# Crafting Sensorial Stimulation and Social Exchange in Dementia Care

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*Abstract*—**In this paper we present a research project, the Multi-Sensory Room (MSR), which developed and experimented with technological solutions for dementia care. The general aim of the Multi-Sensory Room project was to study how robotic and ambient technologies can be designed and used to create a therapeutic environment for people affected by dementia that stimulates their cognitive, social and physical abilities, and promotes the emergence of intrinsic motivation, engagement and self-expression, without renouncing an accurate control of stimulation and fine tuning. The paper describes the design process and some preliminary results of field trials of the MSR. Furthermore in the conclusions we illustrate some lesson learnt for the design of technology enhanced therapeutic environments and provide recommendations for the designers who provide technological solutions for a sensitive settings like the one described in the paper.**

## I. Introduction

Assistive Technology is an umbrella term used to describe any product or technology-based service that helps people with disabilities to live, learn, work and enjoy life. As defined by the International Standard Organization (ISO-9999) – Assistive Technology is «any product, instrument, equipment or technical system used by a disabled or elderly person aimed to prevent, compensate, relieve or neutralise the deficiency, the inability or the handicap. As the literature on assistive technologies demonstrates (for a comprehensive review see [1]) a fundamental issue for the development of such technologies is to design for both accessibility by impaired people and effectiveness of the therapy. But the strategies and the design principles vary, leading to a wide range of potential solutions.

Current technological interventions to assist impaired people are typically designed to provide extrinsic supports for individuals with compromised cognitive ability. These range from alarms to remind people of their medication schedules to interactive robotic caregivers like Pearl [2] a personal service robots which assists elderly people suffering from chronic disorders in their everyday life, SIRA [3] which monitors people 24 hours a day and supports tele-diagnosis with the assistance center or PAMM [4] which provides physical support and guidance, and monitors the user's basic vital signs.

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Assistive technology interventions may address a range of functional activities requiring cognitive skills as diverse as complex attention, executive reasoning, prospective memory, self-monitoring for either the enhancement or inhibition of specific behaviours and sequential processing. They can also address the needs of individuals with information processing impairments that may affect visual, auditory and language ability, or the understanding of social cues, or sensory processing impairments that can lead to social and behavioural difficulties [5]. Depending on the specific needs of the person, these technologies may be used in a number of ways. One approach capitalises on those of a person's skills that have not been compromised so that tasks can be accomplished using alternative strategies or information characteristics, others on maintaining the residual abilities of the individual, training them in the execution of specific tasks.

Even if the literature on assistive technology interventions indicates that they can increase the efficiency of traditional rehabilitation practices [1], more importantly these interventions represent entirely new methods of treatment that can reinforce a person's residual intrinsic abilities, provide alternative means by which activities can be completed or provide extrinsic supports so that functional activities can be performed that might otherwise not be possible.

Assistive technologies have been widely used in therapeutic activities, to allow the patient to perform specific tasks that she could not perform by her self but that have a beneficial value in the treatment of a certain disability. The contribution that assistive devices can bring to therapeutic interventions consists in enabling *more precise and consistent* control of stimulation, especially in therapies that involve *highly repetitive movement* training, while ensuring a constant collection of data that can help in monitoring patients' progress along the recovery process [6]. More details on the use of robotic devices for physical movement recovery can be found in the review on medical robotics carried out by John Speich and Jacob Rosen [7] in the work on neurological rehabilitation by Reinkensmeyer [8] and in the work on post-stroke rehabilitation by Aisen and colleagues [9], or by Burgar [10]. However, a number of fundamental factors like motivation, personal involvement and engagement which are extremely important in the treatment of people affected by dementia are generally not considered in the design of such technologies.

In this respect, a different perspective is opened up by socially assistive robots (SAR), defined by [11] 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.

These robots have the main purpose to engage people in failure-free activities, stimulating the expression of inner emotional states, social relations and processes of meaning negotiation. A number of studies [12], [13] have recently reported encouraging results on the use of these robots in the domain of dementia care. Dementia affected subjects experience a progressive cognitive and behavioural disease which contributes to an early deterioration of the ability to interact socially: a continuous stimulation of social skills constitutes a critical issue in every therapeutic intervention, in order to avoid social isolation which is importantly related to the emergence of behavioural disorders. Nevertheless, in the interaction with SAR the control of optimal levels of stimulation is still an open issue.

In literature, both the fine control of stimuli and the emergence of motivation as well as engagement and personal elaborations, have been considered as two fundamental values that increase the effects of the therapy. Differently from the technologies we have discussed in this section, the multi-sensory room project aims to solve the trade-off that seems to exist among these different values. Our objective was not to develop single solutions to a specific problem but to design an immersive environment where dementia affected people can relax and feel in comfort during the performance of engaging activities, and the therapist can select and tune the most appropriate stimuli to the different patients. Furthermore, in order to reach this goal, we considered the collaboration and communication between patient and therapist as a key issue for the design.

In order to achieve such an objective, it is necessary to complement a traditional engineering perspective with a user-centred design view able to find a balance among a complex set of variable that include non only technological and clinical factors but also patients' needs, wishes and attitudes, patients' biographies, therapeutic practices, social and contextual elements.

## II. THE MULTI-SENSORY ROOM

The Multi-Sensory room project was started in 2005 to tackle the limits of traditional non pharmacological approaches due to the difficulties to control and tune the stimuli provided during the therapy and to get reliable data on the effectiveness of the treatment.

The analysis of the literature concerning the non-pharmacological treatment of dementia and a prolonged period of field observation, led us to identify the vision of the project, the target users and the requirements of our Multi-sensory room.

The vision of the project consisted in designing and building a multi-sensory environment to support the therapists in setting up different activities and tailoring the level and quality of sensorial stimulation to the specific needs of each single patient. The ultimate aim was to stimulate their cognitive, social and physical abilities and contribute to their psycho-behavioural wellness. The target user group was represented by elderly people affected by mild or moderate dementia, that is to say with a Mini Mental State Evaluation score >13 [14], even though we committed to design for more compromised subjects as well. However the progression of dementia is different for every single patient [15] and this is the reason why different therapeutic protocols are required depending on the different degree of impairment.

In relation to the progression of cognitive impairments, dementia affected subjects experience an increasing difficulty in making sense of the external world, since they loose the ability to retain and process complex stimuli. Their perceived competence decreases together with their ability to take initiative or to explore autonomously novel situations.

For these reasons, our project specifically focused on the possibility to capture and maintain patients' attention, to favour the emergence of intrinsic motivation, personal initiative and involvement in the activity, and to support collaborative activities .

### *A. The system*

The Multi-sensory room environment is a 4*4*3 meters booth equipped with ambient technologies and robotic devices. It has been painted with a neutral shade (white walls, ceiling and floor) in order to reduce the amount of undesired stimuli. A projector is mounted on the ceiling to project videos and images on the front wall. Lighting is provided by modular components: each component is controlled by a PC unit. Lighting can be static or dynamic with a selection of about 16 millions of colours and fading effects. Sound is diffused through high definition loud speakers. A smell system is also integrated in the environment and controlled through a PC unit that diffuse pre-selected smells. A system of two re-configurable desks has been designed in order to adapt the furniture to the different therapeutic needs.

Two kinds of robotic components have been implemented: Light&Sound Cylinders (LSCs) and RollingPins (RPs).

**Fig.1** The first and the second images refer to LSCs; the third and the fourth refer to RPs.

A detailed description of the technological equipment is given in [16] LSCs and the RPs are very simple objects with basic shapes and with clear sensory-motor affordances. As shown by figure 1 the LSCs are made to be piled up, while the RPs have been designed to be grasped, rolled and shaked.

These tools can be used in stand alone modality, i.e. without being connected to the PC. Once the software is downloaded into them via radio and infrared communication, each tool is completely autonomous and works independently by the PC. The system has been designed to let the therapist set the session configuration in an immediate way choosing among a pool of possible applications corresponding to different activities.

**Light&Sound Cylinders.** LSCs offer two types of feedback: visual and auditory. The visual feedback is given by six RGB LEDs which can generate any kind of colour. A loudspeaker in each unit is used for the auditory feedback (e.g. small melodies). According to the patients' need and their residual abilities, the therapist can choose whether to stimulate both the visual and the aural channel or to focus on one of these modalities. The patient generally interacts with four Light and Sound Units (LSUs): he/she can pile up the cylinders in different configurations, obtaining different local visual and auditory feedback. LSUs configuration could be used also to trigger ambient feedback, that is each cylinder can activate a specific pattern of ambient lights, sounds and smell. The therapist can decide prior to and also during the activity to remove or add one or more LSU in order to modify the stimulation complexity, without compromising the system functioning.

According to the selected application different therapeutic activities and tasks can be supported like Mixing Colour: it allows to mix the colours of the stacked cylinders; Colour Match: the patient is asked to identify two units with the same colour and piled them up. If the configuration is correct, both units start blinking. Otherwise they become grey. Sequence Match: it checks if the LSUs are assembled in a correct sequence (e.g. increasing or decreasing numbers or squares of different size). When the units are correctly assembled the application activates a feedback (e.g. colour blinking, sounds or ambient feedback).

All the different applications of the LSCs have been designed to stimulate short term memory and reinforce abstract thinking. At the same time, they aim at activating exploratory and proactive behaviours, favouring the emergence of patient's intrinsic motivation (Marti et al., 2006).

**Rolling Pin**s. The RPs  are semi transparent plastic tubes capable of measuring their orientation and the speed of their rotation to activate a visual, tactile or auditory feedback. At a local level they have three types of feedback: RGB light, sound and vibration. As for the LSCs, they can also activate environmental outputs interacting with ambient devices. The peculiarity of the RPs is that they are able to communicate with each other or with other devices equipped with the same radio communication technology. RPs are usually used in couple, since the local feedback of single RPs can be set depending not only on its own speed and orientation, but also on the speed and the orientation of the peer RP. Therefore, the local feedback of each RP can be a function of the sum of the speed rotation of both RPs; potentially, it can be a function of any other operations between the speed rotations (and orientations) of two RPs. Furthermore, since each RPs run its own software, each of them can generate its own feedback in relation to rules which are different from the rules of the other one.

The therapist can therefore modify the sensorial stimuli by selecting different combinations of visual, aural, and tactile feedback. The tactile stimulation can be produced either by the physical surface of the RP (that can be covered by different scabbards) or generated by the vibration actuator. Furthermore, the therapist can also select different "communication rules" between the RPs. In sum, the therapist can adapt the complexity of the interaction to the specific needs of each patients, the therapeutic objectives and the specific therapeutic protocol.

RPs were specifically designed to scaffold dialogic relationships between the therapist and the patient, providing them with the opportunity to establish a dialogue based on visual, aural, tactile and sensory-motor interaction modalities. Different applications of the RPs have been designed. For example, in the "mirror" application a RP can vibrate whenever it moves at a different speed of its peer. The task of the patient is to match the therapist's rotation speed to stop the vibration. The therapist can choose the vibration as a single feedback or to reinforce the output with a visual or aural feedback. The particularity of this task consists in its dynamic nature: the therapist can decide to slow down the rotation speed in order to facilitate the patient in the synchronization or can decide to make the task more difficult to execute, by deliberately challenging the synchronization, moving the pin at different speeds and rotation patterns. In other words, the therapist can adapt the task complexity during the task itself. The opportunity to continuously adapt the difficulty of the task to the skill of the patient is fundamental to create an optimal experience and to maintain the patient's attention.

**Software architecture.** The software framework [16] for the Light&Sound Cylinders and the Rolling Pins (the tools) allow the applications to run autonomously in the tools, while providing the possibility for communication with a host PC. The PC software is responsible for control of application selection; thus allowing the user to select an application for usage. This implies that the application itself is controlled in a distributed manner by the tools. Each tool contains no identification thus enabling maximum freedom in the assembly – each cylinder (pin) can be replaced by another cylinder (pin). This the advantages that a program can run without the presence of the PC, the same program code can be loaded into all cylinders (pins), the program can be made independent of the number of cylinders (pins), less wireless radio communication is needed, and there will be faster information flow.

The PC side of the application consists of an easy to use graphical user interface (GUI) which has the capabilities to plug in the different applications.

## III. FIELD TRIALS

The MRS was installed in 2006 at the nursing home Casa Protetta Albesani, an institution located in northern Italy (Castel S. Giovanni, Piacenza) that gives hospitality to 150 elderly people with different degrees of cognitive and behavioural diseases.

**Fig.2** On the left a trial with RPs; on the right a trial with LSCs.

Different trials (see fig.1) and assessment of the MSR have been performed to collect feedback on the configurability and flexibility of the system, the acceptance of the system by therapists and patients, and the usability of the environment. A full description of different trials is provided in [12], and [17]. As an example of the therapeutic activity and the collected results we report here the case of a lady who entered the nursing home with a diagnosis of mild dementia rated at present 24 MMSE. Her main problem is a profound depression getting her to isolate and to avoid public spaces and social events. She is not used to smile and her talk is always related to dramatic events like her husband's death. The objective of the treatment in the Multi-sensory Room is to involve her in social activities, to attract her attention, to stimulate her to assume positive expressions like smiling and to maintain her short term memory. Since her cognitive and sensory-motor capabilities are still good, the therapist worked with her performing alternatively different tasks: mixing colours, colour match and sequence match with the LSCs and a free exploration of the RPs.

The therapist set the environment choosing a dark ambient lighting but since the lady reported a sense of panic for the small and dark space, he adjusted a bit the light and reassured the lady of his presence with her in the room. The exploration was an extremely successful activity. Even if the lady was a bit scared about touching the tools, after a while she got enthusiast about their behaviours. She perfectly understood the functioning of the LCSs and the RPs, recognising them as sophisticated technological tools. She appreciated so much their behaviour to produce expressions like "If I died yesterday I could not see such wonderful things". She was so able to control the tools very easily to verbalise her intention to try new configurations: "If I put this cylinder on the top of the others, they will become grey".

The negotiation was easily performed. After having tried out the tools, she proposed the sequence task of piling the cylinders from the one with the biggest square to the one with the smallest. During the execution of the tasks with the different tools she smiled a lot and she paid attention to many cues that the other subjects did not notice. For example, she reflected on the tactile stimulus produced from the vibration of the pins, saying that she would never touch the pin if she was alone in the room. Both the sequence and mixing colour tasks were successfully performed, and she was reported the rewarding effect of performing a task correctly. Many times she said "I believed to be foolish but this should not be true if I can solve the task so easily the first time".

During the interview, the therapist reported that the experience was very positive. Even if the environment was a bit scaring for her at the beginning, it was sufficient to slightly change the setting and to involve her in the exploration to overcome the initial embarrassment.

Another experiment focused on the use of the RPs. As said above, the therapeutic objective in using the RPs is mainly to counteract social isolation that can result in dementia through the loss of social skills. The experiment addressed the effectiveness of the therapeutic intervention using the RPs under two conditions: 1) with the RPs communicating each other (dialogic condition); 2) with the RPs used as single devices, fully interactive but not communicating each other (individual condition). 12 randomly selected patients who had received a MMSE (Mini Mental State Examination) score ranging from 16 to 27 (moderate cognitive impairment), were involved in different activities ranging from the execution of structured sensory-motor patterns initiated by the therapist, to the free exploration of the RPs. Each patient was randomly assigned to an experimental condition and we obtained two equally numbered groups: a group working in the Dialogic modality and a group working in the Individual modality.

The activity protocol for each subject included two main phases: Phase A has been designed to understand whether or not the Dialogic modality stimulates autonomous initiative in the patient participating in the activity, without any additional instruction from the therapist. Phase B has been designed to observe the patient's behaviour in a dynamic coordination activity. Each session was video-recorded and a video-analysis was subsequently carried out.

The analysis of Phase A shows that every subject but one working in the Individual condition did not autonomously reproduce any interaction pattern proposed by the therapist; instead, for what concerns the dialogic condition, 4 subjects reproduced every interaction pattern proposed by the therapist. In phase B we codified the patient's behaviour in relation to three indicators concerning the quality of interaction patterns he/she produced on his/her own RP: Tuning (the patient simultaneously reproduces the same interaction patterns of the therapist), Random (the patient does not reproduce the therapist's interaction patterns but generates them randomly) and None (the patient does not produce any interaction pattern while the therapist interacts with his/her RP). Data coming from the behavioural analysis of phase B indicates that in the Dialogic condition patients were tuned with the therapist for a significantly longer time than in the individual condition. Furthermore, while in the Individual condition patients performed indifferently None, Random and Tuning behaviours without any significant difference among them, in the Dialogic condition they performed the Tuning behaviour for a significantly longer time than random and none behaviours.

These results suggest that the Dialogic Negotiation communication modality greatly favours the emergence of sensory-motor coordination between the patient and the therapist, favouring the emergence of a shared interaction space. It is important to note that these trials do not aim to validate the therapeutic efficacy of RPs; rather, they provide some preliminary indications about the potential that the RPs have for modifying the patients behaviour and opening a space for therapeutic interventions specifically oriented to counteract isolation and promote social exchanges.

Furthermore, the results suggest that in the Dialogic condition, differently from the Individual one, the patients participated to the activity without additional verbal instructions; furthermore, in the dialogic condition, patients coordinated their behaviour with the therapist longer than in the individual condition, imitating the same interaction patterns generated by the therapist. This is a particularly remarkable result since different studies [18] confirm the importance of imitation in facilitating and maintaining people with communication problems in the social world.

## IV. CONCLUSIONS

Despite the observational and exploratory nature of the preliminary study presented herein, results are encouraging and seem to support the motivation for continuing this research. The first consideration is that the use of cutting edge technologies for the treatment of dementia, though quite unexplored, can really support a step ahead in the treatment of such syndrome especially in care institutions where elderly people, brought away from their familiar contexts, loose their points of reference both in their physical and affective space. A careful design of the therapeutic context is essential to put the subjects at ease and to provide them with minimal but clear stimuli to both have a pleasurable experience and perform the tasks that better suit their problem. From the therapeutic point of view, a dynamic, flexible environment is the key for obtaining an optimal stimulation tailored to the specific needs of each patient.

From a design point of view, some lessons and recommendations have been learned so far from the project.

First of all it is fundamental to enlarge the design space in order to include not only technological and clinical aspects but also psychological, emotional, social and cultural factors, aesthetics and ethical considerations to address the entire sphere of the patients and have more change to engage in a good relationship with them.

A second aspect is the importance to adapt the design approach to the wishes and dreams and communication capabilities of people that concretely experience the condition of disability. For example, quite early in the project we understood that involving the elderly in the design process was inappropriate and unethical. Discussion, sharing and negotiation are frustrating and unaffordable tasks for most of them. So we turned our attention to a “light observation” of their everyday life practices, a very naturalistic approach where we only used our senses, intuition and respect of the privacy of the Home Care guests. Quite soon we were struck by the behavioural response of these people to simple external stimuli. Very basic sensory-motor patterns like grasping, rolling and pulling recurred in most of their activity; memories were raised by natural and unstructured stimuli like smells, lights, moving objects; a sort of communication was possible by tuning and repeating movements. This inspired a lot the design of the MSR and in particular the LSCs and the RPs. Both tools exploit the patients’ residual skills, addressing the motor procedural memory that remains intact the longest. This memory contains sensory-motor patterns that are activated by specific configurations of stimuli. By evoking consolidated sensory-motor patterns, like rolling, grasp-ing, shaking and piling objects one on top of another, patients can start to interact with tools. Natural interaction modalities trigger a behavioural answer and constitute a bridge to engage the patients in meaningful activities that can help to generate an intrinsic motivation to actively participate.

A further recommendation is to encourage the participation of the therapists and other stakeholders (nurses, doctors etc.) in every phase of the design process. In the MSR project they supported the design team to obtain a thorough comprehension of how the different actors in the home care make sense of what happens, and how the continuous process of understanding is supported. They also played a fundamental role in facilitating the interpretation of the user requirements that emerged through fieldwork activities, and the adaptation of the concept to daily practice in the home care. Moreover, they rendered the sharing and evaluation of the concepts easy.

A last consideration is related to the current use of the MSR. The MSR is still is use at the Home Care “Casa Protetta Albesani”. The therapists are currently involved in the definition, refinement and testing of new therapeutic protocols enabled by the MSR. This is a positive result “per se”: the technology does not simply enable new activities but it sustains a creative and iterative process of design and re-conceptualisation which is fundamental in making visions about technology real and effective.

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