum Disorder (ASD).

ASD, as previously mentioned, is a condition in which deficits in social communication and social interaction can make everyday life difficult. The use of electronic and mechanical devices has proven to be effective in ASD therapy and recently Socially Assistive Robotics (SAR) research has suggested that robots are promising tools for the treatment of this disorder. Starting from these findings, my on-going research aims to identify effective modalities for treatment of ASD through interaction with a robot, and to integrate them into existing therapeutic protocols to improve their efficacy.

In this chapter, I will introduce some preliminary findings of my work towards this objective. I detail the methodology and give the results of a pilot clinical trial, focused on imitation skills, with three children affected by ASD and Intellectual Disability (ID) under treatment in a research centre specialized in the care of children with disabilities. Analysis of these initial results encourages the development of effective protocols in which the robot becomes a mediator between the child with ASD and humans and suggests some research avenues for focus in the future.

NAO (Gouaillier et al., 2009) is the robotic platform used in this experiment and widely used in SAR (e.g., K. J. Kim et al., 2013). NAO robot is built to the size of a two-year old child. This fits the requirements of robot design for autism therapy which advises that the robot should roughly be the size of a human toddler (Giullian et al., 2010). To program the NAO's behaviours I used *Choreographe*, a development environment (Pot et al., 2009). The interface is mainly drag and drop, and allows the programmer to create a sequenced combination of predefined or custom behaviour boxes to manipulate the NAO's joints or attributes, such as its voice or eye LED colours. Using *Choreographe*, I developed a set of pre-programmed behaviours to allow the robot to interact with the children according to the procedure after described. All the behaviours were installed in the NAO's memory, ready to be executed when activated by a remote control application.

In conclusion the initial success of the experiment suggests that the robot could be effectively integrated in the TEACCH therapies currently used in the centre.

5.1 Materials and method

5.1.1 Participants

Three children were selected among patients diagnosed with ASD and ID. All are currently receiving treatment at the IRCCS Oasi Maria SS. of Troina (EN) in Italy, a specialized location for the rehabilitation of intellectual disabilities. The children were selected based on their main pathology (ASD), gender (male), and age (11-12), limited attention spans and the modality of response to the frustration is of the auto-aggressive type.

Children follow a clinical daily program of training using the TEACCH approach (Treatment and Education of Autistic and related Communication handicapped Children) with psychologists and highly specialized personnel. This approach has been developed to encourage children with autism to explore and develop pro-active skills and uses a system of stimulus and response. Like other behavioural approaches, TEACCH emphasizes structure:

specific behaviours are targeted, consequences and conditions of eliciting the behaviour are defined, and behaviour is shaped through the use of prompting and cueing (Schopler & Reichler, 1971).

The diagnosis was made with the following psycho-diagnostic instruments: Leiter International Performance Scale-Revised (Leiter-R) (Roid & Miller, 2002), Wechsler Intelligence Scale for Children (WISC) (Wechsler, 2003), Psycho-educational Profile, Third Edition (PEP-3) (Schopler, Lansing, Reichler, & Marcus, 2004), Vineland Adaptive Behavioural Scale (VABS) (S. S. Sparrow, Balla, & Cicchetti, 1984), Autism Diagnostic Interview-Revised (ADI-R) (Lord C, Rutter M, 1994), and Childhood Autism Rating Scale-Second Edition (CARS-2) (Schopler, Van Bourgondien, Wellman, & Love, 2010).

None of the children or professional educator had previous experience with a robot. Informed consent was obtained from the parents' of children.

5.1.2 Experimental setting

The experimental setting was a room, bright and free from noise, which is where children usually carry out their rehabilitation activities. To record all events and to observe the various interactions, a video camera was positioned, but hidden in such a way so as not interfere with the experiment.

During the session, the experimenter controls the robot remotely from a smartphone (Appendix E – F), implementing a technique named "Wizard of Oz" (WOZ) (Dahlback et al., 1993). Through the use of a WOZ technique, the robot's behaviour is adaptable as the experimenter can have a whole-world view of the interaction environment (e.g., E. Kim et al., 2012; Villano et al., 2011).

The robot was placed on a table in the centre of the room at the height of a child. All chairs were removed to facilitate child leg movement and to prevent a child from hitting them when moving.

In practice, this recreates one usual therapeutic scenario in which one person runs the session. Vice versa, settings found in the literature usually employ many active individuals, which are neither feasible nor economical for actual clinical application (Diehl et al., 2012). To this end, I highlight that all the robot behaviours were pre-set so that the experimenter could easily access them just touching the smartphone screen. Furthermore, to demonstrate the clinical feasibility of the setting, the experimenter was a researcher with short technical training, but with an extensive previous experience as therapist of mental disorders.

The children were brought into the room by the professional educator, one at a time, in front of the robot at a distance of one meter. This distance allows children to create their own personal space for positive interaction (Bar-Haim et al., 2010). The professional educator stayed behind the child to promote a familiar atmosphere and to help the experimenter if necessary.

In this contexts, the professional educator represents the “secure base” (Winnicott, 2002), in fact, she was one of those that are involved in the everyday treatment of the children.

5.1.3 Experimental procedure

The experimental procedure was planned in close collaboration with the therapists in order to identify the basis for the development of a therapeutic protocol.

The experiment was designed with a progressive increase in effort for the child, and the activity could be interrupted if the child was tired in order to avoid a dropout.

The main activity consists of an imitation game in which the role of the child is to engage first as imitator, then as initiator of robot movements.

Interaction activities were divided into four different steps:

Step 1: Introduction. The session begins with the NAO dancing with harmonic movements accompanied by music. This is intended to attract the children's attention to the robot. After dancing, the robot welcomes the child and calls him by name to establish a personal contact and also for relationship building. Then, the NAO explains, in simple language, the imitation game (step 2) to the child.

Figure 5.1 *NAO dancing with harmonic movements for to attract the children's attention.*

Step 2: The child imitates the robot. In this phase the robot solicits the child to imitate its movements. Movements involve upper and lower limbs and are simple, e.g. stretch arms up and down, walk back and forth, to be sure that the child can actually perform them.

During this step the device used to control the robot is hidden from the children. To help the interaction, positive reinforcements are uttered by the NAO when the child is successful in imitating the movements. The NAO can also say a warning, to be used when there are continuous errors, and a reminder of the purpose of the game, to be used if the child is losing focus.

The robot provides positive verbal reinforcement when the child is able to imitate the movements or gives suggestions to be used in case of continuous errors or distraction of the child from the objective.

The robot used random variations in the task order and different verbal reinforcements to avoid increasing motor stereotypies typical of the disease.

Figure 5.2 *NAO robot solicits the child to imitate its movements. The device used to control the robot is hidden from the children.*

Step 3: The robot imitates the child. The robot explains that it will now copy the movements that the child will do. This helps to engage the child's memory. On this occasion, the researcher shows to the child that they are controlling the robot, in order to create a condition of mediation in which the child could team up with the researcher to interact with the robot. This might encourage the child to have more eye contact with the adult as well as share excitement and affection with the researcher, because the child now knows that they are playing with the adult through the robot.

Figure 5.3 *NAO robot imitates the child.*

Figure 5.4 *researcher shows that they are controlling the robot using a mobile phone to the child.*

Step 4: Closure. To conclude the experimental session the NAO says goodbye to the child, with a gesture of the right arm accompanying the speech. The robot then stretches out its hand and asks for a handshake. Finally, it thanks the child for participation and tells them that it must go to recharge its batteries. This was to underline its limitations in order to comply with the ethical requirement of preventing the children, as far as possible, from becoming emotionally attached to it (Fridin, 2014a).

Figure 5.5 *The device is not hidden for child.*

Figure 5.6 *NAO says goodbye to the child, with a gesture of the right arm accompanying the speech.*

5.1.4 Video data analysis

During the interaction sessions, a high-resolution video was recorded to analyse the child behaviours during the interaction using the following five criteria:

1) Eye gaze	When child eye gaze is directed at the robot.
2) Imitation	This included direct and delayed imitation of the robot's movements, response to the robot's movement, and attempted imitation of the robot's movement.
3) Touch	When the child touched any part of the robot.
4) Near	This is the child approaching the robot and trying to stay in close proximity, going beyond the virtual barrier created by the table.
5) Human interaction	Which is when the child voluntarily looks or says something to the researcher, who is unknown to him.

The first four were derived from those proposed by Robins et al. (Robins et al., 2009) for the evaluation of basic behaviour, while the fifth was specifically introduced for this experiment.

Behaviour can be logged simultaneously (e.g. eye gaze and touch).

The evaluation was made with the use of a record sheet divided into seconds by two researchers, which were separately compiled and the results were compared for verification. The reliability was around 81%.

5.2 Results and Discussion

All children were able to successfully complete the experiment within a reasonable amount of time as shown in Table 5.1, which provides information on the participants and the total time of the experimental sessions. To protect the privacy, the children are identified just as ONE, TWO and THREE.

Table 5.1 *Information on the subjects and the total time of the experimental session with the robot.*

Participant	Age	Diagnosis	Total Time mm:ss
ONE	11	ASD, mild ID	9:21
TWO	11	ASD, severe ID, Down Syndrome	10:11
THREE	12	ASD, mild ID	8:14

The mean duration time was around 9 minutes, which is quite a bit longer than standard duration reported by previous experiments in the literature were usually activities last from 5 to 7 minutes (Lehmann et al., 2011).

This was mainly because the children were left free to be distracted and move away from the robot, but they were gently invited to come back both by the robot and by the researcher or the professional educator. The results reflect this behaviour; in fact ONE and TWO spent around half of the time with the robot and the rest in other spontaneous activities. One reason for the distraction is that they were looking for a chair, because they are used to sitting during the rehabilitation activities. The chairs were not use in order to facilitate movement of the child’s legs and to prevent children from hitting chairs when moving.

Table 5.2 presents the imitation results.

Four possible outcomes are considered:

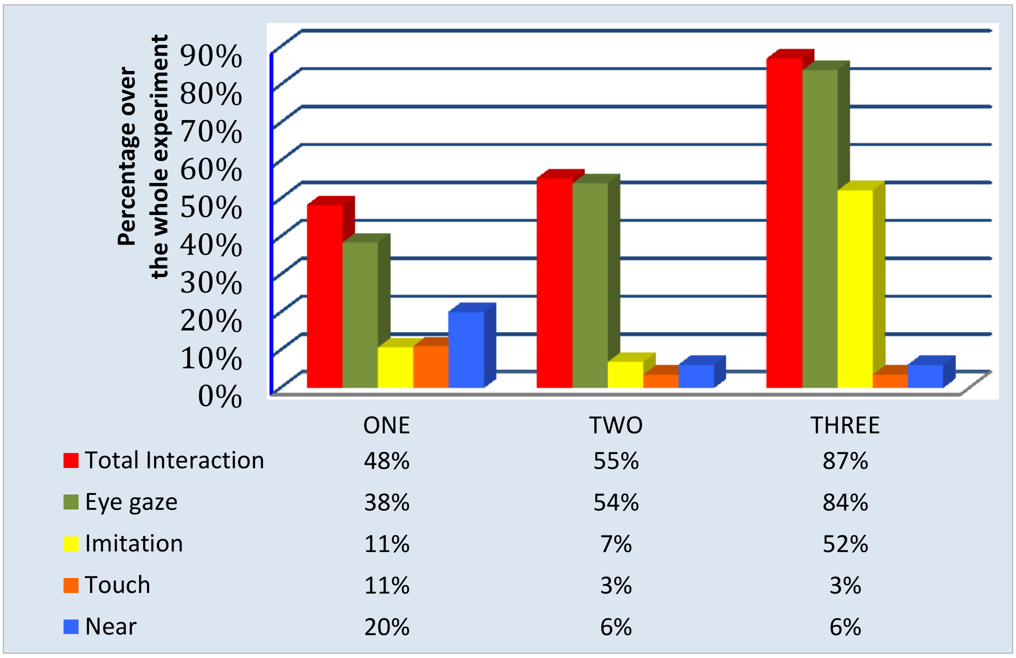
- No imitation (**N**), when no reaction is observed;
- Random movement (**R**), when there is a movement but it is unrelated with the stimulus;
- Partial imitation (**P**), when the movement is similar but imprecise (e.g. arms up only half way);
- Correct imitation (**C**), when the movement corresponds to the stimulus.

Stimuli were repeated (randomly) at least three times or until the child imitated the robot (up to ten times). Table 5.2 reports the best outcome for each child.

Table 5.2 *Success on imitating robot movements: **N**–no imitation; **R**-random movement; **P**-partial imitation; **C**-correct imitation.*

Stimuli (robot movements)	**ONE**	**TWO**	**THREE**
Right arm	N	N	C
Walk forward and back	N	N	C
Arms front & up	P	P	C
Arms front & down	C	C**	C
Arms up & down (alternated)	C*	R	C
Arms laterally extended	C	N	C
Rest position (arms adherent to the body)	C	N/R***	C

*once after seven repetitions; **three times in ten repetitions; ***four times he did not react, twice he did random movements.



	ONE	TWO	THREE
🟥 Total Interaction	48%	55%	87%
🟩 Eye gaze	38%	54%	84%
🟨 Imitation	11%	7%	52%
🟧 Touch	11%	3%	3%
🟦 Near	20%	6%	6%

Figure 5.7 *Experimental results of the three subjects in the criteria observed. Total interaction is the total time in which the subject shows at least one of the assessed behaviors.*

From the analysis of the data we can see that ONE, who usually tends to avoid new situations and people, was the most prone to distraction, but shows interest approaching the robot at close distances and touching the robot for longer time than the others. TWO was the least capable at imitating (only one stimulus after ten repetitions), probably because of his severe intellectual disability he was demotivated by the failures; he was also initially nervous and seemed to desire to walk away. But, without any external intervention, after the robot called him by name, he autonomously decided to stay and complete the session. This was in accordance with of the consent obtained prior to the study. Indeed, I was also interested to evaluate the capability of the robot to motivate and to engage the children in activities that can favour their mental development. This is one of the purposes of the re-habilitation that aims to improve their social skills taking into account their personal strengths and weaknesses.

THREE showed improved interaction; indeed he spent more time watching the robot and imitating the movements than the others. THREE's behaviour towards the robot was particularly interesting considering his restlessness. Observationally, he particularly enjoyed the interaction. Remarkably, at the end of the session, he greeted the robot and the researcher saying “ciao”, although this is not usual behaviour for him.

The interaction of the child with the researcher was analysed by dividing the experiment into two parts: ‘before’, and ‘after’, the researcher showed the children that they were controlling the robot via the smartphone. The time ‘before’ and ‘after’ was roughly the same. It was observed that the interaction between the child and the researcher increased between these sections. Indeed, as shown in the Table 5.3, the children gazed at the researcher more times and for a longer period after they were told that the researcher controlled robot.

Table 5.3 *Total time spent by the child interacting with the researcher (in seconds), before and after knowing she was controlling the robot.*

PARTICIPANTS	BEFORE	AFTER	IMPROVEMENT
ONE	2	4	+100%
TWO	5	8	+60%
THREE	2	9	+350%

5.3 Conclusions

Physical imitation is one of the tools offered by the therapies cognitive rehabilitation via mental simulation (Di Nuovo, De La Cruz, Conti, Buono, & Di Nuovo, 2014). In this research, I presented some preliminary results on a pilot study on the application of robots in the treatment of ASD, which involved three children also affected by intellectual disability.

The pilot study focused on imitation skills, and the analysis of the results suggest further indication that the SAR technology can be an effective tool to support established psychological therapies like the TEACCH. This result, pending confirmation with a larger sample, confirms others reported in the literature (Robins et al., 2009), as the children were able to successfully interact with the robot. Moreover, in all cases, we can observe a slight improvement in the time spent by the children to interact with the researcher.

This result encourages the development of effective protocols in which the robot becomes a mediator between the child with ASD and humans.

Due to the preliminary nature of the study and the results, no definite conclusions can be made at this point. However, the tendencies reported in this paper are very promising for the application of robots as therapeutic tools for children with ASD. Thanks to physical imitation, turn taking and role playing, the three children showed good interaction with the robot despite their disabilities; and some promising results were observed in the interaction with the researcher that was previously unknown to them.

I will also focus our future research with ASD and ID children on the importance of integrating robots with current daily therapeutic protocols, e.g. TEACCH, improving activities in which the robot can support the therapist. These should be effective for the treatment of mental disorders, and, meanwhile, can also be acceptable and easily used by practitioners of mental healthcare.

Finally, I would search for novel control strategies, which would allow the robot to automatically adapt to the individual needs of children and of the therapy (while remaining under the supervision of a therapist) (Thill et al., 2012).

Chapter VI

Cognitive Robotics approach as simulation of Unilateral Spatial Neglect

Introduction

In this chapter, I will present the experimental results of a cognitive robotic approach for modelling the human cognitive deficit known as Unilateral Spatial Neglect (USN).

In this study I will replicate a previous experiment with human patients affected by the USN, and numerical results show that the robot simulate the behaviours previously exhibited by humans. I present a novel artificial neural network model to control the spatial attention of the iCub robotic platform from proprioceptive information including not only visual information but also motor inputs.

To this end, I introduce an artificial neural network architecture designed and trained to control the spatial attentional focus of the iCub robotic platform. In fact, the robotic model used for the experiments is the iCub humanoid robot, which is a child-like humanoid robot platform designed to facilitate developmental robotics research (e.g. Metta et al., 2010).

The architecture is designed to model the RH specialization for elaboration of the visuo-spatial information, which emerges naturally because the network initialization incorporate some mechanisms inspired by the plasticity of the human brain (Gould, Reeves, Graziano, & Gross, 1999). In conclusion, I also simulated recovery after the damage to compare the performance of each of the two hemispheres as additional validation of the model.

This work highlights some possible advantages of the use of robotic platforms to model and study cognitive dysfunctions of the human brain.

6.1 Materials and Method

6.1.1 The neural network architecture

The robot is controlled by an artificial neural network architecture, which is schematically represented in Figure 6.1. The model has few functions of the PPC, which is thought to play a crucial role in the computation of sensorimotor transformations and in linking sensation to action.

The hidden layers are divided into two regions to mimic the separation of the cerebral hemispheres. Inputs are the polar coordinates of the targets, which were identified during the training phase of the experiment and the joint angle of the neck. Input coordinates were different for the RH and LH as they were retrieved using, respectively, the right and left eye cameras pictures, this way the coordinates were relative to the camera position. To simulate the antagonist action of the real human neck muscle, I coded the right input values as the opposite of the left, e.g. if the neck was turned 40 degrees to the right, the right motor input was -40 as the right muscle was flexed, meanwhile the left motor input was 40 as the left muscle was extended.

The role of the final layer (Cognition) is to simulate the final processing of the attentional biases and to give the final out that will be used to select the appropriate action to be started. A linear transfer function combines the inputs from LH and RH and generates the final classification likelihood of the sixteen possible target positions.

Finally, to model the asymmetries between the two hemispheres, I incorporate in this model the following plasticity mechanisms that a stronger activity on the RH should prompt (e.g. Pascual-Leone, Amedi, Fregni, & Merabet, 2005):

i. the reinforcement of the intra-hemispheric connections;
ii. the formation of new pathways.

In practice, when I model the RH specialization in this architecture (see Figure 6.1 for details):

i. the stronger links are modelled via the initialization of the LH connection weights in a smaller range, i.e. between -0.1 and 0.1, while the RH connection weights are greater (e.g. in the standard range [-1, 1]);

ii. the new pathways are modelled allocating four additional neural units to the RH layers. This way, in our experiments the relevant specialization emerges naturally after the back-propagation training.

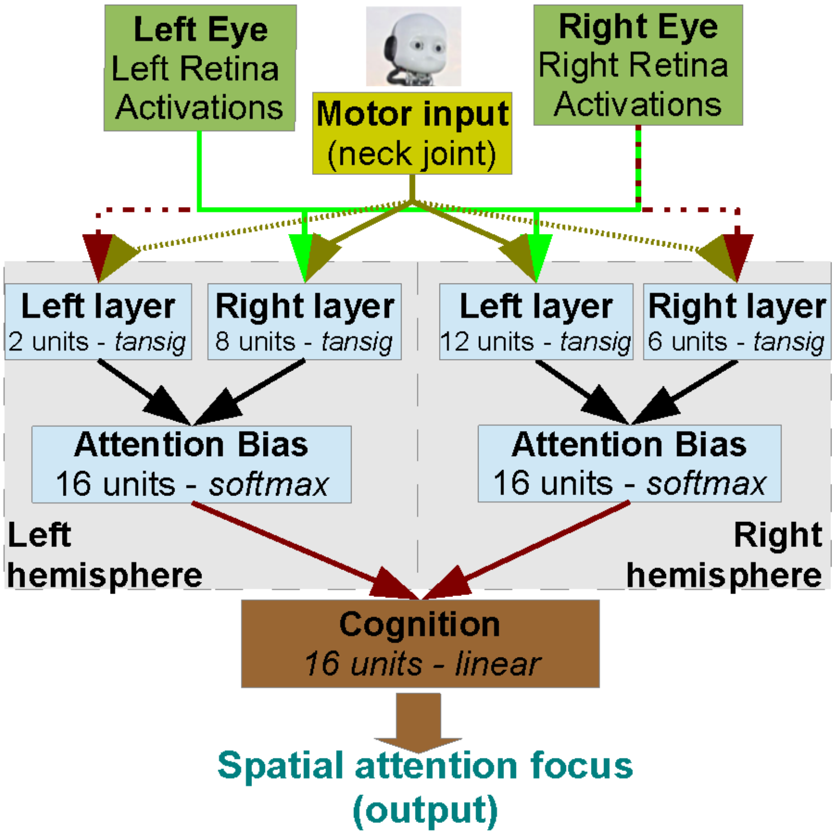


Figure 6.1 *The neural network model for simulation of USN. The hidden layers are divided into two regions to mimic the separation of the cerebral hemispheres. The number of units and transfer functions used to implement the neural processing are specified for each layer. Connections from Attention Bias to Cognition (red lines) are cut to simulate the hemisphere damage. In the control experiment, dotted lines are removed and left layer of RH has 8 units. In the second experiment, the RH has stronger connection weights and more neuronal units to simulate plasticity and prompt the emergence of the hemisphere specialization for processing visuospatial information.*

6.1.2 The experimental setup and procedure

The model presented in this paper is validated through experimental tests that resemble a previous study with human patients. USN patients repeated a manipulation task in four different conditions for placing targets and for orienting longitudinal axes of the head and eyes (Bisiach, Capitani, & Porta, 1985). To this end, I set up the four conditions as represented in Figure 6.2 using the *iCub* robot. In condition (A), the eight targets were placed in front of the robot, so that the longitudinal axes of the head and of the exploring hand lay in the sagittal mid-plane of the trunk, while the eyes looked straight ahead. In condition (B) the targets were (displaced in such a way that they all were) on the right of the sagittal mid-plane of the trunk while the head and eyes were kept at 0°. In condition (C) the targets remain as in (B) but the neck joint was rotated so that head and eyes were at an angle of 40° with respect to the sagittal mid-plane of the trunk. Finally, in condition (D), targets were returned to their original position as in (A), while head and eyes were kept at an angle of 40°, as in (C).

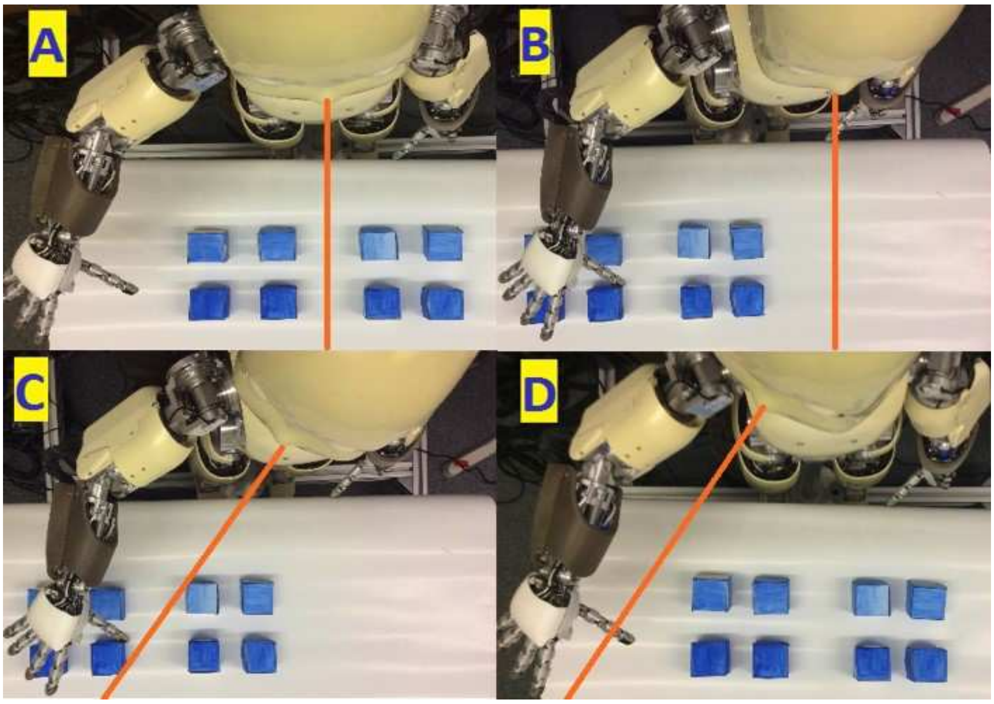


Figure 6.2 *The four experimental conditions. The orange lines highlight the head axes. In conditions A and B, they are right in front of the robot while in conditions C and D the head is turned 40 degrees to the right.*

For each condition, targets were eight small blue cubes placed on the table in two rows of four. The experimental task for the robot was to explore one by one the eight positions and to remove the objects placed on the table, without visual control (see Figure 6.3 for an example).

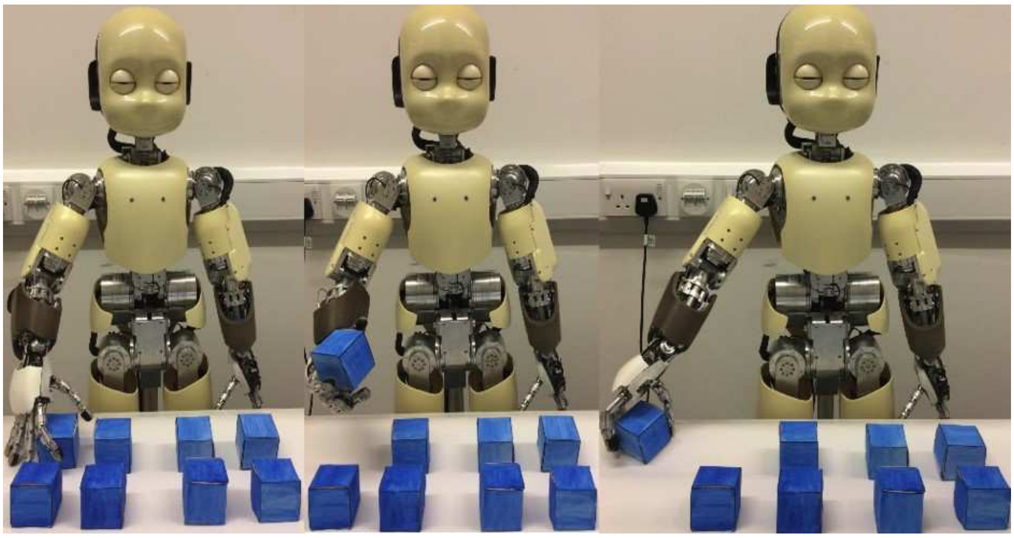


Figure 6.3 *The experimental task: the iCub robot removes an object from the working area.*

In a preliminary phase, the robot was trained to accomplish the experimental task using a pre-programmed routine. The goal of the training was to associate the action routine with the spatial attentional focus that identifies a specific place in the table. The action primitives needed to perform the task were previously learned by the robot. The object positions were calculated from pictures taken by the eye cameras during the training phase. These positions were represented as a pixel matrix and they are the input of our artificial neural architecture (*target inputs*). The other (motor) input is the neck joint angle. The model was trained using all the possible target positions on the table. A total of sixteen positions were identified, equally distributed on the left and on the right side of the robot in order to have a balanced training scenario that covers the entire attentional field.

Finally, in the lesioning experiments, I simulated damages in different parts of the artificial hemisphere by cutting neural links (i.e. assigning 0 to connection weights), obtaining also an intra-hemispheric disconnection between anterior and posterior layers. A similar approach was also found to yield neglect-related behaviour in previous simulation studies (e.g., Di Ferdinando, Parisi, & Bartolomeo, 2007; Mozer, 2002).

6.2 Results and Discussion

In experiments, we can consider a task execution successful when the competitive layer (*Cognition*) activates the output neuronal unit associated with the target area and, consequently, the primitive motor action to remove the target object from the table. Otherwise, the trial is recorded as an omission. Each experiment was replicated 5 times with random weight initialization and I report the median result in the following tables and text.

I considered two test cases for damaging the model: (1) there is no specialization, i.e. LH and RH activate the focus only when the target is in the contralateral area of the attention focus; (2) the RH is specialized and it is able to activate the focus in any area, while the left one can only activate the focus on the right. In both cases, after the training phase, the robot learns to execute the task perfectly.

As a further experiment, I re-applied the back-propagation algorithm to simulate a rehabilitation therapy and the recovery after the damage as additional validation of the model. In this scenario, the results are analysed in terms of the number of repetitions needed to recover and the performance of the two hemispheres is compared.

6.2.1 Test case 1: No specialization (control experiment)

In the first case, the plasticity mechanisms are not included in the model: right-left and left-right connections (the dotted lines in Figure 6.1) are removed from the neural network, meanwhile both sides had the same number of neuronal units (eight) and all their connection weights were randomly initialized in the same range [-1, 1]. On average, the *gradient descent with momentum* back-propagation algorithm required 6193 to find the optimal weights during the training. After the LH and RH connections are damaged, and the results are presented in Tables 6.1, and 6.2 respectively. In this test case, we can see that the specialization for the spatial attention didn't occur as both hemispheres show USN in the contralateral space and results are practically the same.

Table 6.1 *The LH is damaged: green boxes indicate the successful removal of the object in the corresponding area, while orange boxes indicate that the area was omitted (i.e. the object was not removed). The likelihood of the correct target is also shown.*

Condition A			
1.000	0.9957	0.0590	0.1020
0.9902	0.9466	-0.0565	0.0299

Condition B			
0.0590	0.2098	0.0703	0.0577
-0.0565	0.0299	0.0004	0.1196

Condition C			
0.6392	0.8950	0.0747	0.1030
0.8778	0.9742	0.0131	0.0944

Condition D			
0.9694	0.9122	0.8778	0.8950
0.9745	0.8489	0.6392	0.9742

Table 6.2 *The RH is damaged: green boxes indicate the successful removal of the object in the corresponding area, while orange boxes indicate that the area was omitted (i.e. the object was not removed). The likelihood of the correct target is also shown.*

Condition A			
-0.1100	0.0437	0.9752	0.9816
0.0954	-0.1327	0.9513	0.9413

Condition B			
0.9752	0.9816	0.9297	0.9423
0.9513	0.9413	0.9996	0.8804

Condition C			
0.1222	0.1050	0.9253	0.7507
0.1562	0.0258	0.8990	0.9656

Condition D			
-0.1675	0.0878	0.1222	0.1050
-0.0647	-0.1278	0.1562	0.0258

6.2.2 Test 2: Right Hemisphere specialization

In this test case, I simulate the right hemisphere specialization for the spatial attention by incorporating the plasticity mechanisms in the network initialization. Indeed, the right hemisphere had a higher number of neuronal units (as reported in Figure 6.1) and the connection weights of the left hemisphere were initialized randomly in the range [-0.1, 0.1]. Thanks to this initialization, the model shows some behaviour also described in the real experiment we are replicating**.** Numerical results are reported in the following Tables 6.3 and 6.4 the network was trained by using the same back-propagation algorithm, which required an average of 4740 epochs to learn the optimal connection weights and classify the target positions with an average likelihood of 0.9999.

Table 6.3 *Experimental results when the "unspecialized" LH is damaged (control experiment): green boxes indicate the successful removal of the object in the corresponding area, while orange boxes indicate that the area was omitted (i.e. the object was not removed).*

Condition A				Condition B			
🟩 1.000	🟩 1.000	🟩 0.5183	🟩 0.6708	🟩 0.5183	🟩 0.6708	🟩 0.5263	🟧 0.4730
🟩 0.9984	🟩 1.000	🟩 0.6481	🟩 0.6655	🟩 0.6481	🟩 0.6655	🟧 0.3323	🟧 0.4261
Condition C				**Condition D**			
🟩 0.8348	🟩 0.9665	🟩 0.5182	🟧 0.4522	🟩 0.8812	🟩 0.9831	🟩 0.8348	🟩 0.9665
🟩 0.9557	🟩 0.7925	🟧 0.4062	🟩 0.5116	🟩 1.0000	🟩 0.9867	🟩 0.9557	🟩 0.7925

From Table 6.3, we can see that only the right side of the spatial attention focus is slightly affected, indeed problems can be considered minor as only three omissions are registered in condition B, which is the most difficult because all the targets are in the contralateral side of the damage, and two in C.

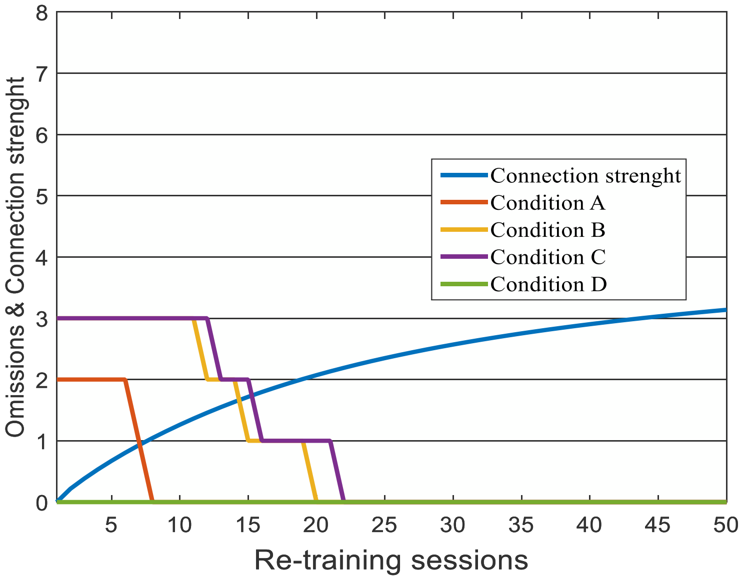
Table 6.4 *Experimental results when the "specialized" RH is damaged: green boxes indicate the successful removal of the object in the corresponding area, while orange boxes indicate that the area was omitted (i.e. the object was not removed).*

Condition A				Condition B			
🟧 0.1020	🟧 0.0187	🟩 0.6706	🟧 0.3912	🟩 0.6706	🟧 0.3912	🟩 0.7120	🟩 0.5777
🟧 0.0709	🟧 -0.0051	🟩 0.5286	🟩 0.5025	🟩 0.5286	🟩 0.5025	🟩 0.7534	🟩 0.7057
Condition C				**Condition D**			
🟧 0.2539	🟧 -0.0022	🟩 0.6639	🟩 0.6693	🟧 0.0351	🟧 0.0351	🟧 0.2539	🟧 -0.0022
🟧 0.1145	🟧 0.2336	🟩 0.5569	🟩 0.5951	🟧 0.1745	🟧 -0.0227	🟧 0.1145	🟧 0.2336

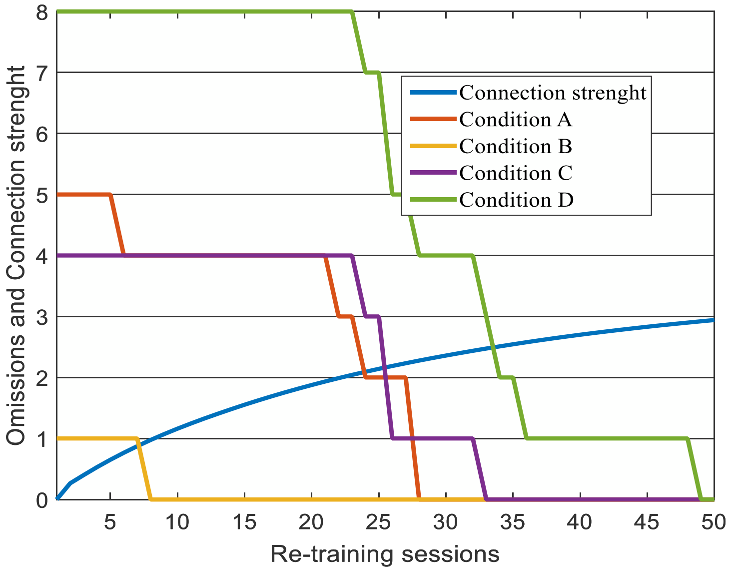
From Table 6.4, we can see that the experimental results are similar to the findings reported in the work that this experiment is replicating. Indeed, in (Bisiach et al., 1985), authors report more omission (i.e. missed targets) in the contralesional side of the brain lesion, i.e. on the left as the RH is damaged. In particular, we can see that the sagittal mid-plane and line of sight contribute significantly to the omissions: when the robot turns its head it is able to remove almost all objects in condition B.

The comparison between results in Tables 6.3 and 6.4 clearly suggest that neglect is less severe when LH is damaged, and this is in line with the findings reported in the literature (Mapstone et al., 2003; Monaghan & Shillcock, 2004).

Finally, Figure 6.4 presents the results of the post-trauma rehabilitation training for both LH (Figure 6.4a) and RH (Figure 6.4b). Figure 6.4 reports also the strength of connection weights, which is calculated as the Euclidean distance from the initial condition (i.e. all weights are zero) and measure the speed of the recovery.



a) The left hemisphere was damaged.



b) The right hemisphere was damaged.

Figure 6.4 *Rehabilitation training results. The figures report omissions and damaged links weights after each session, which comprises 100 epochs of back-propagation. The strength of connection weights is a measure of the recovery speed.*

By comparing the two plots, we can see that the recovery in terms of weights strength is similar between the two hemispheres, but the robot recovers faster when the damage is on the LH than RH. Indeed, in the case of LH damage there are no signs of USN after 22 re-training sessions while in the case of RH damage a full recovery is achieved after 49 sessions. The faster recovery behaviour in case of left damage is frequently reported in the literature (e.g., De Renzi, 1982) and it was also observed by Monaghan & Shillcock (2004) who suggest it is evidence of the RH specialization for the elaboration of visual-spatial information.

6.3 Conclusions

This research presented a cognitive robotics approach to the computational modelling of the cognitive dysfunction known as USN. The aim of the study was to introduce and validate a novel model architecture that incorporates the lateral specialization for processing the visual-spatial information. The design of the model hypothesises plasticity mechanisms that allow the emergence of spatial specialization of the right hemisphere in the experimental task.

Finally, I report results of an experimental with the real *iCub* robot platform that shows behaviours similar to those of human patients reported in previous studies.

The present study also highlights some advantages of using an artificial brain and a robotic platform to simulate cognitive dysfunctions. In fact, I was able to perform tests that are difficult for human subjects. As an example, neglect is less observed in patients with LH damage and will be difficult to find subjects with the lesion in the LH available for the experiment, also because LH damage may imply other problems (e.g. memory, speech, writing, and cognitive processing) that severely limit their capabilities to interact (Karnath, Milner, & Vallar, 2002; Springer & Deutsch, 1985). Another advantage is that robots are “tireless” so they can complete the experimental test right after rehabilitation training, whereas a human patient will be probably tired and this can affect its performance during the test, especially at the beginning of the therapeutic path.

General Conclusions

There is no simple solution or resolution that can be offered by way of a conclusion to a thesis about the robotics and intellectual disabilities. As we have seen, the acceptance and use of robotics in a clinical setting or in simulation condition, are of global challenges that are facing the contemporary world, and can seem so different from the usual way of treating the pathology that it can be hard to see a way forwards. However, it is hoped this book has given you some ideas about ways that the problems can be tackled and arguments to support such changes.

As mentioned, given the increased interest in robotics in recent years toward education and care for vulnerable people, there have been work involving the acceptability of robots as mediator between elderly and home technology (De Ruyter & Aarts, 2004), teaching assistant (You, Shen, Chang, Liu, & Chen, 2006), assistance to diabetics (Looije et al., 2006), reactive and physiological (Kazuyoshi Wada & Shibata, 2007), elderly assistance (Mayer & Panek, 2014), measured their blood pressure (Kuo et al., 2009), studies of behaviour proactive and to motivate users to follow physical activity (Heerink, 2011; Klamer & Ben Allouch, 2010). The researchers have principally seen as protagonist's older people with disabilities in some cases. Specifically, few research with undergraduate students who have made use of Socially Assistive Robotics (SAR) have found that there is a positive acceptance and gender influence (De Graaf & Ben Allouch, 2013) and that the acceptance depends on the familiarity with lecturer (A. Kim et al., 2013).

In agreement with this premise, in the chapter IV has been reported the results of a study on acceptance of robots in the education and care of children by a group of 25 practitioners, specialized in developmental disabilities, and 55 students in psychology and educational sciences. Then, in a cross-cultural perspective, I reported the results of a study on cultural influence in the acceptance of robotics of 74 psychology students from two universities: Catania (Italy) and Plymouth (UK).

In the chapter V, has been used a robots to stimulate, with imitation game, a condition of developmental disability. The tendencies reported in this chapter are very promising for the application of robots as therapeutic tools for children with Autism Spectrum Disorder. In fact, thanks to physical imitation, turn taking and role-playing, the three children showed good interaction with the robot despite their disabilities.

As long as purpose of the chapter VI, have been used of robot to simulate a pathological condition, Unilateral Spatial Neglect, and their rehabilitation. I report results of an experimental with the robot that shows behaviours similar to those of human patients reported in previous trials.

In the first three studies, has been used a robots platform Socially Assistive Robotics (SAR) with the humanoid NAO robot, while in the last section has been used iCub robot.

The choice of using SAR in the first three studies, arises because it is a fast emerging field that develops from the intersection of social robotics and assistive robotics and involves robots that are designed to help through advanced social interaction (Feil-Seifer & Matarić, 2009).

In conclusion as we have seen, a robot will need to be programmed for different relevant tasks during treatment; for practical purposes, it would be ideal for therapists to have the ability to complete this programming themselves. Therefore, therapists and other users must be able to manage and understand how to use the robot for a variety of clinical needs. One potential concern is that the technological knowledge needed in order for mental healthcare consumers (e.g. patients, therapists) to use robots effectively may be beyond the existing skill sets of some users. The goals of the research endeavours are to create systems that can be easily and readily used for treatment applications to increase the acceptance of these instruments (Rabbitt et al., 2014). As reported by Scassellati et al. (Scassellati et al., 2012) "*Few research groups have total coverage of these disparate fields, so groups tend to focus on their strengths, whether they be in robot design, interaction design, or evaluation. Unfortunately, without clinical psychiatrists and psychologists, most research groups lack long-term, continuous access to protected groups such as children with autism, making it difficult to measure the benefit of* *design decisions."*

In conclusion, facilitating collaborations between clinicians and roboticists is probably the only way to enable this kind of in-depth interaction study.

Appendix

Appendix A

Questionnaire - Heerink, Kröse, Evers, et al., (2009)

ANX
1. If I should use the robot, I would be afraid to make mistakes with it
2. If I should use the robot, I would be afraid to break something
3. I find the robot scary
4. I find the robot intimidating

ATT
5. I think it's a good idea to use the robot
6. the robot would make my life more interesting
7. It's good to make use of the robot

FC
8. I have everything I need to make good use of the robot.
9. I know enough of the robot to make good use of it.

ITU
10. I think I'll use the robot during the next few days
11. I am certain to use the robot during the next few days
12. I'm planning to use the robot during the next few days

PAD
13. I think the robot can be adaptive to what I need
14. I think the robot will only do what I need at that particular moment
15. I think the robot will help me when I consider it to be necessary

PENJ
16. I enjoy the robot talking to me
17. I enjoy doing things with the robot
18. I find the robot enjoyable
19. I find the robot fascinating
20. I find the robot boring

PEOU
21. I think I will know quickly how to use the robot
22. I find the robot easy to use
23. I think I can use the robot without any help
24. I think I can use the robot when there is someone around to help me
25. I think I can use the robot when I have a good manual.

PS
26. I consider the robot a pleasant conversational partner
27. I find the robot pleasant to interact with
28. I feel the robot understands me.
29. I think the robot is nice

PU
30. I think the robot is useful to me
31. It would be convenient for me to have the robot
32. I think the robot can help me with many things
SI 33. I think the staff would like me using the robot
34. I think it would give a good impression if I should use the robot.

SP
35. When interacting with the robot I felt like I'm talking to a real person
36. It sometimes felt as if the robot was really looking at me
37. I can imagine the robot to be a living creature
38. I often think the robot is not a real person.
39. Sometimes the robot seems to have real feelings

Trust
40. I would trust the robot if it gave me advice.
41. I would follow the advice the robot gives me

ANX: Anxiety, ATT: Attitude, FC: Facilitating Conditions,
ITU: Intention to Use, PAD: Perceived Adaptability,
PENJ: Perceived Enjoyment, PEOU: Perceived Ease of Use,
PS: Perceived Sociability, PU: Perceived Usefulness,
SI: Social Influence, SP: Social Presence.

Appendix B

Questionnaire

based on the model Unified Theory of Acceptance and Use of Technology (UTAUT) (Heerink, Kröse, Evers & Wielinga, 2009; Fridin & Belokopytov 2014).

Please circle the number that corresponds most closely to your agreement or disagreement of each statement.
Note that 1 corresponds to the highest disagreement and 5 the highest agreement so:

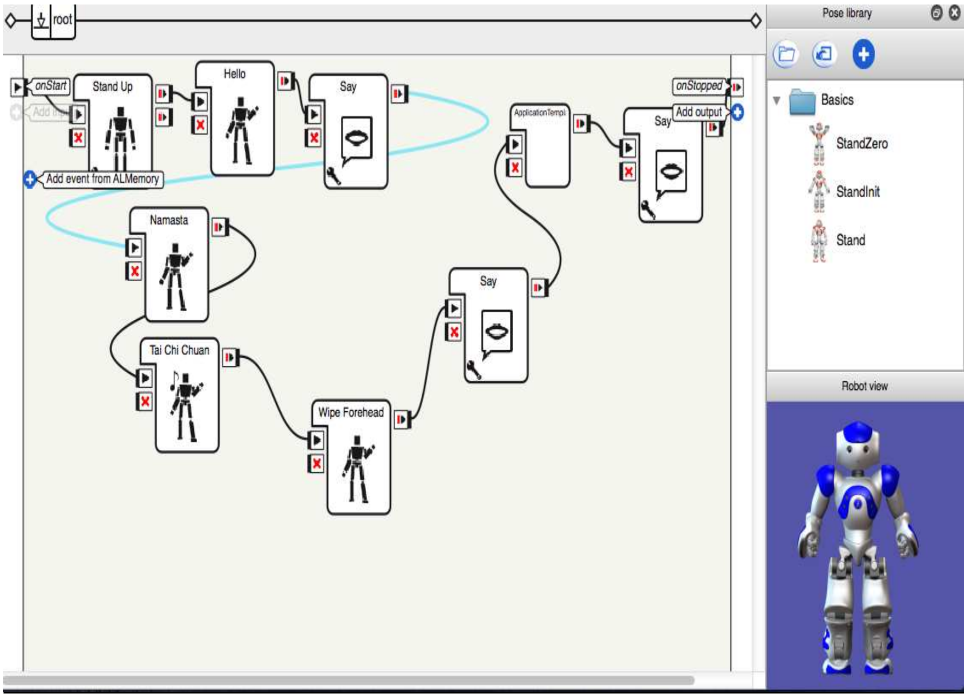
1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

Nationality_______ Age _______ F _____ M _____

1.	I should use the robot, I would be afraid to make mistakes with it.	**1**	**2**	**3**	**4**	**5**
2.	If I should use the robot, I would be afraid to break something.	**1**	**2**	**3**	**4**	**5**
3.	I find the robot scary.	**1**	**2**	**3**	**4**	**5**
4.	I find the robot intimidating.	**1**	**2**	**3**	**4**	**5**
5.	I think it’s a good idea to use the robot.	**1**	**2**	**3**	**4**	**5**
6.	The robot would make my life more interesting.	**1**	**2**	**3**	**4**	**5**
7.	It’s good to make use of the robot.	**1**	**2**	**3**	**4**	**5**
8.	I have everything I need to make good use of the robot.	**1**	**2**	**3**	**4**	**5**
9.	I know enough of the robot to make good use of it.	**1**	**2**	**3**	**4**	**5**
10.	I think I’ll use the robot in the near future.	**1**	**2**	**3**	**4**	**5**
11.	I am certain to use the robot in the near future.	**1**	**2**	**3**	**4**	**5**
12.	I’m planning to use the robot in the near future.	**1**	**2**	**3**	**4**	**5**
13.	I think the robot can be adaptive to what I need.	**1**	**2**	**3**	**4**	**5**
14.	I think the robot will only do what I need at that particular moment.	**1**	**2**	**3**	**4**	**5**
15.	I think the robot will help me when I consider it to be necessary.	**1**	**2**	**3**	**4**	**5**
16.	I enjoy the robot talking to me.	**1**	**2**	**3**	**4**	**5**
17.	I enjoy doing things with the robot.	**1**	**2**	**3**	**4**	**5**
18.	I find the robot enjoyable.	**1**	**2**	**3**	**4**	**5**
19.	I find the robot fascinating.	**1**	**2**	**3**	**4**	**5**
20.	I find the robot boring.	**1**	**2**	**3**	**4**	**5**
21.	I consider the robot a pleasant conversational partner.	**1**	**2**	**3**	**4**	**5**
22.	I find the robot pleasant to interact with.	**1**	**2**	**3**	**4**	**5**
23.	I feel the robot understands me.	**1**	**2**	**3**	**4**	**5**
24.	I think the robot is nice.	**1**	**2**	**3**	**4**	**5**
25.	I think the robot is useful to me.	**1**	**2**	**3**	**4**	**5**
26.	It would be convenient for me to have the robot.	**1**	**2**	**3**	**4**	**5**
27.	I think the robot can help me with many things.	**1**	**2**	**3**	**4**	**5**
28.	I think the staff would like me using the robot.	**1**	**2**	**3**	**4**	**5**
29.	I think it would give a good impression if I should use the robot.	**1**	**2**	**3**	**4**	**5**
30.	When interacting with the robot I felt like I’m talking to a real person.	**1**	**2**	**3**	**4**	**5**
31.	It sometimes felt as if the robot was really looking at me.	**1**	**2**	**3**	**4**	**5**
32.	I can imagine the robot to be a living creature.	**1**	**2**	**3**	**4**	**5**
33.	I often think the robot is not a real person.	**1**	**2**	**3**	**4**	**5**
34.	Sometimes the robot seems to have real feelings.	**1**	**2**	**3**	**4**	**5**
35.	I would trust the robot if it gave me advice.	**1**	**2**	**3**	**4**	**5**
36.	I would follow the advice the robot gives me.	**1**	**2**	**3**	**4**	**5**

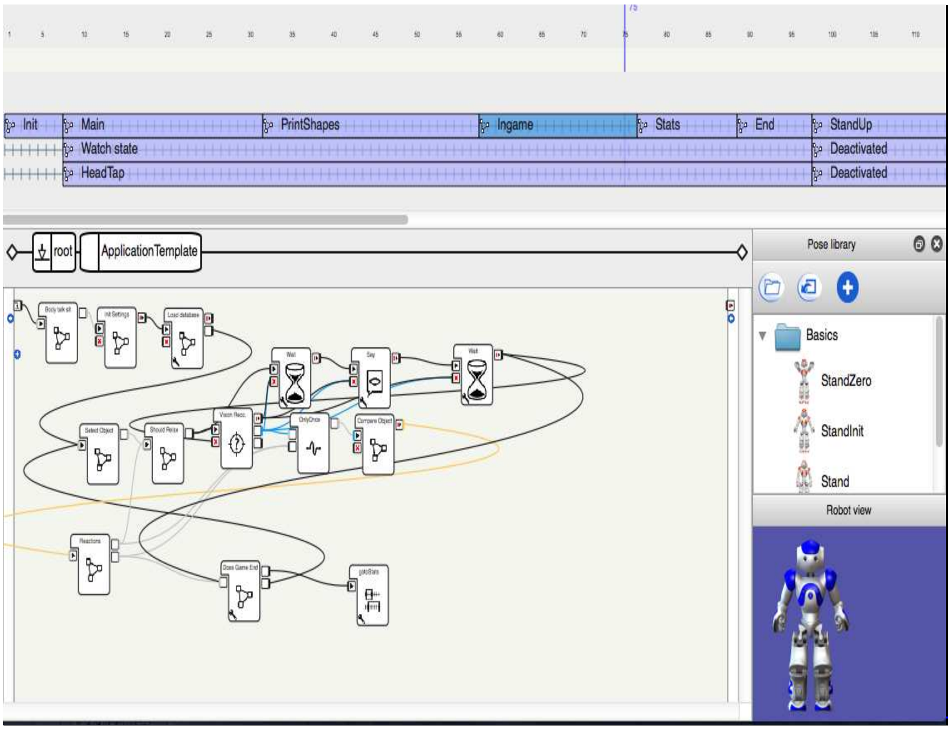
Thank You!!!

Appendix C



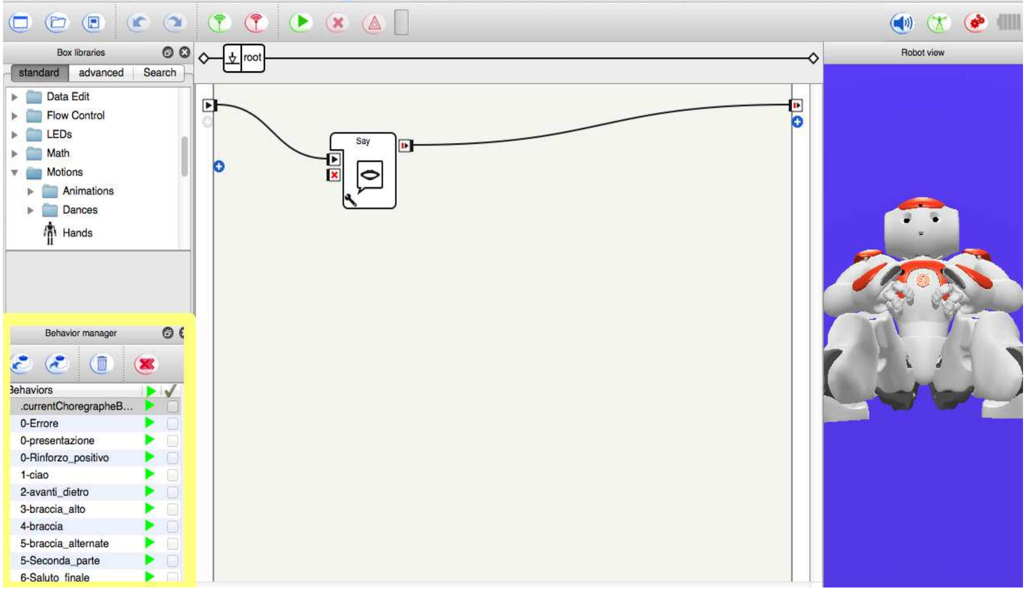
Choreographe: The demo behaviours program.

Appendix D



Choreographe: Detail of the interactive game of picture recognition.

Appendix E



Behaviors
- .currentChoregrapheB…
- 0-Errore
- 0-presentazione
- 0-Rinforzo_positivo
- 1-ciao
- 2-avanti_dietro
- 3-braccia_alto
- 4-braccia
- 5-braccia_alternate
- 5-Seconda_parte
- 6-Saluto_finale

Choreographe: GUI (behaviour manager is highlighted in yellow).

Appendix F

- .currentChoregrapheBehavior
- 0-Errore
- 0-Rinforzo_positivo
- 0-presentazione
- 1-ciao
- 2-avanti_dietro
- 3-braccia_alto
- 4-braccia
- 5-Seconda_parte
- 5-braccia_alternate
- 6-Saluto_finale
- SalutiPasqua
- braccia
- braccia-alto
- ciao
- demo
- get-in-the-box
- gioco_1a
- handoverhand
- handshake
- memorize-face

Choreographe: List of behaviours accessible on a tablet screen.

Publications

The concepts reported in the thesis have been exposed also in the following refereed journal papers, made with the cooperation of other co-authors during the period of the doctoral attendance:

Conti D., Di Nuovo S., Buono S., & Di Nuovo A. (2015). Robots in education and care of children with developmental disabilities: A study on acceptance by experienced and future professional. To be published in *International Journal of Social Robotics.*

Di Nuovo S., & Conti D. (2015). Un robot per terapeuta (e per amico?), A robot for therapist (and as a friend?). *Psicologia Contemporanea*, vol. 248; p. 6-13, ISSN: 0390-346x.

Conti D. (2015). Socially assistive robotics: una possibile unione tra robotica e psicologia, (Socially assistive robotics a possible alliance between robotics and psychology). *Formazione Psichiatrica e Scienze Umane*, vol. 1; p. 61-68, ISSN: 0394- 8897.

Cannavò R. B., Conti D., & Di Nuovo A. (2015). Computer-aided assessment of aviation pilots attention: design of an integrated test and its empirical validation. *Applied Computing and Informatics*, 255, ISSN: 2210-8327.

Di Nuovo S., De La Cruz V., Conti D., Buono S., Di Nuovo A. (2014). Mental imagery: rehabilitation through simulation. *Life Span and Disability*, vol. XVII/1; p. 89-118, ISSN: 2035-5963.

Refereed conference papers and abstracts:

Conti D., Di Nuovo S., Buono S., Trubia G., & Di Nuovo A. (2015). Therapy Enrichment via Robot Assistance for Personalized and Intelligent Support in the Treatment of Autism, *Workshop on "Bridging user needs to deployed applications of service robots", IEEE/RSJ IROS.*

Conti D., Di Nuovo S., Buono S., Trubia G., & Di Nuovo A. (2015). Use of robotics to stimulate imitation in children with Autism Spectrum Disorder: A pilot study. *IEEE RO-MAN The 24th International Symposium on Robot and Human Interactive Communication,* Kobe–Japan, p. 1-6. (Candidate to the RSJ/KROS Distinguished Interdisciplinary Research Award).

Conti D., Cattani A., Di Nuovo S., & Di Nuovo A. (2015). A cross-cultural study of acceptance and use of robotics by future psychology practitioners. *IEEE RO-MAN The 24th International Symposium on Robot and Human Interactive Communication,* Kobe–Japan, p. 555-560.

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Conti D. (2014). La robotica nel trattamento della disabilità mentale, (The robotics in the treatment of mental disabilities), *Midterm Conference of Italian Association of Cognitive Sciences (AISC),* Enna-Italy.

Book chapters:

Conti D. (2015). Applicazioni della robotica al trattamento dei disturbi evolutivi, (Applications of robotics to the treatment of developmental disorders). In: *Vita Naturale, Vita Artificiale. Tecniche di Simulazione e Applicazioni Educative e Cliniche,* Santo Di Nuovo and Angelo Cangelosi (a cura di); p. 77-90; FrancoAngeli, ISBN: 1240.403.

Conti D. (2015). Il problema dell'"accettabilità" dell'artificiale, (The problem of "acceptability" of the artificial). In: *Vita Naturale, Vita Artificiale. Tecniche di Simulazione e Applicazioni Educative e Cliniche,* Santo Di Nuovo and Angelo Cangelosi (a cura di); p. 105-112; FrancoAngeli, ISBN: 1240.403.

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