Chapter 24
Virtual Representations for Cybertherapy:
A Relaxation Experience for Dementia Patients

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ABSTRACT

The development of serious games has enabled new challenges for the healthcare sector in psychological, cognitive, and motor rehabilitation. Thanks to virtual reality, stimulating and interactive experiences can be reproduced in a safe and controlled environment. This chapter illustrates the experimentation conducted in the hospital setting for the non-pharmacological treatment of cognitive disorders associated with dementia. The therapy aims to relax patients of the agitation cluster through a gaming approach through the immersion in multisensory and natural settings in which sound and visual stimuli are provided. The study is supported by a technological architecture including the virtual wall system for stereoscopic wall projection and rigid body tracking.

INTRODUCTION

In the third millennium, the discipline of drawing, in its various forms of representation, is facing a significant challenge in improving the quality of human life. The introduction and the consolidated diffusion of new means of expression and communication have enabled new perspectives of use that embrace very different fields and domains. The concept of Digital Twin contributes enormously to the vision of a Smart Healthcare (Tian et al., 2019) and truly Smart Hospital, where infrastructure, services and people are the crucial aspects to be managed as schematised in Figure 1. The main idea is to have a building with a digital brain and systems that can connect with users' needs and meet them in every respect using advanced approaches and digital technologies. This vision makes the hospital an ideal

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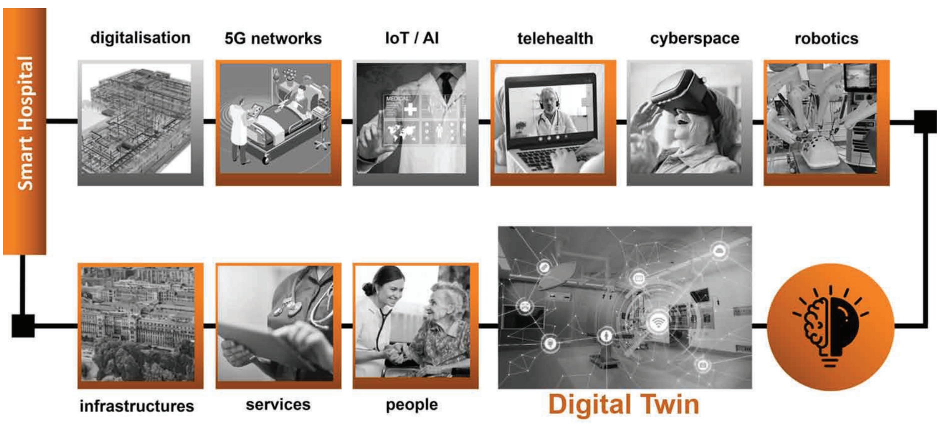
place for experimentation as it must master a multitude of challenges simultaneously. Hospitals must reduce labor and operating costs, enable their staff to work more efficiently, optimize space efficiency, and comply with changing regulations without compromising a positive patient experience (Siemens Switzerland Ltd, 2022). In order to deal with these tasks, they are increasingly leveraging digitalization and technological innovations to build resiliency, enhance productivity and meet their strategic objectives. In this framework, high-tech solutions involving cyberspace, advanced robotics, 5G networks, Internet of Things (IoT) and Artificial Intelligence (AI) are therefore brought into play in a synergetic way to evolve and drive future growth and innovation for the healthcare experience. The tools are exploited to provide a virtual-based field to ensure the broadest participation in even more processes revolutionizing hospitals on the human, financial and operational levels. The focus is to seek the machine's efficiency and improve the quality of healthcare treatments and services delivery for the patient's well-being by combining advanced medical concepts and state-of-the-art devices. Within this context, telehealth and Remote Patient Monitoring (RPM) and Virtual Reality (VR) (Riva, 2002) find their place and acceptance by the patient, especially during and after the COVID-19 pandemic. A Smart Hospital is thus a hospital that uses technology to improve the quality of life of its users across the board, overcoming physical and spatial barriers. In this framework, the relation between three-dimensional digital representation, also derived from parametric models, and Virtual Reality technologies, represents an innovative frontier by enabling multi-dimensional scenarios and levels of interdisciplinary collaboration. This combination can be put to the service of the health sector in several areas: the technical knowledge and design, the usability of spaces and information (Ugliotti et al., 2019), training for nurses and caregivers, patient awareness and entertainment, diagnostics and prevention, and physical and psychophysical rehabilitation (Lányi, 2006). Therefore, they can embrace very different points of view of the hospital occupants, from managers and technicians to medical staff and patients and their families.

Figure 1. Smart Hospital framework



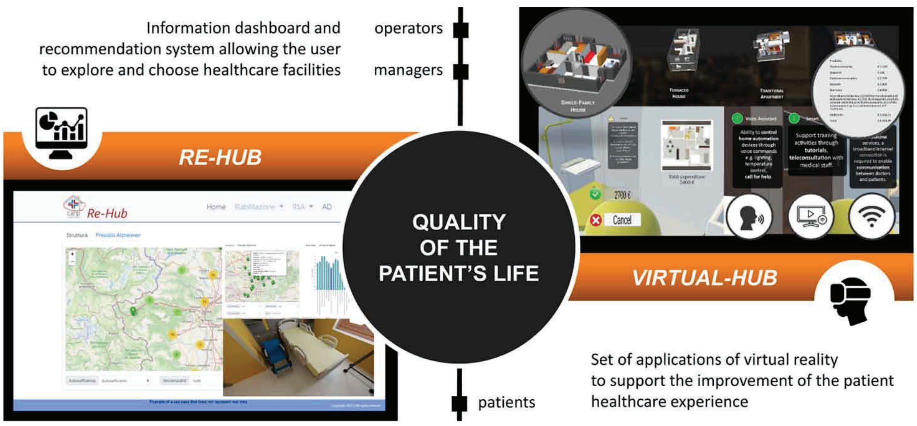
In the context of the scenario outlined, the chapter illustrates the application of Virtual Reality for therapeutic purposes. Compared to telehealth, which uses new technologies to provide health services remotely, cybertherapy employs technology to change the attitudes and behavior of its users, with long-term cognitive and bio-physiological effects (Emmelkamp, 2011). Cybertherapy was born in the United

States in the late 1980s, thanks to the interest and funding of the US Department of Defence. It refers to the different forms of clinical assessment and therapy that are based on the prevalent use of new technologies (Wiederhold & Wiederhold, 2004). In recent years, preliminary investigations have been conducted in this field, focusing on preserving residual skills and executive functions by reproducing of everyday contexts and actions. Through virtual therapeutics (Spiegel, 2020), i.e., Virtual or Augmented Reality experiences used alone or in combination with other tools or with traditional medicines, specific health needs of patients are being addressed. The application fields mainly concern clinical psychology and cognitive and motor rehabilitation (Borgnis et al., 2022). Among psychological impairments, solutions to control anxiety (Opris et al., 2012) and stress, phobias (Morina et al. 2015) and addiction, obesity and eating disorders are studied. The effectiveness of *COVID Feel Good* (COVID Feel Good, 2022), a simple virtual therapy experience able to reduce the anxiety and depression and overcomes the psychological burden generated by the Coronavirus pandemic (Riva et al., 2021), is currently in the news. The clinical trial was conducted by the Italian company *Become* in collaboration with the Università Cattolica and the Istituto Auxologico Italiano. The innovative approach of Immersive Virtual Telepresence (IVT) tools (Riva et al., 2004) makes it possible to improve the performance of rehabilitation and reintegration programs (Rizzo & Kim, 2005) for certain impaired functions. It allows these deficits to be managed, overcome or reduced and enables the patient to benefit from therapeutic support in environments where disorders commonly develop. Cognitive training (Pedroli et al., 2013) based on digital tasks and exercises can be an excellent solution for involving participants in structured mental activities and improving their cognitive functions, especially if the motivational and playful aspect is emphasized. For example, stroke patients (Huygelier et al., 2021) reported less fatigue when using a robotic device to navigate a virtual plane displayed on a regular computer monitor than without this visual feedback (Mirelman et al., 2009). A walk in the park (Moyle et al., 2016), searching for products on the shelves of a supermarket (Zygouris et al., 2015), executing a recipe (Valve Corporation, 2022; Foloppe et al., 2018; X-Tech Blog, 2022), are some activities that require the implementation of choices and strategies. RelieVRx (AppliedVR Inc., 2021) is the first and only Food and Drug Administration (FDA)-authorized at-home immersive Virtual Reality non-pharmacological pain treatment. It is a prescription-use immersive system intended to provide adjunctive treatment based on cognitive behavioral therapy skills (Garcia et al., 2021) and other evidence-based behavioral methods for patients with a diagnosis of Chronic Lower Back-Pain (CLBP). This significant utilization variability is supported by the faithful three-dimensional rendering of human body parts or an avatar that can interact with situations and objects to achieve different goals depending on the subjects involved. The possibility of customizing the scenes and activities, making them more engaging, and adapting the therapy according to patients' feedback on performance are advantages of experimenting with the new visualization method. Volumetric and 360-degree videos (O'Sullivan et al., 2018) are moreover used as low-cost newer technologies in terms of time and resources for development as they are spherical recordings captured by sophisticated cameras with omnidirectional lenses that can collect images from all over the scene. They offer the opportunity to immerse oneself in authentic natural environments that are known to evoke positive emotions (Yeo et al., 2020; Yu et al. 2018; Chirico & Gaggioli, 2019; Lee et al., 2021). For these reasons, they are especially suitable for home-based rehabilitation activities (Pedroli et al, 2022; Pedroli et al, 2021; Boilini et al., 2020) and make sharing content easy with patients and their families on smartphones and tablets beside head-mounted displays. The literature review shows that these innovative digital applications may represent a revolution in cognitive screening methodology within the clinical setting of Dementia (Robert et al., 2014). Preliminary experiences of serious games to assess executive functions (Castelnuovo et.al, 2003), attention, memory and visuospatial orientation are detected (Zucchella et al., 2014; Serrani, 2014; Manera et al., 2015; Dudzinski et al., 2016; Valladares-Rodriguez et al., 2018). The *Cognitive Virtual Stimulation* application presented in this research is created to offer a relaxation/rehabilitation therapy besides an entertainment experience with multisensory stimuli. The serious game developed is used to set up a clinical study.

Research Background

The background of this study is the CANP – la CAsa Nel Parco project. It proposes e-health solutions for management processes, telemedicine and telehealth. The aim is to support the accessibility and interoperability of information to achieve better services, decentralise care, rationalise resources, and improve care pathways. The European Commission indirectly funds it through the POR FESR 2014/2020 regional program within the preparatory actions for realizing the future Turin Health, Research, and Innovation Park. In this context, the activities of the Politecnico di Torino have been focused on the design and development of a service ecosystem to support patients, family members/caregivers and professionals to improve patients' quality of life, as shown in Figure 2. On the one hand, the *Re-Hub* platform has been developed for mapping the healthcare facilities present on the territory. It integrates a recommendation system that allows the user to compare them in a personalized way concerning objective aspects linked to pathology and medical needs and subjective aspects, i.e. territorial services, functional characteristics of preference and user perception. This system, which adopts the logic of booking engines, allows operators and patients to make more effective use of rehabilitation facilities thanks to exploring indicators of interest. On the other hand, a set of Virtual Reality applications for the health sector are promoted within the *Virtual-Hub* platform. These solutions are characterized by a high degree of innovation and creativity, as evidenced by the limited availability of studies in the literature. The approach outline three synergistic lines of research: (i) Design – the creation of multidimensional scenarios for the realization of hospital environments, healthcare facilities and private homes that are increasingly functional and comfortable concerning the needs of users; (ii) Awareness raising: engaging users through interactive experiences to promote consciousness and disseminate information (Ugliotti, 2020); (iii) Cybertherapy – using digital models to test innovative relaxation/rehabilitation therapies for patients (De Luca & Ugliotti, 2020; Fardello, 2020). This last thread is detailed in the following.

Figure 2. Application to raise awareness among patients and their families regarding home hospitalisation



METHODOLOGY

This specific contribution is part of broader research investigating the conditions that can make cybertherapy experimentation effective. As shown in Figure 3, different aspects are considered: such as pathology, patient target (e.g., age, gender, social background), level of self-sufficiency (e.g. autonomous experience, caregiver-assisted or physician-guided), degree of immersiveness (fully immersive, semi-immersive) and place where to carry out the experience (e.g. patient's home, dedicated rooms in hospital or nursing home). This chapter aims to illustrate a virtual experience evaluated for pathologies that lead to cognitive impairment from the generated matrix of combinations.

Dementia is a comprehensive definition that includes various neurocognitive disorders, often in a progressive manner accompanied by a worsening of the quality of life of both patient and caregiver. It impairs various brain functions, such as memory, language, reasoning, orientation and the ability to perform complex problems. These cognitive dysfunctions are associated with personality and behavioral changes, including irritability, anxiety, depression, insomnia and apathy. The pharmacological search for a molecule that can modify the natural history of the disease has met with multiple failures (ADI, 2018). The only possible therapy is the symptomatic one. The focus has therefore shifted toward non-pharmacological interventions (Abraha, 2017). These are indicated as the first line of treatment, especially in psychological and behavioral disorders associated with Dementia. Non-pharmacological interventions can be classified as (i) sensory stimulation interventions (acupuncture, aromatherapy, chromotherapy, touch/massotherapy, light therapy, ortho therapy, music and dance therapy, transcutaneous electrical stimulation, and multisensory stimulation/snoezelen); (ii) cognitive-affective interventions such as reminiscence therapy; and (iii) other behavioral management interventions such as pet therapy. Among sensory stimulation techniques, only music therapy has been shown in the literature to be effective, especially in reducing agitation, aggression and anxiety. There is still a long way to go in this field, overcoming the current limitations of the studies conducted so far (i.e. low sample size, unclear definition of study designs, heterogeneity of intervention protocols, short duration of treatment and follow-up period).

Figure 3. Methodological investigation matrix

	Pathology	Target	Self-sufficiency	Immersiveness	Place
Case 1	Dementia	Senior	Doctor-guided	Semi-immersive	Hospital
Case 2	Dementia	Senior	Staff-guided	Semi-immersive	Nursing home
Case 3	Dementia	Senior	Caregiver-assisted	Full-immersive	Patient home
Case N	…	…	…	…	…

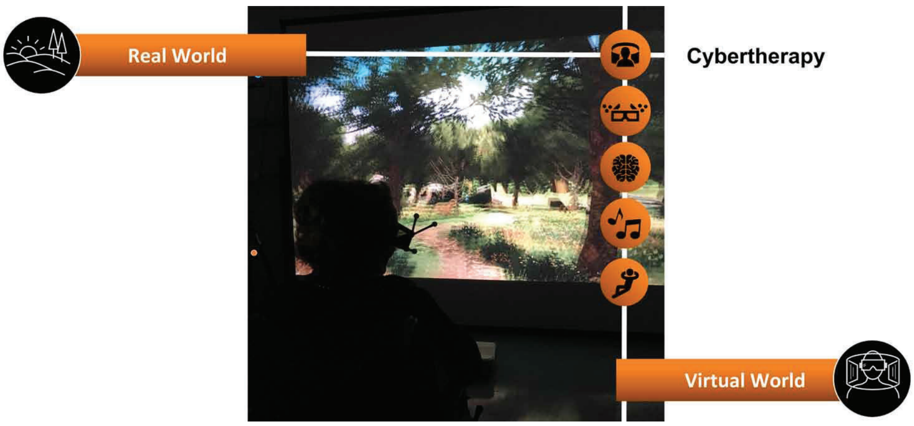
The methodological approach adopted involves an investigation path by successive stages of development to evaluate the involvement of Virtual Reality as an element of support for the no-pharmacological management of Dementia-associated behavior disorders. The primary objective is the relaxation of patients through immersion in peaceful environments. It is then possible to introduce interaction elements until an actual cognitive rehabilitation activity can be set up. As a first step, the reaction of patients to the use of Virtual Reality in the hospital context is evaluated through a guided experience by specialized operators and assisted by medical staff. In a further stage, the application in nursing homes and then in the patient's living environment can be considered. Depending on the specific scenario, several technologies can be tested.

In the context of the CANP project, the study promotes a semi-immersive guided experience with Virtual Wall technology in a hospital setting. A Virtual Reality application has been implemented, and a clinical trial has been designed in collaboration with the Geriatrics Department of the Molinette complex of Turin, as described in the following.

Cognitive Virtual Stimulation Application

At the base of this study is the hypothesis that, as happens in reality for physical spaces, virtual environments can also provide positive experiences for Dementia and Alzheimer's patients. Through cybertherapy, it is being tested how quiet and comfortable places can help reduce agitation and anxiety, making users feel better and improving their mood. The *Cognitive Virtual Stimulation* application is implemented using three-dimensional representations and the *Unity* game engine platform (Unity Technologies, 2022) to create interactive content with real-time animations. It is designed to run with the Virtual Wall system. The semi-immersive navigation shown in Figure 4 is allowed through 3D goggles and the Xbox joypad. As mentioned above, the experience is guided considering the target user's age, around 80 years old, and ability to use new technologies. An operator leads the patient on this virtual walk and initiates the different activities.

Figure 4. Semi-immersive guided cybertherapy experience for Dementia patients



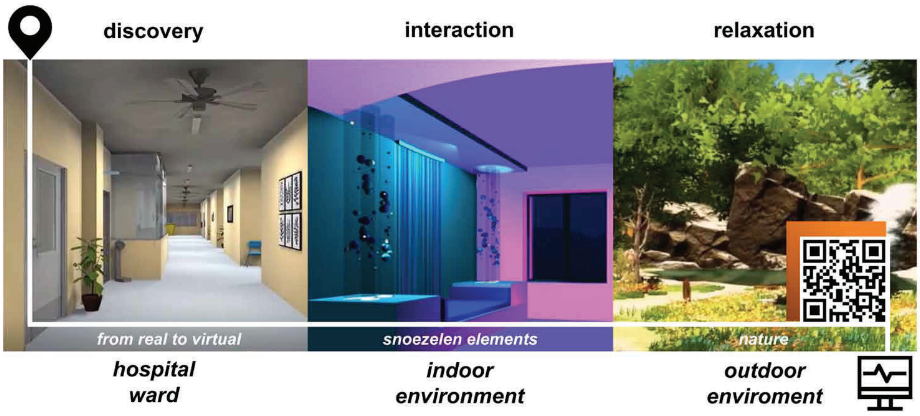
The virtual settings are designed to promote a gradual transition from the real to the virtual context and stimulate different brain areas to slow down the degradation process triggered by the disease. The experience unfolds based on three different scenarios, as shown in Figure 5: the geriatrics ward of the Molinette hospital, an indoor and an outdoor environment, a multisensory room and a natural setting, respectively. The first two scenes come from BIM models, while the third is only graphic modelling. In fact, in the framework of the CANP project, solutions are also analyzed for the digitalization of the built environment, to make information about the building and the assets contained therein usable, and for the participatory design of increasingly high-performance environments available to patients. The indoor setting was originally derived from an actual study and design activity (Carvajal Talero, 2019). This sequence of virtual spaces is conceived to activate different emotions in the patient, of discovery in the initial phase, relaxation and subsequent interaction in the following ones.

The session is started by walking along the corridor of the hospital ward. It recalls the route taken by the patient to reach the place of experimentation. The user's recognition of a familiar environment establishes a phase of acclimatization by establishing a relationship of confidence with the patient, who does not feel disoriented and, therefore, in trouble. The scene is rendered realistically, even if beautified by additional furnishing and natural elements. The path is accompanied by background music to further isolate the participant from the surrounding context. At the end of the corridor, on the right, there is the multisensory room that activates the second set and initiates the appropriate experimental activities.

The indoor scene represents the virtual transposition of a multisensory room designed according to the *Snoezelen* method - a Dutch term deriving from the contraction of the verbs "sniffen" (to explore) and "doezelen" (to relax). The design principles provide a welcoming and relaxing environment. The approach is also known in the literature under the term Multi-Sensory Environment (MSE) (Collier et al., 2017). It is used among the innovative non-pharmacological therapies for patients suffering not only from Dementia but also from other cognitive disabilities and psychiatric pathologies (van Weert et al., 2005). The initial phase of environmental exploration is passive. The objective is to achieve the relaxation of the patient acting in particular through the features of the space such as furniture elements, colors, and soothing sounds to transmit positive energy. The operator accompanies the patient to discover these characteristics. Lighting effects are one of the distinctive aspects achieved by employing bubble lamps, fiber optics, and spotlights. Soft items are placed on the floor, such as pillows or beanbags, simulating comfortable seating in correspondence with a large monitor that reproduces the dynamic vision of an aquarium with colorful fish moving slowly and drawing repetitive trajectories among the corals. Water is also present in the room by bubble tubes that move vertically at a slow and constant speed. They are used as a complementary focal instrument to encourage visual tracking, color recognition, physical movement and hand-eye coordination. Two windows are placed from which well-known Italian points of interest, such as views of the Mole Antonelliana and the Basilica di Superga, can be appreciated. This strategy is used to maintain a connection with reality and open up the environment, not forcing the patient into an utterly locked place that could have triggered feelings of fear and discomfort. Cause and effect items are implemented to allow the individual to control elements within the environment, although not directly as discussed later and return visual- acoustic effects. For example, it is possible to experience different color schemes of the setting by adjusting the room's lighting from cold blue-violet tones to warm yellow-orange tones. Then the patient is subjected to visual and audio cognitive stimuli in the following phase. The focus is on distracting the patient from interrupting possible agitated behavior. The *Memory Train*'s first activity involves scrolling on the screen previously used to show the aquarium a sequence of images evocative of the user's years of youth and maturity, with famous people, familiar places, and advertising slogans. For example, black and white images of the carousel, wooden school desks and some of Totò's films are shown. These inputs aim to evoke lost memories and emotions in the patient, who may express interest in sharing and recounting them, finding peace and serenity. A second activity encourages the cognitive sphere through music therapy, thanks by listening to a choice of very well-known songs and playing different rhythmical musical instruments (saxophone, electric guitar, drums and violin). From the indoor setting, there is a link to the outdoor one.

The outdoor scene consists of a natural landscape characterized by trees, paths, leaves, streams, a waterfall, and small shrubs. Some animals, from cats to lions, cows to giraffes, arouse amazement thanks to their unusual location. Small squirrels are moving under the trees, and little birds are chirping. The presence of the wind is simulated through the gentle fluttering of tree branches. Here again, the presence of water is used as sound therapy for healing. There is a pool of water in which the shadows of moving fish can be clearly recognized. As the user approaches, the natural running sound of the water becomes louder and louder to emphasize the realistic perception of the scene. Exploration is more free form than before, and the patient's involvement within a pleasant environment is assessed.

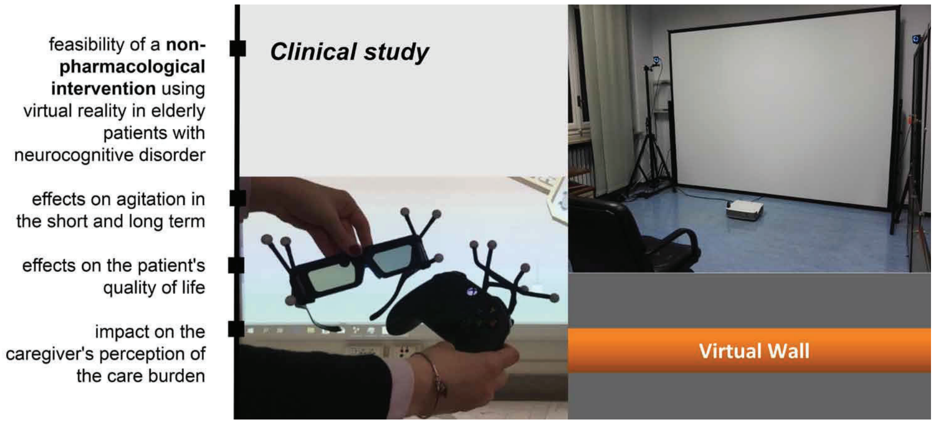
Figure 5. Cognitive Virtual Stimulation application structure



Virtual Wall Virtual Reality Technology

The *Cognitive Virtual Stimulation* application is designed to be executed with the Virtual Wall technology, which integrates stereoscopic wall projection and rigid body tracking tools. It is part of the Cave Automatic Virtual Environment (CAVE) visualization system invented at the University of Illinois at Chicago in 1992 (Cruz-Neira et al., 1992). It consists of a cube-shaped VR room in which the walls, floors and ceilings are projection screens. This VR theatre gives back the feeling of being immersed in the virtual scenario projected on the screens by a correct reading of the spaces, volumes and distances simulated with a scale of 1:1 (Cruz-Neira et al., 1993). The Virtual Wall solution instead involves only one screen for a semi-immersive experience. The graphical environment is realized by transmitting the three-dimensional model to the screen using a high precision stereoscopic holographic projector. The user can perceive its positioning in the three-dimensional space and interact with the screen through devices equipped with reflective markers. These sensors are detected by the cameras connected to the workstation transmitting a tracking signal processed by the software program. The higher the signal accuracy, the greater the user tracking in the surrounding space. In our specific study, 3D glasses, an Xbox joypad and four infrared cameras are used, as shown in Figure 6. For the Virtual Wall system to be installed, it is necessary to have a room of adequate size, with a free wall of at least 2.70x3.10 m. It is essential to be able to darken the room completely. The equipment must be carefully installed and calibrated in the specific place where it will be used to be effective. Some tracking problems may occur due to reflective surfaces, such as tiles, transparent surfaces and cabinet panels, and non-removable light sources. The virtual environment will be more engaging and realistic if the physical room is confined, free of clutter, with neutral tones.

Figure 6. Virtual Wall Virtual Reality technology



Clinical Trial

At the same time as designing the *Cognitive Virtual Stimulation* application, the opportunity arose to carry out a clinical trial as part of the CANP project. The prospective observational study concerns the use of Virtual Reality and the Virtual Wall system to manage agitation in Dementia patients. Precisely, it is planned to subject the older adults with Dementia to a cycle of twice-weekly sessions of semi-immersive virtual therapy for two months. The overview of the technological infrastructure deployed is outlined in the following section. The main primary and secondary objectives of the study are as follows.

- To assess the feasibility of a non-pharmacological intervention using Virtual Reality in the elderly patient with moderate-to-severe major neurocognitive disorder and agitation.
- To rate the enjoyment of different types of virtual environments.
- To evaluate the effects on agitation in the short and long term.
- To consider the effects on a patient's quality of life.
- To value the impact on the caregiver's perception of the care load.

It is expected to enroll fifty people referred to the outpatient of the S.C.U. Geriatrics department, who are 75 years of age or older and have been diagnosed with moderate-severe major neuro-cognitive disorder according to the diagnostic criteria of the DSM-V (American Psychiatric Association, 2013). The level of cognitive impairment is assessed through the Mini-Mental State Examination (MMSE) test (Folstein et al., 1975) and Clinical Dementia Rating (CDR) parameter (Morris, 1997). Irritability, aggressiveness, aberrant motor activity and sleep disturbances are some of the behavioral impairments considered. They are primarily concerned with the agitation cluster. The place of experimentation is the hospital. Depending on the requirements for using the Virtual Wall mentioned before, a suitable room was selected at the hospital ward of *Servizio di Ospedalizzazione A Domicilio della S.C. Geriatria e Malattie Metaboliche dell'Osso – PO Molinette* of the *Azienda Ospedaliero Universitaria Città della Salute e della Scienza di Torino* and the set-up and configuration was carried out. The trail was then carefully engineered to make the individual guided virtual experience replicable and comparable in its modalities for all participating subjects. The study protocol comprises five main phases in which different professionals are involved depending on the actions to be carried out. At least two operators and one doctor participate in the study in addition to the patient.

Phase One: Pre-screening and enrolment

The first step to starting the programme is knowledge-based. It involves the assessment of the patient's initial clinical conditions and the determination of eligibility for inclusion in the study. Mainly the drug therapy and the care load are considered. Information on the patient's biography and the level of digital competence is also essential to evaluate the user feedback during the therapy session. This activity consists of an interview of the patient and his/her caregiver with the doctor.

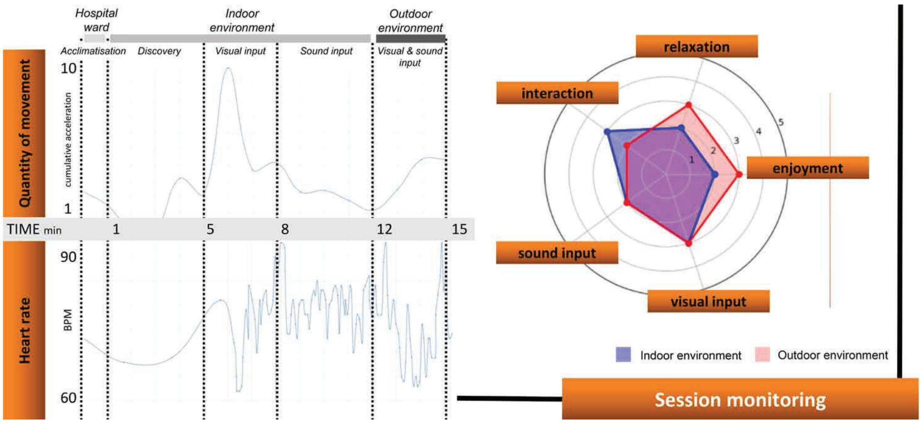
Phase Two: Semi-immersive therapy sessions

Each patient undergoes a program of sixteen sessions, two per week for eight consecutive weeks. Each session lasts 15 minutes, and two experimenters and a doctor are present in addition to the participant. The caregiver can attend the session but should not speak or have eye contact with the patient. It is believed that communicating with a familiar person can distract the patient and affect the session, the enjoyment and the possible outcome of the experience. The subject is welcomed into the experimental environment and made to feel comfortable, allowing him/her to adapt to the situation. He/she is seated in the centre of the room in front of the Virtual Wall screen and is asked to wear an accelerometric sensor placed on the patient's wrist to monitor vital parameters and 3D glasses with markers. To make the session as experiential as possible, the operator positions himself immediately behind the patient and leads him through the virtual walk by moving with the controls of the Xbox joypad. The doctor sits next to the patient and observes his reaction. A second operator also observes the session from the back of the room. The environment is darkened, and the feeling for the patient is that of being alone. The same application is provided to the user for all 16 sessions. Although this may sound repetitive, it is essential for the validation of the study. Moreover, the state of confusion caused by the disease makes the patient forget the contents of the treatment from one session to the next, thus making the experience as attractive and stimulating as the first time. As an experimenter leads the session, it was possible to define precisely all aspects characterising the virtual walk-in terms of actions to be performed and timing and overall duration. The start of the route with the linear exploration of the hospital ward corridor (entrance and exit) is used as an acclimatisation time. It, therefore, has a short duration of 1 minute. The multisensory room is assigned a total of 11 minutes. The gradual discovery of the different elements is 4 minutes long and ends with the user observing the aquarium. The visual stimuli proposed in the *Memory Train* activity take up to 3 minutes. In comparison, the sound stimuli with listening to the instruments and a famous song of the user's choice are set aside for 4 minutes. In the natural landscape, 3 minutes are spent. The experience ends with returning to the hospital corridor, where everything started.

Phase Three: Significant session data recording

At the same time as the virtual therapy session takes place, the patient's reactions are recorded, and observation sheets are filled in by the doctor and the second operator together. At the beginning and immediately at the end of the session, the patient will be measured for blood pressure, heart rate, and respiratory rate. Accelerometric measurements, which are significant for the quantity of movement the subject makes during the session, and heart rate are recorded to check the state of relaxation of the subject. These parameters are measured via the smartwatch-type accelerometer sensor worn on the patient's wrist. The collected data are downloaded using dedicated applications as Comma-Separated Values (CSV) files and made available for analysis. Then these values are correlated with the sequence of the different virtual environments and the visual and sound inputs proposed in the virtual walk. In addition to the trend, the standard deviation, median, mode, maximum, minimum and mean values are also calculated for each dataset. The experimenter also notes aspects of non-verbal communication and body movements: open/closed eyes, the posture assumed in the chair, e.g., whether the back is against the backrest, whether the legs are crossed. These elements help to understand the patient's state of relaxation, whether at ease or in a state of agitation and restlessness. The patient can also be filmed during the session to observe better these elements such as facial expressions, gestures, and behaviour. The patient's reaction to the visual and auditory stimuli is scored, in particular, if the attitude is passive and no interaction is established or if the patient asks questions or comments, telling about their personal experience and verbalising their state of mind. Another significant element is the active listening during the music part, where it is observed whether the patient keeps the rhythm, whistles or sings. At the end of the intervention, the doctor conducts an informal interview with the patient to assess satisfaction. In particular, the presence of emotions such as confusion, fear, sadness, and the appearance of any side effects like discomfort, vertigo, dizziness, and headache due to the use of the technology are checked. The level of gradability of the non-immersive virtual reality tool is assessed by constructing a Likert scale (Joshi et al., 2015). A PDF summary monitoring report is generated using the data storage system discussed in Phase Five based on information collected during each session. The computer language used is Javascript. The experimenter manually loads the punctual information into the system, while the heart rate and accelerometer data are processed from the external datasets recorded by the smartwatch. An example is given in Figure 7. The first part of the report presents a graphical representation of the patient's heart rate and accelerometer fluctuations. Both graphs show on the x-axis the time values, i.e. the time instants in which the recordings are made, while the y-axis shows the values of the monitored data expressed in their unit of measurement. In the graphic restitution of the diagram, vertical reference lines are implemented at specific time instants. These identify the transition between one virtual setting and another, considering the different inputs proposed. They, therefore, correspond to the timing described in Phase Two, i.e. minutes 0, 1, 5, 8, 12, and 15. The second part of the report contains a radar chart indicating: enjoyment, relaxation, level of personal involvement and outcome of interaction with sound and visual input. The two datasets refer to the multisensory and natural rooms. This type of graph is used to quickly visualise the effect and compare the results for the two different environments. It is not possible to establish a priori which of the two virtual environments can return more satisfying sensations. The report's last section is dedicated to collecting a short descriptive text representative of the individual experience. It includes any aspects not considered and evaluated utilising appropriate scales that may prove helpful in understanding the phenomena.

Figure 7. Summary session monitoring report



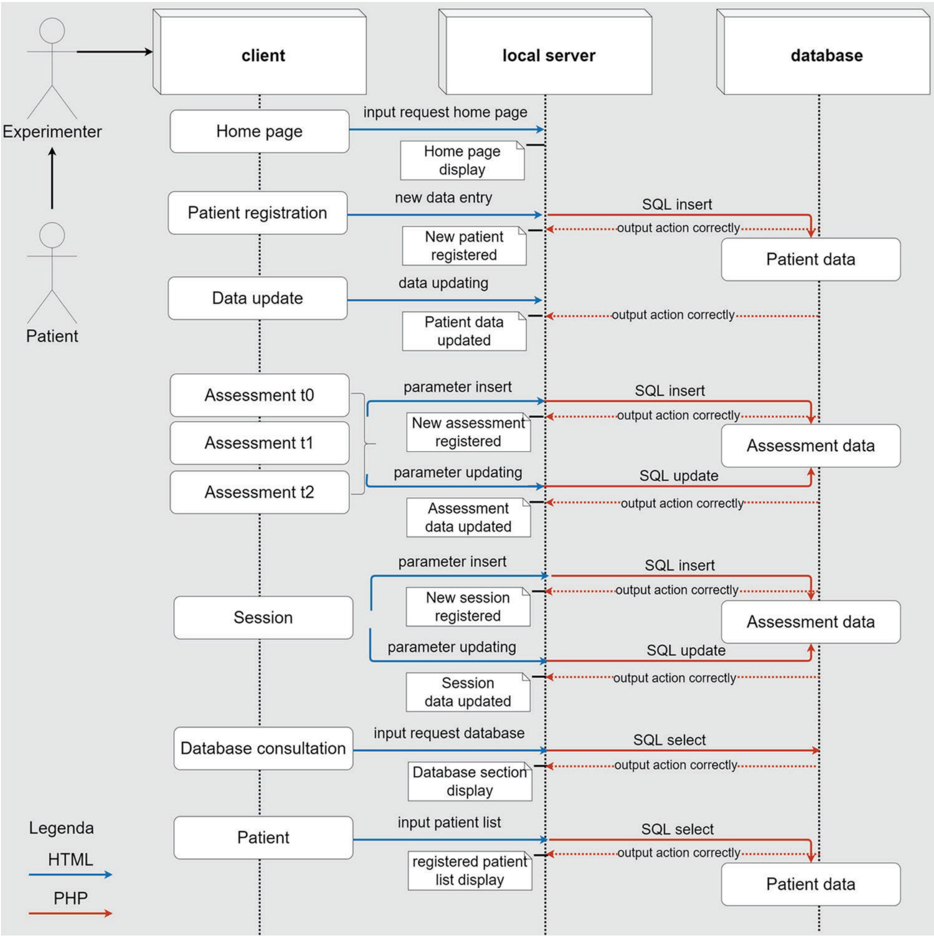
Phase Four: Baseline, conclusion, post-conclusion assessment

During the program, three moments of clinical evaluation are identified. They are conducted by the doctor through a structured interview individually with both the patient and the caregiver. Patients are evaluated at baseline (t0), at the end of 8 weeks of non-pharmacological treatment (t1), and one month after the conclusion of treatment (t2) in order to detect the feasibility of the intervention with Virtual Reality, the immediate and long-term effects of an innovative non-pharmacological approach on agitation. The data collection is done through structured interviews and the completion of validated scales. The evaluation includes cognitive and functional assessment of the patient, measurement of agitation, also considering indirect aspects such as the impact on quality of life and sleep characteristics of the patient, pharmacotherapy and caregiver burden. With regard to cognitive status, Mini-Mental State Examination (MMSE) test (Folstein et al., 1975) and Clinical Dementia Rating (CDR) parameter (Morris, 1997) are considered. The Cohen-Mansfield Agitation Inventory (CMAI) index (Cohen Mansfield, 1986) and the Pittsburgh Sleep Quality Index (PSQI) self-report questionnaire (Buysse et al., 1989) are assessed for the state of agitation, and the EQ-5D-5L for the patient's quality of life (Herdman et al., 2011). Finally, the caregiver's care burden is assessed through the Caregiver Burden Inventory (CBI) scale (Novak & Guest, 1989).

Phase Five: Reporting and data analytics

As anticipated in the previous steps, many parameters must be monitored to validate the effectiveness of the therapy. For this reason, a structured data collection system was deemed appropriate. The systematization of the dataset makes it possible to analyze the information of test subjects' patients, compare results and perform statistical processing through a generalized linear model for repeated measurements. The logical architecture of the computer network is of the client-server type. The Google Chrome web browser is used with desktop visualisation via local address for the user interface. The entry, consultation and updating of the characteristic patient and related session data are managed through dedicated sections created through HyperText Markup Language (HTML) documents. A local server interprets client input requests and communicates with the database. The XAMPP control panel is used to activate the Apache and MySQL modules. Communication between the local server and the database takes place via a specific Personal Home Page Language (PHP). The user can display the output via client-processed HTML pages. The process is schematised in Figure 8. When a new patient is registered, a unique identification code is assigned, which will represent the participant throughout the entire care process. A specific section is implemented in the client to visualise the database without the possibility of modification. It allows the doctor to use the system easily while preserving the integrity of the data.

Figure 8. Logical client-server-database integration process

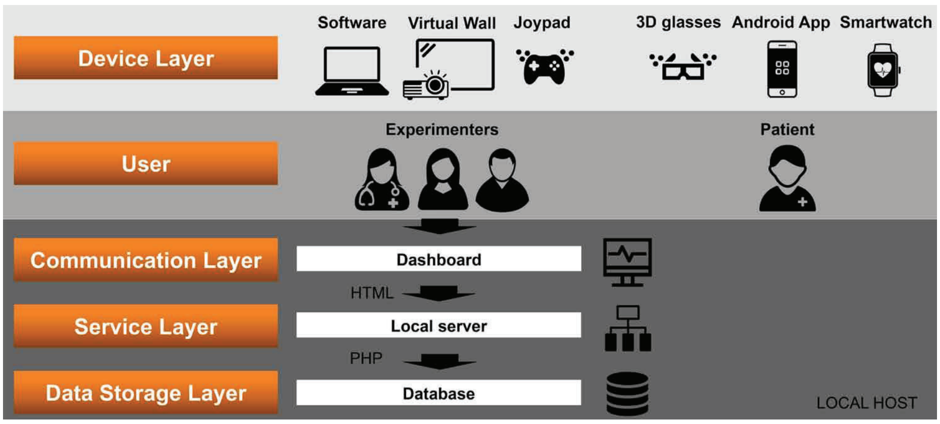


Technological System Architecture

The pilot study is supported by a system of technologies and platforms for testing non-pharmacological interventions using Virtual Reality to manage of cognitive disorders associated with Dementia. The architecture includes several layers of technology, communication and data storage, as shown in Figure 9.

- Virtual Reality Application: designed with Unity software in C#. The application is launched via Unity software. The configuration and the operation require the use of the Virtual Wall system.
- Unity: software for creating and launching virtual scenes.
- Virtual Wall: a system for interactive Virtual Reality based on stereoscopic wall projection equipped with fixed components, transportable if necessary and complete with tools for tracking rigid bodies.
- Optitrack Motive: rigid body tracking software.
- MiddleVR: software for receiving and processing tracking signals by superimposing them on the virtual scene's three-dimensional model.
- Wearable Xiaomi mi band 2: wearable system with accelerometer and heart rate sensors used to monitor movement and heart rate while performing activities non-invasively.
- App Android Mi Fit: Android application combined with Xiaomi mi band 2 Wearable device for activity recording.
- App Sleep As Android: Android application for sleep cycle monitoring used for recording accelerometer data detected by Wearable Xiaomi mi band 2.
- App Tools & Mi Band: Android application associated with Mi Fit used for continuous monitoring of heart rate detected by Wearable Xiaomi mi band 2.
- Front-end: Unity code for the virtual scenes and user interface realized with HTML markup language for the imputation of the characteristic data of the study and the integration of the data recorded by the Sleep As Android and Tools & Mi Band applications. The Visual Studio Code text editor is used.
- Back-end: Unity for the virtual scenes and HTML JavaScript platform that dialogues with the Front-end through PHP programming language calls to the MySQL database, hosted by the XAMPP virtual environment, for the consultation and storage of the characteristics in the MySQL database.
- XAMPP platform: high-level infrastructure used as an application server.
- MySQL: database management system for collecting the study data.
- Apeman A60 1080p HD Sports: Action Camera for image and video capture to assess patient enjoyment of the experience.

Figure 9. Technological system architecture



Pre-Clinical Trial Session

The *Cognitive Virtual Stimulation* application and the prototype configuration of the system have been fully realized and are available for a clinical study. However, the trial has been temporarily suspended due to the COVID-19 epidemiological emergency. In this situation, it was impossible to access the geriatrics department's areas and recruit patients from the target group in question, as it was considered unsafe to have them come to the hospital twice a week. However, a limited test sample is available thanks to some preliminary sessions conducted in concomitance with the installation of the Virtual Wall technology at the Molinette Hospital in Turin. Fifteen patients underwent the first session of the trial on a voluntary basis. No critical issues or adverse reactions emerged at this stage that hindered the session's running. Despite the age target considered, around 80 years of age, the subjects involved were willing to carry out the virtual session. Some did not quite understand why they had to undergo this experience; on the other hand, no one shied away from doing it. They readily agreed to wear the 3D goggles for body tracking and the smartwatch to monitor heart rate and movement. Nobody decided to interrupt the session before the 15-minute time limit. The three-dimensional settings enriched with sound and interactive elements were generally assessed as pleasant. All participants recognized the correspondence of the virtual corridor with the real one of the hospitals they had just walked through to reach the test site, even though it had been decorated with greenery and paintings that were not there. Viewing the aquarium definitely aroused strong interest and entertainment in the multisensory room. Observing the movement of the water and the fishes caught their attention. At the same time, the sequence of pictures proposed in the Memory Train stimulated the patient's openness and willingness to recall moments of lived life. In some cases, the participant reported personal events more or less related to the presented photographs. It was noted that the content of the input was not necessarily related to the patient's stories. Almost no one recognised the Mole and Superga outside the windows present in the room. However, the images were associated with monuments of collective interest familiar to the participant's life. Almost all participants generally achieved a beginning feeling of relaxation in correspondence with the delivery of the sound stimuli. As anticipated, music therapy is widely affirmed in this field. So, it proved to be even when the delivery took place in a virtual setting. It can be noted that all participants showed a more laid-back attitude while listening to the music. The position in the chair is less rigid and more comfortable; the legs are crossed, and the hands and feet keep the rhythm. The patient started to sing in limited cases, more frequently moving his lips or whistling. It was not possible to clearly identify the patients' preferences concerning virtual settings. Thanks to the natural elements, the outdoor setting is indeed rated positively by many users. However, it has been found that being in an environment with a vast horizon can make it difficult for patients, who may even feel disoriented. In contrast, the indoor environment provides a protected environment as it is closed and well-defined, so the user does not feel discomfort. Also, patients with hallucination disorders experienced the presence of shadows often associated with people in the natural environment. For this reason, demented patients with these alterations were excluded from the study. On the other hand, however, the user detected a complete feeling of immersion in the natural environment. This aspect may be due to the gradual patient acclimatisation to the virtual context. For example, some subjects shifted their heads, intending to dodge tree branches during their walk. The observation of the non-verbal language expressed by the patient is fundamental to verifying the performance of the experience both in terms of the quality of the graphic representation and possible calming effects. Only in the case of a drug-sedated patient the session was not very useful as the subject's attention span was minimal, and he tended to fall asleep. Notably, one patient, who was not very communicative during the session, manifested a condition of total relaxation by whistling a song while virtually walking in the natural landscape setting guided by the operator, as shown in the video shown in Figure 10. This episode in which the most significant involvement was found encourages further feasibility studies and experiments related to the use of virtual technologies.

Figure 10. Feeling of total relaxation achieved in the natural environment

FUTURE RESEARCH DIRECTIONS

The experimentation mentioned above constitutes the first methodological step in a broader research project introducing the use of Virtual Reality for the treatment of cognitive-behavioural disorders. In the event of positive, or at any rate not negative, results from the clinical trial carried out in the hospital setting, new paths of investigation would open up. On the one hand, it is possible to evaluate the customisation of the application to provide an experience characterised by the most significant elements of each participant's life and respond to specific needs. Starting from the *Cognitive Virtual Stimulation* application, for instance, it is possible to replace the images proposed in the *Memory Train* activity with photographs from the patient's private sphere so that they can recognise themselves in different situations at different times in their lifetime. On the other hand, it is planned to set up an actual cognitive rehabilitation programme with the gradual enrichment of the proposed sensory activities and the introduction of a section dedicated to the performance of some basic and more advanced memory exercises (De Luca & Ugliotti, 2020; Carvajal Talero, 2019). For example, the caregiver can ask the patient to remember a meaningful date for him/her or the current date and compose it virtually using a slider. Alternatively, patients can exercise their minds by recomposing the order of a sequence of colours or a jigsaw puzzle. The use of representation, shapes and colours becomes essential to make the experience enjoyable. The patient can also become autonomous in exploring space and performing cognitive exercises. After an initial period of using cybertherapy in a hospital setting, it is expected that the application can be extended to nursing homes and home settings. It is essential to remodel the experience using less expensive and less complex technologies in this latter case. Dementia appears to be just one of the possible pathologies for these studies and activities.

CONCLUSION

This chapter presents the most exciting results of cyberspace exploitation obtained within the CANP research project framework. The therapy is evaluated for the non-pharmacological treatment of Dementia-related cognitive disorders. The *Cognitive Virtual Stimulation* application proposes a multi-sensory indoor scenario and a natural outdoor setting to evaluate the effectiveness of Virtual Reality for the relaxation of the elderly patient with moderate-to-severe major neurocognitive disorder and agitation. Solutions involving serious games are currently evaluated to improve patients' quality of life through innovative, captivating experiences. The implementation as a diagnostic and therapeutic tool offers innovative possibilities for the understanding, evaluation and rehabilitation of numerous cognitive, psychiatric and motor disorders. The study examines Dementia and considers a target group of senior users. However, this experiential approach is considered extraordinarily versatile and can embrace a broad spectrum of case histories and pathologies. From the elderly to children, from care to entertainment. Creating a specialized virtual technology center would undoubtedly enrich the hospital's range of services and be of interest to multiple hospital departments. It is also essential to assess the impact of research on the ability to design actions for the future, considering the development and maturation time of studies and prototypes and the characteristics of possible users. In particular, the target audience is not the patient and older adult of today but the one who will be able to take up interactivity and deal more naturally with technological devices in the medium to long term. The multidisciplinary approach applied to the healthcare context can contribute to the patient's well-being from the perspective of the Society 5.0 and foster new market and research fronts. In this scenario, the role of representation is put at the service of the Smart Hospital to extend and enrich the processes of participatory design and user experience activities.

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KEY TERMS AND DEFINITIONS

Cave Automatic Virtual Environment (CAVE): Surround-screen projection-based virtual reality. Theater immersive visualization system was invented at the University of Illinois in 1992, consisting of a cube-shaped VR room in which the walls, floors and ceilings are projection screens.

Cognitive Stimulation Therapy: Treatment which aims to improve cognitive skills and quality of life of people through activities such as categorisation, word association, discussion of current affairs and executive functions.

Cyberspace: Digital space navigable in virtual mode by people from different realities communicating with each other within a computerised world of digital networks.

Cybertherapy: Different forms of clinical assessment and treatment that use new experiential technologies as their primary intervention tool.

Dementia: Global deterioration of the cognitive state, often in a progressive manner that impairs various brain functions, such as memory, language, reasoning, orientation, and the ability to perform complex problems. These cognitive dysfunctions are associated with personality and behavioural changes, including irritability, anxiety, depression, insomnia, and apathy.

Digital Twin: Virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making.

Multi-Sensory Environment: Dedicated space or room where sensory stimulation can be controlled (intensified or reduced), presented in isolation or combination, packaged for active or passive interaction, and matched to fit the perceived motivation, interests, leisure, relaxation, therapeutic and educational needs of the user.

Serious Game: Games designed for educational purposes.

Smart Hospital: Hospital building with a digital brain and systems that can connect with users' needs.

Virtual Wall: Screen projection-based virtual reality part of the CAVE visualisation system. It involves only one screen for a semi-immersive experience and the use of peripherals equipped with markers such as 3D glasses and a joypad.