Socially Assistive Robotics in the Treatment of Behavioural and Psychological Symptoms of Dementia

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Abstract **– Socially Assistive Robotics is an emerging field of research focused on assisting people through social interaction. While much attention has been paid in the past to robots that provide assistance to people through physical contact, as well as to robots that entertain through social interaction, more recently attention has been paid on socially assistive robots that mediate communication and social exchange. In the paper the argument is developed describing an exploratory study related to the use of the seal robot Paro for the treatment of dementia. The case is illuminating since it highlights the potential of social robots in supporting non pharmacological therapeutic protocols for the dementia care**

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Index Terms **– Socially Assistive Robotics, Dementia, Behavioural and Psychological Symptoms of Dementia, Therapeutic Protocols.**

I. Introduction

Attempts to create a robot capable of showing social behaviour and interacting with human beings have been very popular in the recent history of robotics. Research in this sector has rapidly expanded from the design of robots inspired by the biological and behavioural characteristics of animal organisms – the reproduction of stigmergic communication in robot-ant communities in the studies carried out by Beckers, Holland and Deneubourg [1], for example – to the design of social robots inspired by the way human relationships and communication are carried out. We can refer to robots designed for engaging in interaction with humans as Socially Interactive Robots (SIR). The concept of sociality in robots has taken on a wide variety of nuances and meanings that basically depend on two elements: the ability of machines to support the social model they refer to, and the complexity of the interaction scenarios they can face [2]. In line with these two elements there are various kinds of social robots, from those which evoke sociality (socially evocative robot) by placing the accent on anthropomorphic or zoomorphic characteristics; to those known as social interface robots, which adopt social and behavioural rules to provide their human interlocutors with a "natural interface"; from socially receptive robots with learning abilities by means of imitation; to sociable robots capable of pro-actively engage in interaction with humans.

The increasing robot ability to involve humans in social interactions opened up the possibility to explore the usage of robots also in therapeutic interventions addressed to cognitive and behavioural rehabilitation. A number of studies have been conducted on the capacity of robots to stimulate social and relational capabilities in both children and elderly people [3-7]

In the specific context of therapeutic activities, SIRs offer a novel opportunity for the definition of non pharmacological protocols specifically oriented to the stimulation of residual communication and relational skills.

Feil-Seife et al. [8] define the category of Social Assistive Robots (SAR) as the intersection between Social Interactive Robots and Assistive Robots (AR), where the latter refer to robots that assist patient in recovering physical disabilities through physical interactions. SAR share with Socially Interactive Robots the focus on social relation, but they are designed to engage in interaction with a human subject for the purpose of giving assistance. At the same time SAR share with Assistive Robots the therapeutic and assistance purpose specifying that the assistance is achieved through social interaction.

This paper presents an exploratory work carried out with Paro, a socially assistive baby harp seal robot, used to support therapeutic interventions for the stimulation of social and communications skills in dementia affected subjects. The study has been carried out with the main aim to collect data on the role the robot plays both in calming aggressive patients and in supporting rehabilitation protocols. For this reason, the study has been conducted through ethnographic observation of the activity in two different contexts: dyadic relations between the patient and the robot, and triadic relations involving also the therapist. The data collected in the study are currently used to define an experimental plan to collect quantitative and qualitative evidences of the robot as social mediator. A number of field observations have been conducted on individuals and groups of patients interacting with the baby harp seal robot, in the dementia ward of "Casa Protetta Albesani" Nursing Home (Castel San Giovanni, Italy) over a period of 8 months (February – October 2005). In the paper we focus on the specific clinic case of a patient affected by a severe neuropsychiatric disturbances. The patient was treated with Paro over a period of 6 months and the data reported in the paper come both from the direct observation of the interaction with the robot and the assessment of physicians and nurses involved in the study.

II. DEMENTIA

Dementia is a progressive disabling neurological condition that may be seen in a wide variety of diseases. The most common cause of dementia is Alzheimer's disease, which accounts for approximately half of the people with dementia followed by vascular disease, Lewy body dementia and a number of other diseases causing dementia [9].

Dementia is not a natural part of ageing but age is the most significant known risk factor. Over the age of 65, the risk of developing dementia doubles approximately every five years [10].

Yet there is no known cure for dementia.

The Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R) [11] indicates that before a diagnosis of dementia can be made the loss of cognitive functions the patient must impair or compromise his/her ability to adapt to environment, thus interfering with social and/or occupational functioning. Impairment in memory is a pre-requisite. Furthermore, at least one of the following impairments must be present:

- Impairment of abstract thinking;
- Impairment of judgement;
- Other disturbances of the higher cortical function, such as aphasia or other language disorders, apraxia (inability to carry out motor activities despite intact comprehension and motor function), agnosia (failure to recognise objects despite intact sensory function), constructional difficulty (inability to copy three dimensional figures, assemble blocks, or arrange sticks in specific configurations);
- Personality change (apathy, indifference, irritability, disinhibition),

Associated to the cognitive decline of the affected patients, dementia brings about behavioural and psychological disturbances too: deliriums, illusions, hallucinations, delusions, mood shifts, anxiety, agitation, physical or verbal aggressiveness, wandering, rummaging, depression.

While not specifically relevant for diagnosis, behavioural and psychological symptoms of dementia (BPSD) are important because they cause particular stress and pressure on caregivers and often become a reason for institutionalisation. Furthermore since there is no available treatment for cognitive deficits due to dementia syndrome, existing pharmacological regimes focus on non-cognitive features. But if sedative treatment makes the patient more manageable it has a negative drawback on the overall residual abilities of the subject.

BPSD can be seen as a natural reaction of people with dementia to an hostile environment and to the knowledge that they are going to lose their abilities [12]. At an early stage of the disease, patients with dementia realize their diminished cognitive capabilities and progressive inadequacy to social relations: this often causes a voluntary isolation that results serious relation difficulties.

With the progressing of the disease, the isolation process is accentuated due to the growing loss of autonomy and the appearance of more severe behavioural symptoms. Furthermore, the greater the severity of behavioural disorders, the greater the need for professional care and institutionalization [13]. Moving to a long term care institution causes patients to loose their bearings and breaks up their social networks: subjects lose their familiar spaces, habits, proprieties and they are expelled from their community. All these factors concur to cause depression, apathy, loneliness and an increasing loss of social and communication skills. According to Silvestri et alii [13] the loss of communication ability has a key role in worsening and arousing patient's behavioural disorders. Patients find themselves not able to communicate and to share their life and their experiences with the rest of the world. This contributes to an important deterioration of their mood, to an elevation of a general state of anxiety and often to psychotic-like behavioural disorders which affect the quality of life of the patient [14].

Recently greater interest about good control by non-pharmacological assistance of these symptoms is emerging but few studies of non-pharmacological approaches to psychological symptoms are available in literature [13].

Socially Assistive Robotics can contribute to the definition of therapeutic protocols aimed at maintaining residual cognitive, affective and global functioning in patients with dementia. Our research is focused on exploring the role of Paro in supporting therapeutic activities oriented to the stimulation of social and communications skills in dementia affected subjects. The research presented in this paper is at an early stage but it provides insights on the potential capabilities of Paro to activate dyadic relations and to positively affect socio-relational dynamics between therapists and patients, and among groups of patients.

The study aims at understanding the value of a socially assistive robot in the context of therapeutic intervention through the observation of patient's behaviour both in dyadic interactions with the robot and triadic interactions with the therapist or other patients mediated by the robot.
The goal of the research is to collect data necessary to define an experimental plan and conduct pilot sessions to assess the potential of Paro as a therapeutic aid in the treatment of behavioural disorders of dementia affected patients.

III. THERAPEUTIC ACTIVITIES

Findings in dementia studies and the characterization of behavioural and social aspects of the disease have opened up the way to the development of non pharmacological therapies [15]. This kind of therapies aim at slowing cognitive and behavioural decay working on patients' residual functionalities [16]. Non pharmacological therapies actively involve the patients in specific tasks (memory, orientation, motivation, physical training) or operate holistically to work on all the residual abilities together (aspecific therapies) [16]

With the progression of the disease specific therapies become less effective [16] because they are focused on particular cognitive or physical functions that progressively decay. On the other hand aspecific therapies are based on sensorial stimulations, consolidated procedures and emotional engagement and even if they are less powerful than specific therapies in sustaining a particular function, they can be applied throughout a longer period of time obtaining effects on a wide range of functionalities.

Among the most experienced non pharmacological aspecific therapies there are music therapy, sand therapy, occupational therapy and pet therapy. The common assumption underlying these treatments is that any intervention on behavioural and social problems should focus on patients' internal states providing them with a meaningful and "meaning-creating" activity [17]. In this way it is possible to bridge the gap between patients' abstract thought and their concrete experience [18]. Sand play, listening or playing music, carrying on a structured activity or the contact with a pet are instruments for establishing a relationship between the patient and the therapist. Patients are engaged in a meaningful activity and actively use cognitive capacities. Therapists design and drive the activity to intervene on the patients' specific problems.

From field observations, interviews with therapists and literature surveys we found that these therapies usually follow a common model of activity going trough three stages:

- *Familiarisation:* The patient explores the therapeutic setting and tries out simple activities: consolidated patterns of actions and sensorial stimulation sustain the interaction, motivating the patient in carrying on the activity to receive positive feedback.
- *Engagement*: The pleasure gained and the rewarding feedback lead the subject to emotionally engage with the object of the activity. Through the manifestation of emotions the patients project their internal states into the activity.
- *Communication/exchange*: The therapist is now able to intervene: the emotional contact between the patient and the object of the activity is the leverage point to get in touch with the patient, to negotiate meanings and to directly externalise internal states.

These three phases have different weights in different therapies and their balance is orchestrated by the therapist. The way in which this general model of aspecific non-pharmacological therapy is implemented in each single intervention critically depends on the therapeutic objectives and protocols which are defined by the therapist after an in depth evaluation of the patient's conditions.

Each aspecific therapy makes use of techniques such as regression, "mise en scene", memory recalling and storytelling to stimulate the patients to externalize their internal states

Pet therapy is primarily focused on the first stage; the physical contact with the pet creates an intimate experience that stimulates senses and favours posture maintenance. Pet therapy is particularly appropriated with patients affected by serious neurobiological problems which prevent the elaboration of complex stimuli. It can also be used with less severe cognitive decay; in this case therapist can go trough all the three stages.

Music Therapy, Sand Therapy and Occupational therapy are more balanced on the three therapeutic activity stages. Nevertheless even in these cases it is part of the therapist work to decide on which of the three stages to focus the intervention.

In our research the introduction of Paro was done respecting the three phases model adopted by other non pharmacological therapies like the ones described above. The model was also used as a framework to interpret the data collected during the observation.

IV. Paro

Paro was designed by Shibata et al. [3] using a baby harp seal as a model (see Figure 1). Its surface is covered with pure white fur and its weight is around 2.8Kg. The robot is equipped with several sensors and actuators to determine its behaviour. As mentioned above, Paro has the appearance of a baby harp seal. Previous attempts to develop cat-robot and dog-robot [19] demonstrated the inadequacy of these models in supporting interaction dynamics. The physical appearance of these robots turned out to be unsuccessful in meeting human being expectations during the interaction. The unlikeness from real cats and dogs was so evident to compromise any possibility of engagement with the robots. The baby seal model was therefore attempted.

Figure 1: The seal robot Paro

The choice was inspired by the idea to reproduce an unfamiliar animal that could barely create expectations in the human agent during the interaction. The design of Paro tried to balance the need to guarantee the likeliness with a real baby seal with the capability to stimulate exploration and sustain interaction. In this perspective a considerable effort was devoted to the design of eyes and gaze and all the facial expressions in general. The body is equally harmonious and balanced in all its parts.

In designing Paro, a particular attention was devoted to create an impressive tactile experience, a fundamental perceptual source of stimuli and information during the interaction [20], [21]. Its surface is covered with pure white and soft fur. Also, a newly-developed ubiquitous tactile sensor is inserted between the hard inner skeleton and the fur to create a soft, natural feel and to permit the measurement of human contact with Paro. The robot is equipped with the four primary senses: sight (light sensor), hearing (determination of sound source direction and speech recognition), balance and the above-stated tactile sense. Its moving parts are as follows: vertical and horizontal neck movements, front and rear paddle movements and independent movement of each eyelid, which is important for creating facial expressions.

The combination of these technical features provides the robot with the possibility to react to sudden stimulation. For example, after a sudden loud sound, Paro pays attention to it and looks (turns the head) in the direction of the sound.

Along with the reactive behaviour described above, Paro has a proactive-behaviour generation system consisting of two different layers: a Behaviour-Planning layer and a Behaviour-Generation layer.

The *Behaviour-planning layer* consists of a state transition network based on the internal states of Paro and its desires, produced by its internal rhythm. Paro has internal states that can be named with words indicating emotions. Each state has numerical level which is changed by stimulation. The state also decays in time. Interaction changes the internal states and creates the character of Paro. The behaviour-planning layer sends basic behavioural patterns to behaviour-generation layer. The basic behavioural patterns include several poses and movements. Here, although the term "proactive" is used, the proactive behaviour is very primitive compared with that of human beings. Paro's behaviour has been implemented similar to that of a real seal.

The *Behaviour generation layer* generates control references for each actuator to perform the determined behaviour. The control reference depends on magnitude of the internal states and their variation. For example, parameters can change the speed of movement and the number of instances of the same behaviour. Therefore, although the number of basic patterns is finite, the number of emerging behaviours is infinite because of the varying number of parameters. This creates life-like behaviour. This function contributes to the behavioural situation of Paro, and makes it difficult for a subject to predict Paro's action. The behaviour-generation layer implemented in Paro adjusts parameters of priority of reactive behaviours and proactive behaviours based on the magnitude of the internal states. This makes the robot's behaviour appropriate to the context, being able to alternate reactions to external stimuli and generation of behaviours for gaining attention. Moreover, Paro has a physiological behaviour based on diurnal rhythm. It has several spontaneous needs, such as sleep, that affects its internal states and, consequently, the perceived behaviour.

In order to keep traces of the previous interactions and to exhibit a coherent behaviour, Paro has a function of reinforcement learning. It has positive value on preferred stimulation such as stroking. It also has negative value on undesired stimulation such as beating. Paro assigns values to the relationship between stimulation and behaviour. Gradually, Paro can be tuned to preferred behaviours. Eventually, the technical features allow Paro to engage distant interactions, in this being aware of contextual information.

IV. Method

An ethnographic study based on direct observation and video analysis is currently underway on a group of patients affected by different relational disorders provoked by dementia. The choice to conduct a field study is motivated by the necessity to observe interactions dynamics between humans and robots in their real context of occurrence. This implies that therapists autonomously choose when and where to present Paro to patients, as they would do with any other kind of therapeutic intervention.

Pro is currently being used in therapeutic sessions to mediate patient-therapist relation as well as in group activities to enhance social exchanges. Paro is given to patients both in long term planning therapeutic activity but also in critical situations, in order to contain unexpected behavioural disturbance episodes.

In spite of the large number of the non-controllable variables, a "naturalistic" perspective allows us to observe how social relations spontaneously emerge and evolve thanks to the interaction with the robot. The activity we observed was articulated along the three phases of Familiarisation, Engagement and Communication / Exchange as described in section III.

Patients were filmed in everyday life situations with and without Paro. The video analysis was based on the definition of a set of behavioural and verbal indicators related to the activation of cognitive functions necessary to the social exchange. In the followings we present the outcomes of a first explorative data analysis concerning the patient GP. The subject showed severe neuropsychiatric disturbances preventing him from interacting with others, creating stable social relations and finally causing intense distress of caregivers.

V. Case Study

At the beginning of the study GP underwent a MMSE test [22] to evaluate the severity of his cognitive decline: With a score of 13 his dementia was stated as moderate, even though during the testing period the staff acknowledged a severe loss of cognitive abilities which though was not evidenced by other tests.

GP was also subjected to the UCLA Neuropsychiatric Inventory (NPI) [23] developed to assess psychopathology in dementia patients. The test evaluates 12 neuropsychiatric disturbances common in dementia: delusions, hallucinations, agitation, dysphoria, anxiety, apathy, irritability, euphoria, disinhibition, aberrant motor behaviour, night-time behaviour disturbances, and appetite and eating abnormalities. According to the test GP showed severe agitation, aggressiveness, irritability, disinhibition, aberrant motor behaviour and night-time behaviour disturbances. Frequent screaming, violence episodes and continuous moaning were daily manifestations of GP's agitation and anxiety that increased when the patient got a hip girdle fracture. These factors led the staff of the nursing home to experiment the use of Paro with the patient to alleviate unexpected critical episodes.

Therapists and caregivers therefore presented the baby harp seal robot to the subject to distract him from pain and frustration and reduce his agitation by reducing his isolation. The therapist who was responsible of the experimental treatment highlighted that for the whole duration of the test, GP *accepted Paro* whenever proposed. He commented this positively since dementia affected subjects hardly react positively to unfamiliar artefacts. The presence of Paro seemed to catalyze the patient's attention distracting him from his worries and physical pain. Video recordings show that this *shift of attention* persists during the whole interaction with the robot. As long as the robot is present, the patient continues to look at it, to stroke it, to talk to it or to talk to the therapist about it. When the therapist takes Paro away, GP's symptoms of anxiety progressively start to appear again.

The *persistent attention* on the robot can be explained by the quality of interaction between the patient and the robot, characterized by a deep engagement and a rich and meaningful emotional experience. Paro was recognised as an agent, being called by name and treated as a living pet as shown in the following speech excerpt:

GP: (looking at Paro) "hello!"
GP: (looking at Paro and stroking it) "you are so cute, aren't you? I'm sorry I can't do much for you"
GP: (looking at Paro) "I'm sorry, but I have to leave you, I really have to leave you. You are so cute"
GP: (looking at Paro) "Good bye darling"

Both the structure of the sentences and the vocabulary indicate an attempt to establish an emotional exchange with the robot. During the interaction GP gently continued stroking the fur of the robot and the video recordings show how patient's intonation, gestures postural movements and facial expressions aim at communicating emotional states to the robot.

Moreover when GP talked to the therapist about Paro, he referred to the robot as if it had emotions (as fear, loneliness, tranquillity) and cognitive states.

GP: "is it really calm?"
GP: "do we leave it alone?"
Th: "is it a good one, isn't it?"
GP: "it's a smart animal…"

This intersubjective capability of reading the "robot internal states", attributing a sound meaning to its behaviour during the interaction is a manifestation of the intention to engage in a social exchange.

Video analysis also shows another important aspect of the human-robot interaction: Paromediated successful triadic exchanges between the therapist and the patient, exchanges that were always difficult and fragmented in the daily communication without Paro.

For GP, behavioural symptoms of anxiety such as screams, violence episodes and continuous moaning were not always related to contextual reasons. For example, he had a pelvis fracture that could reasonably be interpreted as a cause of pain and so a as a consequence of the continuous moaning. However, during the sessions with Paro we observed GP calming down and turning his anxiety into taking care of the robot, shifting from a condition of plea for care and attention to a condition in which he took care of the robot devoting all his attention to this activity.

GP: "I talked to your colleague; he said that someone should look after it"
Th: "Yes, sure"
GP: "It's a problem because…"
Th: "Don't worry"
GP: "It's a problem because I have no time"
Th: "don't worry, it's a good animal"
GP: (to Paro) "nice, you are so nice".

Interacting with the robot, the patient had the opportunity to externalize his inner emotional states. The emotional relationship between the patient and the robot was a mediating element of communication. In other words, Paro contributed to the negotiation of a "common ground" where the patient and the therapist could relate. As we can see in the following speech excerpt, the therapist tried to modify the internal state of GP (agitation), exploiting the emotional relation between GP and Paro.

Th: "It was waiting and looking for you"
GP: "Was it really waiting for me? My son is waiting for me too; I have got many things to do".
Th: "Be patient, everything shall be done".
GP: "But I'm not patient"
Th: "Don't worry, look at Paro".
GP: (to Paro) "I'm sorry, but I have to leave you, I really have to leave you. You are so cute".
Th: "You can hold it another five minutes"
GP: "Why?"
Th: "Because if you are here, it stays calm"
GP: "Does it really stay calm?"
Th: "Yes"
GP: "but I won't stay calm"
(Th and GP smile together).
Th: "Look at it, it is calm"
GP: (looking at Paro) "Hello, hello dear…you are so cute, you are so nice, nice, nice, nice…"

V. Discussion

This preliminary study on the use of Paro in the treatment of BPSD opens interesting perspectives with respect to the possibility to use a robot as a non pharmacological therapeutic aid in dementia care. Data collected through the ethnographic observation are currently used to design an experimental plan to experimentally evaluate the role of Paro in supporting non pharmacological therapeutic protocols for the treatment of dementia. Of course the study is still preliminary and it has to be extended to a larger number of patients to support also texts with controlled variables. Anyhow, the observation we made is extremely rich and allows to raise important issues for the future use of robotic aids in the dementia care. Furthermore the results summarised below are confirmed by trials conducted on other 8 patients hosted in the Albesani premises.

First of all, we observed that Paro is able to support the complexity of a therapeutic scenario in a flexible way. Paro is able to engage the patient and to sustain the expectations and the mental model developed during the interaction. For example, the robot stimulates feelings like "taking care," affection, tenderness and docility, favouring the socio-relational exchange. The relation patients establish with the robot becomes a privileged "space" where they can externalize their internal emotional states.

Paro is also able to activate triadic exchanges. In this case it works as a social mediator and allows the therapist to negotiate with the patient a common emotional ground. As stated before, the emotional relationship between the patient and the robot constitutes a "leverage point" for the therapist to open a communication channel with the patient. This means that Paro is also able to support a dialogical process between the patient and the therapist.

Furthermore, the use of Paro in the Albesani Home seems to support the idea that Paro may represent a therapeutic aid able to reduce stress events, to induce positive feelings and allow an emotional commitment. Its capability of being a "catalyser of emotion" is the key point of its therapeutic efficacy. Even if we performed a medium term observation period, the therapists mentioned that they could use Paro in the long term to reduce behavioural disturbances not only in their episodic manifestation.

In the therapeutic activity, human-robot interaction is the element that mediates a creation of meaning between the patient and the therapist. The meaning construction process does not depend on the physical and functional characteristics of the machine only, but also and mostly on the specific context of interaction i.e. on the personal history of each subject and on the perception of mutual affordances, some of which come from the stimulus given by touching, hearing, seeing, moving, some others from psychological processes that mediate the empathic responsivity. For this reason, the research on Social Assistive Robot should not only focus on the technological challenge of building life-like robots that behave as living agents. It should definitely design for the dynamics that generate from the aesthetical, perceptive and emotional experience of interacting with such a robots, so decisive in the therapeutic context.

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