A multi-sensory environment for the treatment of dementia affected subjects

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P. Marti, H.H. Lund, M. Bacigalupo, L. Giusti, C. Mennecozzi, A multi-sensory environment for the treatment of dementia affected subjects. Gerontechnology 2007; 6(1):33-41. The paper describes the early outcomes of a multi-sensory room project conducted in an Italian long-term care home to study non-pharmacological therapeutic protocols to stimulate and maintain residual abilities of dementia affected patients. This includes setting, technological solutions, therapeutic protocols and pilot testing. In a nursing home clinical cases and therapeutic practices have been studied before designing the multi-sensory environment enhanced with ambient intelligence technologies. Aim is to obtain an optimal level of stimulation of dementia affected patients through engagement, active participation and intrinsic motivation in a therapeutic (leisure) activity, and favouring the emergence of personal meanings (memories, interpretations, narratives). The outcome of this pilot includes a blended therapeutic model with controlled stimuli, adapted to the patient's stage of dementia. Therapeutic significance is discussed, as well as design opportunities for future development.

Keywords: dementia, non-pharmacological therapy, multi-sensory stimulation

Dementia is a clinical term to designate an acquired permanent deterioration of neurons with impairment of intellectual faculties in several cognitive domains, from memory loss, to abstract thinking, from language disorders to the failure to recognise objects despite intact sensory function[1]. Dementia commonly implies behavioural and psychological disorders as apathy, indifference, or irritability and aggressiveness. To be diagnosed it has to impair competence in daily living, occupation, and social interaction[2]. Dementia is not a natural part of ageing, but age is the most significant risk factor.

No cure exists. Pharmacological interventions are limited. No consensus exists as to administering protocols, identification of severity range for drug efficacy, appropriate time to suspend drugs, and management of the combinatory effects of different drugs[3]. These limits and contra-indications have raised interest in non-pharmacological support, which is being progressively integrated with standard allopathic

interventions[4,5]. For the slowing down of functional decay in dementia, two major trends can be identified: non-specific and specific protocols of non-pharmacological treatment.

Non-specific protocols

Non-specific protocols are based on the principle 'use it or lose it' for patients' residual abilities[5]. They are carried out through a global stimulation of the subject who is involved in various activities, such as arts and crafts, housekeeping, entertainment and relaxing occupations. Examples are occupational therapy, music therapy, art therapy, and multi-sensory stimulation. Such techniques are commonly adopted in elderly care institutions, but no scientific evidence of their efficacy exists[5].

The non-specific therapeutic protocol runs through five phases: (i) setting, (ii) exploration, (iii) negotiation, (iv) sharing, and (v) evaluation. In the setting phase, the therapist configures the room choosing familiar tools to support the activity, for example, a collection of different instruments in music therapy, or a set of colours in art therapy. Sessions are generally carried out in a familiar context that is likely to be well-accepted by the patient. The setting has to be considered as an 'opportunity space', since the activity is not rigidly defined.

The therapist's role is to define the therapeutic objectives after a careful analysis of the patient's background, attitudes and residual abilities and to scaffold the process by encouraging creativity and self-expression. Identification of activities that have an emotional significance for the subject is in fact a pre-requisite for success.

Once the setting has been configured, the patient is invited to freely explore the environment and to choose, with the help of the therapist, an activity to perform, for instance, to paint flowers. Therapist and patient agree (negotiation phase) on the duration and the modalities of the activity, and at the end there is a discussion about what has been done and, in case of group activity, to share the results of the work with other patients. At the end of the therapeutic session, the therapist assesses the intervention (evaluation). The last phase allows the therapist to monitor advances of the patient and to re-define the setting of the next therapeutic session.

Specific protocols

The theoretical foundation of specific therapeutic intervention is cerebral plasticity, the ability of the adult brain to adapt and compensate severe acquired damages[5].

Specific therapeutic protocols are characterized by a precise control of the stimulus targeted to the specific loss and the actual level of neuropsychological decay of the treated subject. This implies a strong structure, and prevents the patient from expressing preferences since the activity consists mainly of the execution of tasks (cognitive intervention). In case of cognitive disorders, specific therapies are techniques for the stimulation of explicit memory (spaced-retrieval, vanishing cues and visual imagery); implicit memory (external memory cues and errorless learning) and techniques for personal orientation (reality orientation therapy and validation therapy). The therapist provides the patient with instructions to face a problem. The patient's motivation, subjective emotional background and experience are not considered as relevant features, even though these are important factors in case of memory rehabilitation[6].

Specific therapies have received experimental confirmation and they have become trusted techniques to face dementia cognitive decline[6,7]. These protocols follow four sequential phases: (i) setting, (ii) proposition, (iii) execution, and (iv) evaluation.

In the setting phase, the room is configured and the tools selected according to the therapeutic objectives. The session

takes place in a dedicated space, purposely empty and white to reduce environmental non-controlled stimuli. After this phase, the therapist introduces the patient in the room and the session begins. The next phase is activity proposition: the therapist explains the task, showing the usage of the tools if necessary. These are mainly symbolic artefacts as for example cards or pictures. During this phase the patient is passive and listens to the therapist's verbal instruction. At the end of this phase, the patient undertakes a more active role starting the task execution. The therapist holds the direction of the activity providing instructions for a correct execution of the task and monitoring the activity to dispense a balanced level of stimulation. The patient is mainly an executor of the task that may be repetitive, boring and difficult to grasp in its ultimate goals. No space is left for interpretation and personal involvement. At the end of the session, the therapist accompanies the patient to the ward and evaluates the session. The evaluation phase is the same in non-specific and specific protocols.

A new, blended, protocol

Both non-specific and specific protocols have strengths and weaknesses. The non-specific protocol creates conditions for engagement, intrinsic motivation, active participation and personal meaning elaboration, key elements for actively and successfully involving the patients in an activity. The patient is stimulated at different levels but it is difficult to control every single stimulus since many variables are at stake. Specific protocols enable the therapist to maintain an optimal stimulation level but these protocols are less effective to engage patients and to elicit personal meanings during the activity.

Therapeutic multi-sensory intervention aims at non-pharmacological therapeutic protocols and IT solutions for dementia care in institutionalised contexts. A multi-sensory room has been designed to explore the opportunities of ambient computing for developing innovative multi-sensory environments.

Detailed objectives of our project include: (i) stimulation of patients' cognitive abilities: addressing memory loss, spatial and temporal disorientation, attention and other dementia related disorders; (ii) contribution to patients' psycho-behavioural wellness: addressing aggressiveness, hallucinations, delirium, wandering, hyperactivity, depression, mood instability; (iii) reduction of patients' isolation and stimulation of social interaction and communication exchange; (iv) stimulation of patients' motor abilities; and (v) allowing therapists to design different therapeutic activities according to patients' specific needs.

The project exploits advances in social robotics, edutainment robotics, modern artificial intelligence and interaction design. Participatory design techniques have been applied including activity analysis and design, prototype development and evaluation in an iterative process with therapists and dementia affected people.

In our multi-sensory room a flexible and adaptable therapeutic environment is created that is augmented with flexible and intelligent technologies, allowing the therapists to tailor activities to specific cognitive and behavioural problems of dementia affected patients. In addition the environment provides relaxation, engagement and stimulation without renouncing stimulation control and fine tuning.

Key values of the newly developed protocol are: (i) stimulation of multiple senses; (ii) dynamic tuning to optimal levels of stimulation; (iii) engaging patients; (iv) supporting intrinsic motivation; (v) emergence of the patient's personal interpretation; and (vi) patient's active participation. The room is equipped with ambient technologies and active tools, to create an immersive experience and raise the patient's interest. The

system is designed to be flexible enough to allow the therapist to dynamically modify the configuration of the stimuli in relation to different activities, therapeutic objectives and the patient's need. The room is a re-configurable system, supporting both specific and non-specific protocols. The new protocol that results is a blended product that preserves patients' engagement, motivation, participation and elicitation of personal meaning, while allowing control and fine tuning of the stimuli (*Figure 1*).

A main feature of the blended protocol is the non-sequential nature of its phases. The therapist may define different orders of phases in relation to therapeutic objectives, and patients' specific needs. The configuration of the setting and the evaluation are integral parts of the therapeutic activity (*Figure 1*). Our multi-sensory room allows for a continuous assessment and tuning process, within a single therapeutic session to better suit patient skills, ensuring smooth passages among phases, and avoiding activity breakdowns.

The blended model makes our system different from any other multi-sensorial environment for therapeutic treatments[8]. Other set-ups are aimed at relaxing and engaging patients in failure-free activities without the possibility to accurately control stimulation levels or to carry out structured therapeutic activities.

Tools and ambience

The multi-sensory room is a 4x4x3 meter space, with white walls, ceiling and floor, located in the nursing home Casa Protetta Albesani[9]. A projector is mounted on the ceiling to project videos and images on the front wall. Lighting is provided by modular components designed by Targetti SpA and controlled by a PC unit. Lighting can be static or dynamic with a selection of 16 million colours and fading effects.

Sound is diffused through high-fidelity loudspeakers. The therapist can decide to work with ambient music, or to switch to sound modalities. A simple desk and comfortable chairs complete the furniture. Two kinds of tools have been implemented so far: Light & Sound Cylinders and Rolling-Pins[10].

Both tools exploit the patients' residual skills, addressing the motor procedural memory that remains intact longest. This memory contains sensory-motor patterns that are activated by specific configurations of stimuli. By evoking consolidated sensory-motor patterns, like rolling, grasping, shaking, piling objects one on top of another, patients can start to interact with tools. Natural interaction modalities trigger a behavioural answer, but it is important to engage the patients in meaningful activities that can help to generate an intrinsic motivation to actively participate.

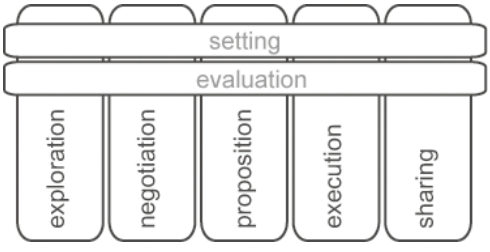

Figure 1. Blending the session phases of non-specific and specific treatment protocols into a new model

Figure 2. Light & Sound cylinders consisting of a base unit and five Light & Sound units (LSUs, left), and Rolling Pins (RPs, right)

To engage patients in the exploration of objects and their responses we designed simple, but unfamiliar artefacts, pleasurable to manipulate, with different kinds of feedback (visual, audio, tactile). The therapist coordinates the session by defining the protocol, the setting, the most appropriate level of stimuli according to patients' needs, and also supports the patient in remaining involved in the activity.

The flexible tools we designed were inspired by the building block concept developed in modular robotic work[11]. The overall behaviour of the robotic artefacts emerges from the coordination of a number of physical building blocks each one expressing a primitive behaviour.

Light & sound units (LSUs)
A basic light & sound cylinder system consists of three types of units: a PC unit, a base unit and a number of Light & Sound Units (LSUs). Each LSU consists of a semi-transparent plastic tube of 150 mm diameter and 75mm height with solid top and bottom caps, weighting 1100 gram including batteries. The PC unit is connected to an ordinary PC. It contains a radio module to communicate with the corresponding radio module in the base unit. This base unit serves as a remote base to download applications into LSUs when they are placed on top. In addition, the base unit contains an infrared (IR) module in the top cap to communicate with LSUs. Each LSU has two IR windows: one at the bottom and one at the top. So, LSUs can communicate with the base unit below as well as with neighbouring LSUs.

Through the PC software the therapist selects an application for use in the session. Once the software is downloaded into LSUs, each unit is autonomous and works independently from the PC. During an activity the therapist may decide to remove or add one or more LSUs, in order to modify the stimulation complexity.

The patient interacts with the LSUs only. S/he can pile up LSUs in different configurations, obtaining different local visual and audible feedback. Visual feedback is given by six RGB LEDs embedded in each LSU that are able to generate any kind of colour. A loudspeaker in the LSU is used for audible feedback, such as short tunes.

Rolling Pins (RPs)
A Rolling Pin (RP) consists of a semi-transparent plastic tube with solid end caps of black sandblasted plastic. All the electronic components are placed on one large printed-circuit board inside the tube. The RP has a length of 300 mm, a diameter of 50 mm, and a total weight of 350 gram including batteries. RPs are used in pairs. They are aware of their own and the other pair member's orientation and speed of rotation, and they can communicate with the base unit of the LSUs. The RP has three types of feedback available: RGB light, sound and vibration. RPs reciprocally influence each other's behaviour, enabling complex dialogic activity and interactions between therapist and patient. Applications can be downloaded in RPs. Once the software is downloaded, each RP is autonomous and works independently from the PC.

Initial trials

Three patients were characterized with the Mini-Mental State Examination MMSE that ranges from 0 (severe cognitive disability) to 30 (normal)[12] and subsequently entered the trial (*Figure 3*). Aim was to collect qualitative feedback on the applicability of the blended model, the configurability and flexibility of the system, the acceptance of

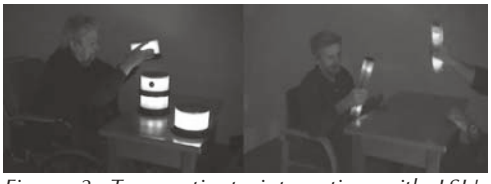

Figure 3. Two patients interacting with LSUs and RPs

the system by therapists and patients, and the usability of the environment.

The following tasks were chosen: (i) *Colour mix*: mixing the red, green and blue (RGB) primary colours of stacked LSUs; (ii) *Sequence match*: enumerating the LSUs with the application 'checking the correct increasing or decreasing order with sound feedback'; and (iii) *Free dialogic use of the RPs*: automatically summing the number of movements with a gradual colour change from green (little movement) over different colours to red (much movement), emitting harmonic sounds from low tones (little movement) to higher tones (much movement), and vibrating at maximum input. The trials were video recorded, and after each session the therapist was interviewed.

Avoiding negotiation

Lady CA entered the nursing home a few years ago with a diagnosis of severe dementia, now rated 10 MMSE. She is usually quite active and available to be involved in new activities. However, even if she is quite curious about any novelty, she presents difficulties in maintaining focused attention on a task. She shows logorrhoea and when involved in a discussion she correctly respects the conversation turns, but her talk is mostly unrelated to the discourse. The objective of treatment was to stimulate her residual capabilities, to attract and maintain her attention during a task, and to work on her short term memory. One of the residual cognitive abilities she correctly exhibits is mathematical reasoning. She used to work as accountant and seems still to be at ease in manipulating numbers. Based on these considerations, the therapist selected the sequence task with numbers, and the following steps of the blended model: exploration, proposition, execution, and sharing.

He avoided the negotiation phase because of the problems the lady has in catching the context of a discourse, in particular before starting a concrete activity. At the beginning of the session, the therapist configured the environment, setting the LSUs to the sequence task with numbers. They explored the tools together but when the therapist realised that the presence of different stimuli related to sound, colours and numbers distracted the lady, he decided to disregard the sound and concentrate on the visual stimulation. After the exploration the lady looked relaxed and demonstrated to have acquired a certain familiarity with the tools (piling, moving, waiting for feedback). The sequence task was executed without any particular difficulty and at the end of the session the therapist invited the lady to share the experience with him. She reported a general sense of pleasure, and even after a while, when she could not explain what she had just done, she said to be happy and to look forward to spending time in the multi-sensory room again.

During the interview at the end of the session, the therapist said he was satisfied with the flexibility of the environment, and in particular with the opportunity to tune the stimulation before the execution of the task. The specific setting composed of a dark and silent environment with the coloured lights of the tools allowed the lady to be more focused on the task and to reduce unrelated talk. Even though the numbers attracted the lady more than the changing lights, the manipulation of the tools engaged the lady and the repetitiveness of the task and the constant feedback encouraged her to go on.

Exploration, negotiation and sharing

Lady SC entered the nursing home with a diagnosis of severe dementia, currently rated 11 MMSE. She is hyperactive and logorrheic showing frequent rummage. She does not focus attention and her short term memory is seriously damaged. The objective of the treatment in the multi-sensory room was to relax, to stimulate sensory-motor coordination with objects through imitation of patterns (this to reduce apathetic manipulation typical of rummage),

and to convey her physical activity on a task she can consciously reflect upon.
The therapist selected for her the free dialogic use of RPs, and the following steps of the blended model: exploration, negotiation and sharing. The therapist configured the lighting of the environment in a dark nuance and invited the lady to explore the tools. Three basic patterns were proposed: rolling the pin on the table, shaking the pin and rolling it through the hands. At the beginning of the session the therapist explored the tools together with the lady, pretending to share the lady's surprise to the behaviour of the tools. After the exploration, the therapist started to roll the pin on the table without explicitly asking the lady to imitate his actions. After a while, the lady started to imitate the movement pattern (for instance, rolling the pin on the table slowly), and in response to the sound and light feedback, she tried to reproduce also the pace of the movement to obtain the same feedback the therapist had on his pin. The activity went on for ten minutes without pauses. The lady was mainly silent during the activity (an unusual behaviour for her who likes to talk continuously and attract attention) just saying from time to time "Can we continue?" In the sharing phase she could not really verbalise the experience but she held the pin in her hand without any rummage.

In the interview, the therapist commented that the use of the RPs was extremely engaging also for him. The lady accelerated the movements in response to his implicit invitation and the obtained feedback acquired after a while a perfect synchronisation. The RPs seemed to be effective in training the lady to perform structured sensory-motor patterns, but they failed in raising an interpretative endeavour in the lady.

The complete blended model

Lady CO 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 will not smile and her talk is always related to dramatic events like her husband's death.

The objective of the treatment in the multisensory 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. Earlier the therapist had worked with her on these three tasks, and now decided to follow all the steps of the blended model since the lady's cognitive and sensory-motor capabilities are still good. 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 with his presence in the room. The exploration was an extremely successful activity. Even if the lady was a bit scared in touching the tools, after a while she got enthusiastic about their behaviours. She perfectly understood the functioning of the LSUs and the RPs, recognising them as sophisticated technological tools. She appreciated so much their behaviour to produce expressions like "If I had died yesterday I could not have seen such wonderful things". She was able to control the tools very easily and verbalised her intention to try new configurations: "If I put this cylinder on 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 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, even the first time".

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

Discussion and conclusions

In care institutions elderly people are away from their familiar contexts and have lost points of reference both in their physical and in their affective space. A careful design of the therapeutic context is essential to put the subjects at ease and to provide them with stimuli to bring leisure and perform tasks to train their residual abilities. From a therapeutic point of view, a dynamic, flexible environment is the key factor for obtaining an optimal stimulation tailored to the specific needs of each patient. Despite the pilot nature of this preliminary study, results are encouraging. Cutting edge technologies supported non-pharmacological therapy in our three cases of institutionalized older women with dementia symptoms.

As said above, the trials in the multi-sensory room are at the initial stage. Therapists have to be trained in configuring and controlling the room and in selecting an optimal path within the blended model. Next steps in multi-sensory design will be to complete the implementation of the tools to include ambient feedback and to try different configurations of the tools and the environment, for example, associating a smell feedback to the tools, or covering the tools with different tissues and materials to enrich the tactile stimulation. Future tests will be enriched with quantitative measurements. We plan to measure severity of dementia, number and type of errors, and duration of the task execution. Furthermore, we are designing an environment that includes pre-test and post-test questionnaires to have comparative data on the impact of the treatment.

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