Brain@home:

Moving and enhancing brain training for an active life

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4 Partner	Pannon Business Network Association	PBN	RTO acting as end user organization	Hungary
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Authors:
MH
(Alessandra Tzannis, Fabrizio Basso, Stefano Triberti)

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Abstract: This statement describes a specific investigation about the technology currently in use, the potential of technology and the state of the art of ecological and VR cognitive training .

Keywords: State of the art, technology, cognitive training

Project Co-ordinator

Company name : *SIVECO Romania S.A.*
Name of representative : *Monica FLOREA*
Address : *73-81 Bucuresti-Ploiesti Drive, Building C4, District 1, 013685, Bucharest, RO*
Phone number : +4 (021) 302 3300
Fax number : + 4 (021) 302 3391
E-mail : monica.florea@siveco.ro
Website :

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V1.0	Initial draft	10/07/2016
V2.0	Redefined the structure of the paper, conclusions added.	18/07/2016
V3.0	Added an analysis of comparable solutions	24/07/2016

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1. Introduction

This document intends to develop a systematic analysis of the available hardware and software technologies which can be used for the realization of a low cost Virtual Reality platform.
The research work is part of a complex action aimed at identifying, analyzing and evaluating the enabling potential of Virtual Reality (VR forwards from here) technologies to support neuro-cognitive and neuro-motor training programs.
In recent years there has been a continuous growth in demand for care and rehabilitation services for people suffering from some form of mental or physical disability and other kind of people like healthy ageing people.
Dementia is an important public health issue representing one of the major causes of disability and dependency among older people worldwide, determining physical, psychological, social and economic impact on caregivers, families and society.
As an evidence, since years World Health Organisation has added the neurologic diseases among the priorities in its Agenda
European Union and the European Commission have also raised the specific issue of dementias in the center of research activities and joint actions are promoted and supported in the United States. It is accepted that the greatest risk factor associated with the onset of dementia is age. The elderly population is steadily growing. Globally, in 2000 elderly people were about 600 million; in 2025 will be 1.2 billion in 2050 will reach 2 billion. International epidemiological estimates also predict that in 2020 we'll see more than 48 million cases of people with dementia (81 million people over the next 20 years). This will also have an impact on the costs of health care, considering the estimated costs for dementia in 2008 accounted for more than 160 billion euros. Predictions based on demographic trends in Europe seem to indicate an increase of about 43% of these costs by 2030.
The increase of elderly population not only impacts on the demand for care and rehabilitation services for people with mental and physical disabilities but actually create an unprecedented demand for preventive services. Identifying sustainable paths for delivering similar services is one of the challenges that health care is bound to face both the short and the long term.
The concept of sustainability is rightfully expressed by the sentence "from cure to care," which emphasizes the search for an higher quality of life of the elderly, trying to prevent the emergence of problems and accompany him every step of the diagnostic and therapeutic rehabilitation, where necessary. The elderly population has the need to be assured a continuity of care through the creation of support networks. An important role in this is played by the technologies for remote training, monitoring and rehabilitation offered by Telemedicine.
Promoting an healthy ageing can be seen as an instrument to prevent or slow down possible processes of cognitive and motor decline. Therefore they would configure themselves as a great tool to improve clinical and economic sustainability of the health care system.

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Telemedicine can actually be considered a tool to improve quality of life, improve and facilitate the work of health care professions and positively impact on the productivity and efficiency of the service, allowing to monitor all the path of prevention and care for chronic or degenerative situations from health facilities to the home of the patient.
The rapid progress in the field of ICT (Information and Communication Technology) and the increasing availability of wireless devices and touch-screen (such as smartphones, tablets, laptops and so on.) As well as the interconnectivity guaranteed by the global network offer a potential for the creation of a technological tool dedicated to the support of the Elder in paths of preventive care as well as rehabilitation, the support of the doctor-patient relationship, the continuity of treatment and monitoring of patients with chronic degenerative diseases, the continuation of some intervention programs outside the facilities, as well as the promotion of active aging both in healthy elderly people and in that subjects with cognitive or motor deficits.
The need to provide a platform like this is also born from the intention to encourage a cultural revolution implemented in some European country. To allow the positive inclusion of telemedicine within the health care system, it's necessary, in fact, to start from the education of the Elder, of his loved ones, the caregivers and doctors themselves about the advantages as well as about the enabling potential offered by technology.
A shared view must exists between with all stakeholders of the care pathway: Telemedicine is a simplification of the system and an improvement over sanitary procedures already in place that allows to monitor chronic conditions and simplify the life of the individual, without detriment to the medical service or invalidating the doctor-patient relationship.
As for what concerns the setup training of the user, it should not be limited to the technological aspects (a training that might prove necessary for the elderly population), but it should also take action on social aspects and relations, the change in the doctor-patient / client relationship and the reassurance that, even if performed remotely, the assistance and care process is not impaired.
Active ageing programs and chronic disease management must move from a system that reacts to a sudden and unplanned procedures to a system that educates and empowers the individual to actively take care of their own human story, despite the presence of disease or a neurocognitive condition or motor impairment, and their treatment regimen.
Provide effective prevention programs, improve management of chronic disease insurgence and cure and improve quality of life with the direct and responsible participation, is a challenge for the financial sustainability of health systems.
An important role in this regard seems to be played by the technologies for Virtual Reality (from here forward VR).

2. Literature review on VR in Health-Care

Moving from the considerations expressed in the preceding paragraphs, in this paragraph, we focus on the research work that has been aimed at the production of the elements of knowledge that could provide an understanding of:

- the potential **advantages of the VR** to support rehabilitation programs both in neuro-cognitive and neuro-motor training;
- the **clinical implications** that may arise from the use of such technologies;
- the main **facilitating and restraining factors** which may influence the spread of this type of technology;

Many contributions have highlighted the role of VR to support different areas of physical, psychological and cognitive rehabilitation and training, especially for aged but healthy people (Weiss and Jessel, 1998; Glantz, Rizzo and Graap, 2003; Zimand et al., 2003; Rizzo, Schultheis, Kerns and Mateer, 2004). Technological development itself has made available more and more powerful systems which are substantially more accessible both from the purely economic point of view and from the associated knowledge needed for their use.

The possibility to establish an interaction with a valid technologically defined environment, the ability to control and modify the conditions of the environment in which you perform these interactions, as well as the ability to record the results obtained, give the VR a rehabilitative potential that can draw profit of the adaptive ability of the nervous system in terms of plasticity and personalized learning paradigms.

It is significant in this situation to note that the traditional approach to rehabilitation has been criticized as not being "ecological" enough, in other words, it fails to relate to situations of "real world", and consequently, to develop skills and capabilities applicable to everyday reality (Neisser, 1978) .

Moreover, the VR can be developed so as to offer stimuli specifically studied for both cognitive and physical rehabilitation, designed to allow a variation in the hardly controllable variables of the real world.

In addition, the possibilities offered by this technology to manipulate objects and to move naturally through a virtual space, means that it is perceived as being similar to the opportunities that can be found in the real world, regarding the outcome of physical rehabilitation. (Sveistrup, 2004)

Exploratory analysis on the role of virtual reality technologies in support of neuromotor and cognitive rehabilitation, reveals some interesting confirmations about the search and operational areas.

From a research point of view, we report the need to further investigate what are the real dimensions of effectiveness of new technologies to support the rehabilitation programs, whether they are preformed remotely or not. The interest of the scientific community begins to exist, as well evidenced by the literature review, although currently, there is little evidence, especially on representative samples and for an extended period of time, or at home.

From an operation point of view, they are indications, from different perspectives, of both an interest in the creation of care pathways that integrate the neuro cognitive and neuro-motor perspective, as well as an interest about the potential benefits (effectiveness of treatment), although yet to be proven.

Multiple benefits of this innovative course of treatment are reported (not only on the patient's side, as it allows an homogeneous reference between operators at the various levels of service path), its potential in terms of increasing control over care continuity is also noted in literature suggesting routes for assistance that starts in the health facilities and accompany the patients toward a greater autonomy, up to bringing the tools in his own home.

The issue of compliance is reported as a factor facilitating the transition, the support provided by the operator and the caregivers is reported as a key factor in the continuing motivation and assistance. A service that will be shared by the supplier of the equipment.

Another strong theme in literature is the usefulness of a shared scientific rationale in the health facility, including all the different actors of the care pathway, to confer more stability to a treatment that should not be confused with gaming or entertainment.

Exploratory analysis shows certainly an interesting space for development which would seem to suggest the inclusion of other training from those typically offered in rehabilitation centers, such as cognitive training in healthy ageing.

It is due to note the value and the importance of being able to offer to the end user the opportunity to continue rehabilitation in the "private" of his own home, with the resulting positive impacts on the path of recovery or acceptance of one's disability in everyday life. All it facilitated by the availability of appropriate technologies at reasonable prices.

The ability to monitor and record performance parameters related to the performed rehabilitation exercises on the one hand allows a detailed clinical vision of the performances results achieved by the user, on the other it enables the system to adapt and intervene to appropriately choose the setting parameters of the exercises (based on the user's performance) both in the facility and at home (remotely). The possibilities offered by ICT would thus help to configure a real link, a privileged communication channel between doctor and patient, regardless of whether the latter is in the hospital or at his home.

Since users will likely not be experienced in computer technologies, the different interfaces will need to be as flexible and intuitive as possible, to ensure an approach as user friendly as possible to the chosen technology and to the rehabilitation exercises.

Finding sustainable paths for the provision of rehabilitation and training services to patients with chronic diseases and healthy elderly people is surely one of the challenges which health care is likely to face in the coming years. Sustainability carries a double meaning: the clinic, but even more the economic side should be taken into account.

The concept of clinical sustainability is efficient synthesized in the sentence "from curing to caring," which emphasizes the search for higher quality of life of the elderly people conditions at every stage of ageing / diagnostic / therapeutic / rehabilitation.

In a nutshell, the literature highlights the following advantages of using of VR in the field of rehabilitation (Sveistrup, 2004):

- It offers the opportunity to perform the exercises in environments changing over time, with different levels of difficulty, but safe and ecologically sound;
- It allows to maintain the experimental control on the stimuli and enables a measurement of results;
- It offers the opportunity to administer individually “treatments” and with defined objectives, in a functional/ecological and motivating context;
- It offers the opportunity to provide a sense of actual presence and, consequently, the behavior that results is congruous with the situation of the subject in the environment;
- It offers the opportunity to improve the functional abilities of the subjects associated with the execution of graded tasks and increasing complexity;
- It gives a chance to continue treatment in the "private" of own home;
- It gives the chance to monitor and record the results related to the exercises, allows a detailed clinical vision of performance achieved, and allows the doctor to intervene to appropriately set the features/setting parameters of the exercises;
- Multi experiential setting (visual, tactile, auditive) (Weiss e Jessel, 1998; Glantz, Rizzo e Graap, 2003; Zimand et al., 2003; Rizzo, Schultheis, Kerns and Mateer, 2004; Sveistrup, 2004).

An element that must be carefully calibrated and tested is that of the potential side effects. In this regard, the literature identifies two main types of potential side effects: on the one hand the "cybernetic sickness" or “virtual Reality sickness” that basically consists in a sense of nausea, disorientation and dizziness than is commonly assumed associated with a certain sensory inconsistency (Kennedy, Berbaum , and Drexler, 1994); other so-called "after-effects" that include symptoms such as locomotion problems or postural changes, fatigue, perceptual-motor disorders (Rolland, Biocca, Barlow and Kan-Cherla, 1995; DITIO and Lackner, 1992; Kennedy and Stanney, 1996).

Regarding the use of such platforms as they are similar and correlated to the more traditional "systems" of tele-rehabilitation, some further difficulties should also be taken into account (Brennan 2009; RESNA annual conference, 2012):

- Scarcity of reliable evidence (evidence-based) related to:
  - clinical results;
  - actual savings (economic aspects);
  - acceptance of the technology;
  - user satisfaction.
- technological difficulty:
  - integration of functions;
  - "Aesthetic" aspect of the tools, exercises, etc;
  - difficulties in monitoring, analyzing and presenting data.
- As most of nations have yet to implement telemedicine in their health system, there isn’t a unique and shared pricing system for telemedicine
- Organizational changes needed to support the implementation
- Privacy

Table1 - SWOT analysis of VR

Strengths	**Weaknesses**
• greater ecological validity • control and consistency of the stimuli • real-time performance feedback • sequence of stimuli to support learning by doing approach • independent practice and self-guided exploration • contingent changes in the interface to suit the user • complete records performance • Safe training and testing environment • "Game" factor increasing motivation • low-cost environments that can be duplicated and distributed	• first challenge for the interface : interactive methods • Second challenge of the interface: cables and display • not very mature engineering process • platforms compatibility • front-end flexibility • extraction of the back-end data management, analysis, visualization • side effects (cyber sickness)
Opportunities	**Threats**

• first emerging technology: the processing power, graphics and video integration
• second emerging technology: equipment and cables
• third emerging technology: real time data analysis and intelligence
• gaming industry drivers
• virtual rehabilitation with intuitive appeal
• acceptance by academic, professional and scientific community
    • integration of the VR with physiological monitoring and brain imaging
    • tele-rehabilitation
	• little evidence regarding the cost-benefit relationship
	• potential legal threats
	• ethical issues
	• the perception that these technologies can get to replace the medical staff
	• limited awareness
	• unrealistic expectations

Source: authors' elaboration on literature review

3. Definitions, Creating Consensus

There's another aspect to be investigated before we can proceed with the task at hand in this paper. When we are talking about these technologies there is no consensus even at a definitional level since not only ICT technologies have taken a support role in cognitive and motor training only in recent years, but also because this project has interest in a field of ICT that recently caught attention and is building its fundaments right now, rapidly changing and evolving, rendering any attempt to define its shape and parts really challenging.
In the current paragraph we will report some definitions in order to create a shared consensus and an unique interpretation of what will be discussed in this paper.

3.1. Game and training

3.1.1. Game
It's a physical or mental contest, played according to specific rules, with the **goal of amusing** or rewarding the participant. It differs from usual entertainment and content fruition also because it offers and **require an active interaction**. A game represents a structured form of play used for enjoyment. Game have key components such as goals, rules and challenges. Designers put the user interests and motivation in the center of a game design.

3.1.2. Gamification
The application of game design elements or game principle in **non-gaming contexts**, usually **to improve user engagement and commitment**. It uses an empathy-based approach to improve organizational productivity, learning, flow and user evaluation. Gamification aims to emphasize people's desires for learning, mastery, achievement, self expression, altruism, socializing and closure. Different gamification strategies have a reward based design to help engage the users.

3.1.3. Serious game
A game where the **primary goal is different from entertainment** and is usually aimed to educate or train the user toward a desired progress. (from advergames to educational).
Also know as applied game, this kind of games is used by education industry, scientific exploration, health care, planning, engineering, emergency management and even politics to emphasize the added pedagogical value.

3.1.4. Training
It's **an organized process** aimed to **improve** one's capability and **performance** or to help him or her attain a required level of **knowledge or skill.**

3.1.5. Computerized training
A training accessible through the means of a computer system, providing **standardization** in training and performance measurement as well as **typical ICT advantages** as remote access, easy data manipulation and analysis, etc.

3.2. Useful types of games and disambiguation

3.2.1. Electronic game
A game where electronic components are used to build the interactive system. Since today the most common form of electronic games are the video games, the terms are often mistaken.

3.2.2. Video game
An electronic game where the inputs of the user generate a visual feedback on a video display. Video games are electronic games that involves human interaction by using a user interface to generate visual feedback. The systems used to run the games are also known as platforms.

3.2.3. Computer game
A video game played specifically on PC.

3.2.4. Action games
All video games with a fast pace, where hand-eye coordination and reaction time are fundamental and reasoning could have a marginal role (shooting, fighting, platform, etc..).

3.2.5. Exergame
a video game where the interaction is based on body tracking and physical movements and thus result in fitness training when played. Also known as fitness game, they are seen as an evolving from video games.

3.3. Types of Virtual environments and experiences

3.3.1. Virtual Environment/Virtual world
a **computer generated reconstruction** of a real or imaginary setting. It is a computer based simulated

enviroment which presents perceptual stimuli to the users. The users can manipulate the worlds elements in order to experience a degree of presence.

3.3.2. Virtual reality/VR


a virtual environment presented to the user in such a way that the user **suspends disbelief** and accepts it as a real environment. It provides software generated realistic outputs like images, sounds, sensations to replicate an existing environment or a computer generated environment. The user is able to "look inside" the computer generated world and move around it.

3.3.3. Immersive virtual reality


a virtual reality system where the user has the perception of being physically present in a virtual environment (immersion can be cognitive, emotional, tactical, etc.) usually achieved **overtaking sensory inputs**. The immersion is achieved when the user's awareness of physical self can be transformed.

3.3.4. Augmented reality/AR

An augmentation of the usual sensory inputs, where a computer system provides **additional information** by superimposing digitally generated content to the live feed. The additional information can consist of sounds, videos, 2D and 3D graphics containing for example GPS data. In AR, the view or reality is modified by a computer. Augmentation should be in real time and in context with the environment specifications.

3.3.5. Mixed reality/MR

(Hybrid reality) Merging of real and virtual worlds creating a new environment where **physical and virtual objects exist** and interact in real time.

4. Goals of the paper

Moved from the arguments set out in the previous lines (literature review about VR in Health Care), present paper intends to carry out an analysis of VR technologies available on the market in order to identify those with the best conditions of efficiency and effectiveness for the purposes of the defining a platform for cognitive (and motor) rehabilitation and tele-rehabilitation of aged but healthy people.
This paper will mainly focus on three classes of products[2]:

- hardware equipment for the fruition of the VR;
- hardware devices for interaction with the VR;
- the software frameworks necessary for the realization of virtual environments and managing interactions

It should be noted, since now, that there is a strong relation of direct causality between the identified technologies on the first two points in the list above: the methods of interaction with the VR are closely linked to the mode of use made possible by specific technologies.
As a further topic of interest, we found that an analysis of existing solutions may help to better understand what could be produced by this project and better evaluate its value.
This paper will then analyze existing solutions and the proposed exercises for cognitive training in healthy adults.

[2] This project may rely on other technologies for the creation of content and data manipulation and presentation, but these areas fall outside the scope of this paper

5. Research Methodology

In order to answer to the previous research objectives looking for highly advanced technologies in a rapidly expanding and changing market, we cannot ignore the opportunity provided by the virtual space of the Internet: the web is effectively where we can find most of the answers to our questions.
From a methodological point of view, the research has been conducted with a multimethod approach and a 3 step analysis.
In order to improve efficiency and provide a usable answer, at each step certain criteria of inclusion and exclusion are set, and the results from the previous step is used to filter the list of products analyzed in the current step in order to highlight the most valuable one.

5.1. Step 1 – Scouting Phase

5.1.1. Method

This phase was a desk analysis carried out with a massive use of internet in order to collet secondary data. Specialized websites, forums and social networks have allowed to gather important findings which not only relate to technologies already available on the market (in some cases only by a few months or even by a few weeks), but in several cases compared to solutions still in a "prototype" phase that will likely see their approach to the market in the next few months or years.
This research was conducted on the web by manually searching for specific keywords in order to find any possible products.
Once a product has been identified, we collect specification data from the official website and available sources (specialized reviews, user feedback, etc.)

5.1.2. Research parameters

We used a set of keywords that were independent from any class of device and then proceeded to explore search results for class specific keywords.
General keywords: Virtual Reality, VR, Virtual Experience, VR Experience, Next Generation VR, VR games, VR training, VR exercises, VR exergame, Immersive VR
Keywords for the hardware for the fruition of VR: HMD, VR googles, VR view, VR Kit, VR Display, 3D Display, CAVE, VR window
Keywords for the hardware for the interaction with the VR environment: HMD, VR googles, VR view, VR Kit, VR Display, 3D Display, CAVE, VR window, VR interaction
Keywords for the Development framework for VR: 3D environment, game engine, VR game engine, VR environment, VR interactions, VR framework, VR integration, VR IDE, VR capabilities

5.1.3. Exclusion criteria

We decided, given the applied nature of the project, to exclude technologies that **aren't yet on the market** and given the rapidly evolving panorama of the VR to exclude technologies that are **older than 3 years or have been discontinued**.

VR is a newly explored space in ICT technologies and every clue seems to point to high and higher hardware requirements over a due technological adaptation to fully support VR, where the lack of this resources seems to translate in a poor experience with higher incidence of motion sickness. For this very reasons we decided to exclude from the scope of this research all **VR project which rely on middle or low performance hardware, such as smartphone based VR**.

Smartphones devices cannot be used as a normal screen as well since an aged population usually has a declining eyesight and struggles with **smaller screens**

Since this project aims to provide tools for training at the home of the patient horizontal scalability should be economically supportable, therefore we excluded from analysis products whose **cost exceeded** the average of comparable products targeted to **the consumer market.**

Another aspect where we have to set some boundaries is the **physical footprint** of the device, since this project aims to a sustainable home solution, the analyzed product should at least be transportable and adaptable to the home of the users.

5.2. Step 2 – Assessment phase

5.2.1. Method

We conducted a quantitative research based on a questionnaire in order to collect primary data.

5.2.2. Research parameters

Technology assessment carried an undoubted greater complexity: assumed the survey methodology as the only way for the collection and analysis of the factors in objective nature, the definition of the actual parameters to evaluate the technologies was still an open question.

The working group has therefore defined a grid (Table 1)

We asked our sample to provide an evaluation from 0 to 5 on many aspects regarding user, context, development and commercial side of each product.

Table 2 - Questionnaire topics.

Context parameters	Development parameters
Potential for use in clinical purposes	Easy take over
Potential response to the patient's clinical	Development potential

needs	
Customization	Vertical integration
Presence in the Health-Care context	Horizontal integration
User parameters	**Commercial parameters**
User engagement Level	Pricing and Licensing
Ease of use	Scalability
Safe use	Portability
System physical footprint	Vendor evaluation
Setup simplicity	Units sold in the World and Europe
	Vendor national presence
	Future perspectives

5.2.3. Sample

The questionnaire was brought to the attention of a group of experts, 32 responses were collected and while they don't cover the requirements of statistical significance, they delineate a substantial trend line.

The expert participating come from
www.anandtech.com;
www.technologyreview.com;
www.theverge.com;
www.engadget.com;
www.cnet.com;
www.gamespot.com;
www.techradar.com;
www.tomshardware.com;

5.3. Evaluation Phase

After observing the results from the scouting and assessment, we combined them in a general evaluation aimed to better represent possible uses for every specific product.

5.3.1. Method

This step consists of a desk analysis of the results of the previous step producing a prosaic description of devices and software products highlighting their potential and limits.

6. Preliminary results of phase 1 - The Scouting Phase

In the light of the methodology presented in the previous paragraphs, this session will present the results of the first phase of analysis or hardware technologies for fruition of VR, hardware technologies for the interaction with the VR environment and Development framework for VR.

6.1. Hardware devices for the fruition of VR

As first step, the search for technologies has been regarding the identification of devices for the fruition of virtual reality environment.

Except for the normal displays (PC Display, TV, etc.), there are two main class of implementation of immersive VR: Head-Mounted Display (HMD) and Cave automatic virtual environment (CAVE) designed specifically for the fruition of digital content in an immersive context.

The HMD can be simple glasses (goggles) or whole helmets, depending on the technology used and the objectives pursued; Inside an HMD there are one or two displays capable of generating a different image for each eye, thus giving the effect of three-dimensional perception thanks to the projection of a stereoscopic image.

Cave systems use projectors directed towards the walls of a room-sized cube and tracking markers on the head of the user to adjust the images projected to his point of view and position. As previously said this type of systems will be excluded from the paper for its physical footprint and its high cost.

The first example of integrated technologies for the development of an HMD dates back to 1967, when Bell Helicopter accomplished with the successful test in which a pilot could maneuver a helicopter in a night flight based on the images presented to him through a HMD and from a infrared camera mounted under the aircraft. The camera was guided by the same movements of the driver's head, giving him the degree of immersion needed to fly the helicopter.

Nevertheless, it is only very recently that the VR technology on HMD began to point to the consumer market, which is why the technologies mentioned in this paper will be mainly projects started in the past four years, as each previous project failed to meet the constraints of cost (Eg products Sensics) or image quality and immersion required

6.1.1. Parameters for the Analysis of Hardware technologies for the fruition of VR

For this class of devices will be considering some additional parameters:

Field of View (FOV) or viewing angle is an angular expression of the width of the displayed image.

Human vision has a horizontal FOV of 180 °, even if the attention area is reduced to just over 110°.

The more a viewing angle is reduced the more the perceived vision approaches the sensation of looking at a screen in a dark tunnel. A diagonal viewing angle of 35 °

corresponds crudely to fruition on a 24 "screen seen at the distance of 1 meter or a 100", 4 meters away.

Inter Pupillar Distance (IDP): the distance between the center of the right pupil and the one of the left pupil varies from person to person and a HMD must take account of this variation to be able to present the best stereoscopy effect, which is why the majority of HMD provides methods of adjustment of this parameter.

Resolution: The resolution has a significant impact on the perception of quality. It, however, is the least worrying factor given the considerable dynamism of the display market.

Head movement tracking: the application of dedicated sensors that allow tracking of the movements of the head allows to record the changes of angle and orientation and, consequently, the part of the virtual world to which the user turns his gaze: the displayed image is adjusted so as to create the effect of visual exploration of the virtual environment through head movements. Since this feature identify the direction in which the user focuses his attention, it can also be used for the selection of objects in the virtual environment literally just "watching" them, although not with the effect and precision that a Eye tracking sensor could offer. Adapting the image displayed based on the corresponding movement of the head is certainly the most important step towards the immersive fruition, but it can bring disadvantages. The computer system seeks to emulate what would be the human experience, but is inevitably limited in the comparison due to the processing time.

Weight: the weight of a helmet or a pair of glasses can be compromising factors for an effective user experience.

6.1.2. Excluded products

In this phase dedicated to the scouting of technologies the first output coming from the internet environment presented many products. Some of the devices found were extante removed from the analysis because of the exclusion parameters declare in the methodology paragraph.

As for what concerns HMD, we excluded all products for smartphone based VR, from the acclaimed GEAR VR or Zeiss VR One Plus to the economic Google Cardbox as well as all products from secondary brands that have started to appear in shops during the last months the Freefly VR headset, Homido, etc.

CAVE system have been deemed unfit due to their high cost and huge physical footprint.

Some promising project has been excluded since they haven’t yet been released on the market like the Sony Playstation VR which could actually fuel a lot of the VR market despite the compromises in hardware resources.

Another special mention goes to Sulon Q VR who promises to bring the computational power need for a primary VR/AR experience directly into the headset removing the need for a supporting pc or cables that should see commercial release next year.

FOVE VR is another interesting project excluded because yet to be seen on the market. This project focus is on eye tracking inside an HMD delivering precise information about the user attention moving to more natural and immediate form of interaction with the VR environment.

Many like Epson BT-300, Vuzix M300 have yet to complete the iteration cycle, others have seen their release date postponed year after year, through iterations of dev-kits, and have yet to find a spot on the market, even if they seem so close to it, like Meta VR (Meta 2), Atheer ONE, CastAR, GlassUP, etc..

We also excluded discontinued products like the Dev Kits for nowadays commercially available devices (OCULUS DEV kit 1 and 2, VIVE pre kit, etc.) as well as previous discontinued iterations (Meta.1, Google Glasses)

6.1.3. Scouting results

The table below shows the specifications of the products available according to the previously mentioned parameters.

	Company	Edition	Official Website
Oculus Rift VR	Oculus	RIFT VR	oculusvr.com
HTC VIVE	HTC	VIVE	htcvive.com
Epson BT-200	Epson	BT- BT-200	epson.com/...
Avegant Glyph	Avegant	Glyph	avegant.com
Vuzix M100 smart Glasses	Vuzix	M100	vuzix.com/...
OSVR HDK 2	Razer	HDK2	osvr.com/...
Traditional Display	-	-	-
Tablet	-	-	-

	Price	Development Phase	Release date
Oculus Rift VR	$599,00	Produzione	March 2016
HTC VIVE	$899,00	Produzione	April 2016
Epson BT-200	$699,00	Produzione	March 2014
Avegant Glyph	$699,00	Produzione	March 2016
Vuzix M100 smart Glasses	€1079,00	Produzione	2014
OSVR HDK 2	€399	Beta	July 2016
Traditional Display	€150-€10000	-	-
Tablet	€100-€2000	-	-

	Augmented Reality (AR)	Virtual Reality (VR)	See-Through	Weight	IDP
Oculus Rift VR	No	Yes	No	470g	Yes (digital)

HTC VIVE	No	Yes, obscured lenses.	Yes.	555g	Yes (digital)
Epson BT-200	Yes	No	Yes		-
Avegant Glyph	No	Yes	No	434g	Yes(56mm 69mm)
Vuzix M100 smart Glasses	Yes	No	Yes	371g	-
OSVR HDK 2	No	Yes	No	-	Yes(digital)

	Field of View (FOV) (Gradi diagonali)	Resolution	Display Panel technolgy	Smartphones connectivity	PC connectivity	Ports and connections
Oculus Rift VR	110°	2160x1200	OLED	No	Yes	DVI/HDMI e USB
HTC VIVE	110°	2160x1200	OLED	No	Yes	DVI/HDMI e USB
Epson BT-200	23°	960x540	Micro Projectors: LED LCoS	No	No Only to copy files	USB, WiFi, Bluetooth
Avegant Glyph	45°	1280x800	Micro Projectors: 3-LED DLP	Yes MHL/HDMI	Yes	MHL/HDMI
Vuzix M100 smart Glasses	15°	480×272 (per eye)	Micro Projectors	Yes	Yes	WiFi and Bluetooth
OSVR HDK 2	110°	2160x1200	OLED Dual display	Yes	Yes	HDMI

	Videocamera frontale	Head rotation tracking	Position tracking	Include CPU/Processor
Oculus Rift VR	No	Yes (IR Camera, gyroscope, compass)	Yes (IR Camera)	No
HTC VIVE	Yes	No	No	No
Epson BT-200	Yes	Yes (gyroscope, compass)	Yes (accelerometer, GPS)	Yes 1.2Ghz dual core

Avegant Glyph	No	Yes	Yes	No
Vuzix M100 smart Glasses	Yes	Yes (gyroscope, compass)	Yes (accelerometer)	Yes 1.2Ghz dual core
OSVR HDK 2	No	Yes	Yes	No

We added ssome editorial notes to provided specific comments about the scouted products

	Notes
Oculus Rift VR	Being Oculus the company that started the VR Hype back in 2012, and now backed by a colossal business network like the one of Facebook, its first commercial products represents the fruit of avanguard research and it represents a standard de facto that every stakeholder of theVR market must confront with.
HTC VIVE	HTC VIVE has been the first commercial product not only able take its spot in a market previously dominated by Oculus, but in many cases even to outshine Oculus itself, gaining traction and subtracting fans and supporters to its direct rival
Epson BT-200	A wireless device with a battery for up to 6h of use
Avegant Glyph	Virtual Retina Display is actually made by projecting light into the eye, to simulate a natural vision
Vuzix M100 smart Glasses	-
OSVR HDK 2	Being an open source device, even if its hardware and maturity can't compete with colossal rivals like HTC or OCULUS, it offers unprecedented possibilities of development

6.2. Hardware Devices for interaction with the VR environment

Since the investigated therapeutic method requires direct interaction with the VR to leverage the immersive aspect, such interaction should be linked to the training actions and then offer methods for tracking and monitor such action.
Since the digital contents are managed by a computer, various devices can be used for input interaction with the proposed virtual reality (Eg mouse and keyboard,) but the purpose of this study is to identify those devices able to ensure a natural interaction via the direct tracking of the movements of the body, so as to enhance the possible actions in a neuromotor training program.

Devices for the tracking of the movements of the body for interaction with digital content are already present in the consumer market, but only recently the market has seen the need for their use within a virtual reality environment, mainly because of the recent developments in 'field of HMD dedicated to video gaming.
Therefore, since this need only recently appeared in the consumer market, the supply side is mainly represented by optical tracking devices, typically operating with a combination of normal video images and infrared images; By contrast, the much more precise and expensive technologies where the body of the tracking is delegated to the sensors on the user's body have so far linked to the professional environment, with particular utility in the Health Care and in film production.
The devices based on optical sensors use infrared to obtain information about the depth of field; subsequently, by combining this information with a normal video stream it is able to identify objects in the visual field and their position relative to the tracker.
Usually these systems are accompanied by a support framework that provides advanced features for analysis and interpretation of the object in the field of view, such as the user recognition and in more advanced cases even voice recognition, facial expressions and so on.
Projects that use wearable sensors to track body movements and are dedicated to the consumer market are still very young projects, mostly born between 2014 and 2015, and, therefore, if they are already available, they are still too immature to be able to support the main therapeutic task and offer the flexibility and development potential necessary for this project.
Obviously they will be a competitive choice in a few years or even a few months, but the fact that none of these recent projects have yet reached the stage of production and attained a wide acceptance by users and the incredible novelty of this slice of the market makes it extremely dynamic and unpredictable.

6.2.1. Parameters for the Analysis of Hardware technologies for the interaction with a VR environment

To better analyze this class of devices we are introducing the following measurement parameters:
Tracking area or space: The physical space in which the tracking functionality operates. In the case of optical devices where the detection is achieved with a camera this parameter is indicated by the angular width of vision and minimum and maximum distance from the lens.
Number and type of sensors: The quality and the redundancy of detection systems constitute quality index of the data detected as well as an expression of its accuracy

6.2.2. Excluded products

As happened in the previous class of devices some very promising technologies has seen their release date pushed forward, year after year, like the prioVR wearable tracking system others have better defined their target exiting completely from the consumer market to favour the accuracy and value of data from tracking (like Notch VR from Xsens). This kind of tracking system expand up to extremely sophisticated room scale solutions for body tracking that are also used in Health care but exceed by far economic boundaries set by this project.

6.2.3. Scouting results

	Company	**Edition**	**Official Website**
Leap Motion	Leap Motion	Leap Motion Controller	leapmotion.com
Creative SENZ3D	Creative	SENZ3D	creative.com/...
MS Kinect	Microsoft	Kinect for Windows	microsoft.com/...
Razer Hydra	Razer	Hydra	Minisite razer.com/..
SoftKinetic DS525	SoftKinetic	DS525	softkinetic.com/...
VIVE Controller	HTC	VIVE bundle	htcvive.com
Smartphone	-	-	-
Tablet	-	-	-

		Range of interaction
Leap Motion Controller		Semisferica circa 0.22m^3 sopra il dispositivo
SENZ3D		72° HFOV 54° VFOV 15 – 100cm
Kinect		57° HFOV 43°VFOV 50cm-400cm

Hydra		30cm – 100cm
DS325		72° HFOV 54° VFOV 15 – 100cm
VIVE Controller		3,3mx3,3m
Smartphone		Wireless connection range

	Year of release	**Price**	**Sensors**
Leap Motion Controller	2013	€ 100,00	2 cameras
SENZ3D	2013	€ 200,00	2 cameras (1280x720 + 320x240 IR) 1 array con 2 microfoni
Kinect 2	15 July 2014	€ 250,00	2 cameras (1280x720 + 320x240 IR) 1 array con 2 microfoni
Hydra	2013	$ 150,00	Magnetic sensor
SoftKinetic DS525	2015	$ 149,00	2 cameras(1280x720 + 320x240 IR) 1 array with 2 microphones

VIVE Controller	2016	Bundle with HMD 899€	2 laser lighthouses provide full tracking of the controller movements and buttons.
Smartphone	-	€100,00€1000,00	Accelerometer, gyroscope, compass, GPS, touchscreen display
Tablet		€100-€2000	Accelerometer, gyroscope, compass, GPS, touchscreen display

6.3. Development Framework for VR

This chapter will analyze the 3D game engines available on the market.
The definition of Game engine is not so strict and generally define a software framework and a collection of tools whose ultimate goal is to provide functionality to develop a video game.
A game engine aims to provide a foundation of reusable functions, whether they are related to rendering, sound, animation, network connections, etc.

6.3.1. Parameters for the Analysis of development frameworks for VR

This chapter will focus mainly on the set of tools and associated framework of the evaluated Game Engines, since the set of features offered can vary according to the Software Development Kit (SDK) associated with the particular engine.
The presence of associated software development tools simplifies and speeds up the work especially in the presence of a software Integrated Development Environment (IDE), which offers all the functionalities and tools of the framework in a single GUI interface.
In this study we will analyze engine game with 3D capabilities, or those frameworks that can be integrated into a virtual reality project.
Although it would be possible to potentially develop the integration between two systems where missing, the availability of existing solutions on the market with devices of the previous classes and their degree of integration would mean a decisive factor in choosing a developing solution.

6.3.2. Excluded products

In this class of products there is a main limiting factors, cost and available resources.
Obviously we must contain costs and we cannot afford framework and tools aimed at professional game content creators who aim to earn from that activity. This exclude from use some notable name like UNREAL Engine and CRYEngine that represent the top tier in graphics quality on the market.

6.3.3. Scouting results

We added some editorial notes to provided specific comments about the scouted products

Product	Producer	Notes
Unreal Development Kit (UDK)	Epic Games	This software supports 3D development and has an SDK that is suited to the desired development of this project.
Unity Pro	Unity Technologies	This software supports 3D development and has an SDK that is suited to the desired development of this project.
Torque 3D	GarageGames	This software supports 3D development and has an SDK that is suited to the desired development of this project

7. Preliminary results of phase 2 - The Assessment Phase

7.1. Hardware devices for the fruition of VR

After the scouting phase a selection has been made according to the information found and the following devices have been eliminated

- **Epson BT-200 –** This device is actually better suited for noninvasive AR and poorly relatesd to the project
- **Avegant Glyph–** Its use may be better suited for entertainment and movies
- **Vuzix M100 smart Glasses -** Its use may be better suited for noninvasive AR and poorly relates to the project

	Traditional Display	Tablet	Oculus rift	HTC vive	OSVR HDK2
Context parameters					
Potential for use in clinical purposes	3	3	4	4	4
Potential response to the patient's clinical needs	2	2	3	3	3
Customization	2	2	3	3	3
Presence in the Health-Care context	4	3	1	0	0
User parameters					
Ease of use	4	4	3	3	3
Safe use	4	4	2	2	2
System physical footprint	2	2	3	3	3
Setup simplicity	4	4	3	3	3
User engagement level	1	2	4	4	4
Development parameters					
Easy take over	4	4	4	4	4
Development potential	4	4	4	4	4
Vertical integration	4	4	4	4	4
Horizontal integration	1	1	1	1	1
Commercial parameters					
Pricing and Licensing	4	4	3	3	4
Scalability	3	3	4	4	3
Portability	4	4	3	3	4
Vendor evaluation	NA	NA	4	3	NA
Vendor national presence	4	4	NA	NA	NA
Future perspectives	4	4	4	3	2
	3.05	**3.05**	**3.00**	2.84	2.68

7.2. Hardware Devices for interaction with the VR environment

No device was filtered after the scouting phase

	Gamepad tradizionali	Sens3D	SoftKinetic DS325	Microsoft for Kinect	Leap Motion	Razer Hydra	Smartphone	Tablet	VIVE controller
Context parameters									
Potential for use in clinical purposes	2	2	2	4	3	1	2	2	1
Potential response to the patient's clinical needs	0	2	2	3	2	1	0	1	1
Customization	3	3	3	3	0	3	4	4	2
Presence in the Health-Care context	0	0	0	3	0	0	1	1	0
User parameters									
Ease of use	2	3	3	3	4	2	3	3	2
Safe use	4	4	4	3	4	4	4	4	4
System physical footprint	3	4	4	3	4	2	4	4	2
Setup simplicity	4	4	4	4	4	3	4	4	3
User engagement level	1	3	3	4	2	2	0	0	2
Development parameters									
Easy take over	4	4	4	4	4	4	4	4	4
Development potential	4	3	3	4	3	2	4	4	4
Vertical integration	4	4	4	4	4	4	4	4	4
Horizontal integration	3	3	3	4	3	4	4	4	4
Commercial parameters									
Pricing and Licensing	4	3	3	3	4	3	4	4	2
Scalability	4	NA	NA	3	NA	NA	4	4	NA
Portability	4	3	3	2	4	1	4	4	2
Vendor evaluation	NA	4	3	4	2	3	NA	NA	NA
Vendor national presence	NA	4	NA	4	NA	2	NA	NA	NA
Future perspectives	4	3	3	4	2	2	4	4	3
	2.63	**2.95**	**2.68**	**3.47**	**2.58**	**2.26**	**2.84**	**2.89**	**2.11**

7.3. Development Framework for VR

No product was filtered after the scouting phase

	Unity Pro	UDK	Torque 3D
Context parameters			
Potential for use in clinical purposes	NA	NA	NA
Potential response to the patient's clinical needs	NA	NA	NA
Customization	NA	NA	NA
Presence in the Health-Care context	NA	NA	NA
User parameters			
Ease of use	NA	NA	NA
Safe use	NA	NA	NA
System physical footprint	NA	NA	NA
Setup simplicity	NA	NA	NA
User engagement level	NA	NA	NA
Development parameters			
Easy take over	3	3	3
Development potential	4	3	2
Vertical integration	4	4	4
Horizontal integration	3	3	3
Commercial parameters			
Pricing and Licensing	3	3	4
Scalability	3	3	3
Portability	4	3	4
Vendor evaluation	3	3	2
Vendor national presence	NA	NA	NA
Future perspectives	4	3	2

8. Preliminary results of phase 3 - The Evaluation Phase

8.1. Hardware devices for the fruition of VR

8.1.1. PC Display/ 3D TV

In addition to the devices for immersive fruition of a virtual environment, this study also examines the possibility to deploy on conventional screens.

With a normal display or a 3D television the limited viewing angle remains a debatable point, undermining at least partially the immersive aspect of VR, but for this avoiding every safety complication related to the immersion. Nevertheless, this technology remains the most convenient in terms of availability and this is a safe choice on which to rely for a fast spread of the therapeutic practice.

Since the display technology is widespread and widely developed, any choice of a display panel should be considered acceptable.

8.1.2. Tablets

Although tablets push the limits of the screen size to its lower boundaries for the scope of this project and do not provide acceptable hardware for being an head mounted display, they do some particular advantages that could bring a solution to the problem of VR.

Being able to adapt the projected image based on the information given by its sensors, and being a handheld device, tablets could prove to be a decisive solution for VR using them as actual orientable Windows to look into the virtual environment (Window On World). In this situation the user would have complete control on its physical surrounding, simply moving the tablet around and being an non immersive experience, it removes many safety and motion sickness problem from consideration.

Furthermore, tablets rely on a touch interface system, giving the possibility to adapt and redesign the interactions controls over time.

These motivations and the actual high availability and diffusion of tablets could configure it as a winning solution even if not usually associated with the exploration of VR.

8.1.3. Oculus Rift

Oculus is the company that started to attract interest on the VR in videogames with its HMD project released to Developers back in 2013.

It currently maintains a very important role in the development of this new and rapidly changing market.

Oculus released the first consumer version of their HMD in March 2016 after two DevKit iterations that served as base platform for many developers and companies to invest in this product, creating the right settings for an extensive user base and documentation, on a relatively novel niche product.

Oculus Rift offers an OLED Display with a 2160x1200 resolution with a 90Hz refresh rate and 110° of FOV.

Since its second iteration Oculus provides its HMD with position tracking in addition to rotation, with a single IR tracking camera which is capable to track an area of 1,5m x 3,3m.
Oculus developers seems to be oriented to a seated experience since the technologies offered at the moment aren't considered enough to grant a safe and engaging experience.
Oculus is set out to offer the best and most immersive experience but to be able to achieve the quality required, the operating computer must have quite advanced specifications to meet the requirements set for the experience.
Oculus offers also a paired controller called oculus touch, sold separately.

8.1.4. HTC Vive
HTC is HTC is the main competitor of Oculus Rift and tackles the Virtual reality immersion from another point of action.
While offering the same specification of hardware such an OLED display of 2160x1200@90Hz resolution, it does require a little more advanced hardware than the rift, while user feedback seems to suggest the quality of the image is inferior to the one of the Oculus Rift.
HTC sees the VR experience as dynamic and as interactive as possible moving its attention to the user instead that on the pure VR experience.
Focusing its attention on the user and its environment, HTC offers tracking capabilities on an area of 3,3x3,3m, performed by two laser-based Lighthouse stations, creating the definition of "room-scale VR" where the actions and movements inside the VR environment can be tracked throughout a room.
HTC tackled the safety problem of a room scale VR experience including a front facing camera which offer limited visibility of the surrounding environment.
HTC offers also an included set of two interaction controllers one for each hand.

8.2. Hardware Devices for interaction with the VR environment

8.2.1. Traditional Gamepad
A Gamepad is a device designed for interaction with video games, which in most cases are set in VR environments. Traditional gamepads are those devices without motion or acceleration sensors, with analog controls (joystick and pressure sensitive lever or buttons) and digital (buttons).
These devices have a high availability and low cost for the interaction with a VR; they, however, would need specific training and offer no way to track user action and movements.

8.2.2. Leap Motion Controller
Leap Motion controller is a device for interaction with VR, in particular for the handling of maps and 3D objects. It is consisting of a small rectangular block (10cm x 3cm) with its tracking space is an hemisphere of about 60cm of radius.

Leap Motion offers extreme precision in the detection of the hand and, consequently, of the semantically charged movements called gestures; tracking, however, stops with the hands and offers no support for the body or the face, also due to the strongly limited scope.
Leap Motion provides support for Windows and MacOSX platforms as well as a comprehensive development framework and an online market dedicated to assist developers. On the side note, leap motion does not allow access to the raw tracking data, which could be compromising for future developments.
The small size and ease of transport and setup make it suitable for use at home, the price makes it an extremely competitive object, but in spite of its features make it perfect for hand rehabilitation operations, its ability to tracking are too poor to give full support to a complete VR experience.
LeapMotion become a exceptional object when paired with oculus rift, offering the ability to track hand movements in VR with extreme precision and allowing for a natural interaction with the VR environment.

8.2.3. SENZ3D Creative

The reference product is the SENZ3D webcam developed by Creative in collaboration with Intel under the Intel Perceptual Computing program.
It is a device equipped with optical sensors coupling normal video with infrared to provide information on the depth.
This system is proposed as a demonstration of the potential offered by Intel Perceptual Computing SDK 2013, a project in which Intel has invested heavily over the past three years.
Intel wants to introduce the natural interaction interface with digital content, and therefore concentrates its efforts on a framework of development associated to different hardware products, offering support for speech recognition, as well as for body tracking, facial and gesture recognition.
In addition to advanced features, Intel gives developers full control of raw tracking data, which would be useful for the clinical analysis; the speech recognition engine is reliant on the technology behind Dragon Naturally Speaking produced by Nuance, leaders of the speech recognition industry, offering more than commendable performance.
Intel has also invested heavily in body and face tracking, being now able to offer recognition of gestures and facial expressions through appropriate hardware. Age and sex estimation are made possible by the powerful SDK, which offers support for popular development frameworks such as Processing, Unity and Open Framework.
Being part of a larger program, Senz3D remains competitive in terms of price while providing a wide range of functionality. Unfortunately, however, this one's strength also remains its limit: being, in fact, designed for interaction with a PC, failing to provide adequate tracking space of the movements required for a VR Experience.

8.2.4. SoftKinetic DS325

This webcam produced by Softkinetic is a duplicate entry of the Senz3D Creative camera, as both are based on the same hardware, they are sold at the same price and refer to Intel Software for the part thanks to the 'Intel Perceptual Computing SDK 2013

The following table shows the characteristics of the product, but they are worth the same feedback of Senz3D regarding advantages and disadvantages.

8.2.5. Microsoft Kinect

Microsoft Kinect is a mature product that has already seen an extensive development in both software and hardware.

This device was created for tracking the position and movements of the entire body of the user, with the purpose of using such information for interacting with a digital projection, often a virtual reality, which makes it the ideal companion for a project of neuro-motor training.

The Kinect for Windows SDK Framework provides access to the raw collected data and a set of predefined actions (gestures) and advanced controls, such as the direct control of a cursor on any screen, the recognition of facial expressions and skeletal tracking.

The maturity of the associated development Framework makes this product even more attractive because of its flexibility and ease of development. Moreover, the longevity and the dominant role in the market ensure the integration support with leading development Framework.

The system allows a simple instant scalability to trace multiple users at once, or to obtain an even wider tracking: at the moment a single Kinect sensor can track the movements of six players at once, but only two in detail.

Compared to its competitors, the resolution of the Kinect sensor is not particularly high in the current version and this, coupled with the wide range of action, makes it difficult to individually track the fingers of one hand.

Kinect is supported on MacOSX and Linux systems using open source toolkits, but to access the full range of listed tools and functionalities Microsoft SDK should be used and it is currently only supported by Windows 7, Windows 8 and Windows 10.

The second version of the Kinect sensor dramatically improves the performance of the sensors and the functionality compared to the previous version.

This version, in fact, has the potential for a much broader set of functionalities, ranging from facial expression recognition to the ability to operate in the dark, a new skeletal tracking for its ability to trace the rotation and twist of the limbs, the weight distribution and heart rate, but many of them are yet to be provided by the new SDK.

8.2.6. Razer Hydra

Razer Hydra represented a completely innovative approach to interaction with virtual reality, reinventing the gamepad controller and adapting it for use with both hands with position tracking technology and was the first to provide such concept.

Hydra relies on two controllers for a direct manipulation by the user for interaction both via the controller and buttons, for tracking of hands movement, to which the absolute positions in space of the two controllers is associated. All this makes it a suitable tool for the exploration of virtual worlds in first person view, where the Point OF View (POV) is exactly in sync with what the virtual character would view and the main interactions are managed via hands.
Anotehr great innovation brought by Hydra regards the detection system which is based on a magnetic system able to offer an incredibly low latency and the precise and direct estimation of the absolute position and orientation without having to resort to the combination of field depth IR and video 2d, as happens instead for the optical sensors mentioned previously.
Sixens SDK is the reference framework for developing applications that support interactions via Hydra; This framework is mature enough and allows integration with Unity.
Unfortunately for the poor craftsmanship of patients considered for this therapeutic process and the limitations of detection to one position of the hands, Hydra does not provide a solution to a full suite of neuro-motor rehabilitation.

8.2.7. Smartphone

Smartphones have now become widespread in the population and represent a highly available resource.
These computing devices bring with them an always increasing computational power and an LCD touch screen (thus an interface reconfigurable depending on the needs of the patient or the application) and the information carried by the internal accelerometer and 3-axis gyroscope that make it suitable device for movements tracking and / or only as an input tool.
Their purpose in a project dedicated to training through an immersive VR experience may be to provide an input device for movement in the 3D environment and / or for interaction with the exercises provided inside the VR environment.

8.2.8. Tablets

As for tablets, they bring all advantages of smartphones but, offering a greater area of interaction they offer the possibility to show custom control as well as the scene projected.
The possibility to provide a dynamic and custom interaction interface, is one of the tablet greatest strengths from the point of view of this class of devices

8.3. Development Framework for VR

8.3.1. Unreal Engine Development Kit (UDK)

Unreal offers Unreal Engine 4 Game Development Tools, commonly called UDK, a suite of software for developing Virtual environments for games with UnReal Engine 4 that offers support for oculus at a price ranging from € 100 to € 2,500 depending on the number of developers and the type of license (internal or per seat).

This engine is stable and reliable, it reached a full maturity with his 16 years and his four versions, providing a high-quality graphics, but its strength remains its IDE with an extremely user friendly and easy to navigate interface and a very powerful tools thanks to so many features implemented.
Unreal Engine has developed its own programming language that exceeds the scripting logics, and comes to object-oriented programming, with the resulting benefits of the case, but it requires a restart of UDK for each compilation inexorably slowing the workflow in development. The actual time spent writing code is, however, less extensive compared to its competitors due to the extensive library of features its IDE acquired thanks to its maturity.
UDK provides examples of integration with oculus, 3D televisions and 3d frame packing as well as support for MS Kinect.
The great minus of this engine and that this tool remains very oriented to PC platform and to the development of a First Person Shooter mode, perhaps making it difficult to deviate from this mode, limiting the potential development.

8.3.2. Unity

Presented in 2005, Unity is a relatively new graphics engine that focuses on performance and portability on any type of device, without excluding the mobile market share represented by tablets and smartphones.
Although targeting devices with limited computational capabilities should lead to less attention to graphics, Unity3D, even if it cannot match the quality offered by UDK on PC, remains largely good quality in this respect.
Its young age, reflected in the minimalist IDE, is compensated by a very stocked Asset Store maintained directly by Unity, as well as a powerful support for the C # Scripting, UnityScript (modeled on Javascript) and Boo (a .NET language like Python) through which ensures total functionality and versatility and a full control on the scene and interactions, facilitating the introduction of developers with previous experience.
Unity supports any type of 3D output, and is the predominant choice for the development of applications for the recent HMDs.
Prices for Pro licenses are € 1,500.00 for each type of target device (Windows + Android would cost € 3,000.00).

8.3.3. Torque 3D

Torque is a 3D graphic engine born in 2001 for First-Person Shooter videogames.
The strength of 3D Torque is the fact that it is entirely open source licensed under the MIT license, which allows access at no cost to the development potential of a complete GameEngine, which is why it has been for many years the point of reference for independent developers.
It provides an editor of virtual environments, solid physics and lights systems as well as the ability to publish on almost all available platforms.
The main advantage of being an open source platform, it's the access to the source code of Engine. This has meant that over time the user needs were fulfilled by the community itself,

in fact Torque supports Oculus Rift VR and other 3D devices-through frame-packing, and also MS Kinects finds space in the panorama of Torque3D integrations.
The main disadvantage of Torque3D is the age of the actual engine whose community failed to properly upgrade and update to keep up with emerging technologies and hardware, consequently undermining the quality of achievable graphics. Moreover, the lack of a business plan of the product seems to cast doubt on the real potential for the future.

9. Comparable solutions

This contribution aims at constituting a base reference regarding the description of the global available offer on the market in terms of evaluation in healthcare contexts.
Products that can be used for neuro-psychologic training and for quality of life improvement for the elderly can be summarized in three different categories.

9.1. Existing solutions

9.1.1. Clinical products

This category comprises those products that are developed to be used in the context of systematic treatment interventions: in other words, they are based ICT and VR providing support to the therapeutic approach that is employed while addressing specific pathologies or disabilities. So, such applications usually do not reach the market as commercial products, rather their use is restricted among the limited customer base of health professionals (clinical psychologists, physicians, nurses). Therefore, users often need specific and professional training in order to be able to proficiently and properly use the applications.
Notable examples that, differently, reached a commercial phase are **CAREN by Motekforce** (https://www.motekforcelink.com/product/caren/) for VR motor rehabilitation or **Cognuse** (http://cognuse.com/), **Neuro@Home** (http://www.neuroathome.com/en/) and the very same **MediaHospital** (www.mediahospital.com) as examples of traditional computerized training.

9.1.2. Neuro training

The "Neuro training" category regards those VR applications and/or ICTs for the training of cognitive abilities that can be used by the trainee without a continuous support by the health provider. Generally, such technologies abstain to formally express the intention to provide an effective therapeutic effect. These platforms mostly rely on the mobile market targeting smartphones and tablets and usually also PC, and they offer a dedicated and personal path of training, through the log of user activities and progress.
There are many notable names in this category and each has its currently expanding user base; for what regards cognitive empowerment, it is possible to cite **Lumosity** (https://www.lumosity.com/), **Peak** (http://www.peak.net/), **Elevate** (https://www.elevateapp.com), **NeuroNation** (http://www.neuronation.com/), **FitBrains** (http://www.fitbrains.com/), **Kognitivo** (http://cheparev.com/kognitivo-challenge-your-brain/), **BrainWell** (https://www.brainwell.com/), **Coachme** (https://www.coach.me/), etc.

9.1.3. General training with non-specific games and activities

Most of the offer available to the end user is constituted of single applications and games that can be used to train both motor and cognitive skills, and track its health state through time.

Such solutions are not specifically aimed at providing some sort of training program, rather they are devoted to promote an engaging experience and therefore usually defer to the user the complete control over its own actions and training choices, as well as the responsibility to track and monitor its own performance and health status, in order to understand the benefits of its own current experience. This category comprises the broad world of technologies for "patient engagement", namely those technologies that help a patient to be first-person involved in his own care management (e.g., digital scheduling of treatment to better adhere to the therapy; dedicated telecommunication systems to improve patient-doctor communication; etc.).

There are many examples of this kind of application and some even rely on 3D environment such as

RehabCity (https://play.google.com/store/apps/details?id=com.NeuroRehabLab.RehabCity&),

many of them provide the user with games and tasks to complete in a more traditional game setting such as

memoryGames (https://play.google.com/store/apps/details?id=id.imajlismobile.memorygamestraining),

BrainGames (https://play.google.com/store/apps/details?id=jalfonso.brain.games),

Brain workout (https://play.google.com/store/apps/details?id=link.workoutbrain),

MathWorkout (https://play.google.com/store/apps/details?id=com.akbur.mathsworkout),

etc.

or more commercial games like

aa (https://play.google.com/store/apps/details?id=com.aa.generaladaptiveapps)

and all applications from their creators

General Adaptive Apps Ltd (https://play.google.com/store/apps/dev?id=5287980258369385464),

Color Speed Tap (https://play.google.com/store/apps/details?id=com.SallyAndStang.ColorTap),

Transmission (https://play.google.com/store/apps/details?id=com.lojugames.games.transmission),

Unblock King (https://play.google.com/store/apps/details?id=com.mobirix.slideking),

Interlocked (https://play.google.com/store/apps/details?id=com.wecreatestuff.interlocked),

Brain Dots (https://play.google.com/store/apps/details?id=jp.co.translimit.braindots),

Brain it on (https://play.google.com/store/apps/details?id=com.orbital.brainiton),

Flow free (https://play.google.com/store/apps/details?id=com.bigduckgames.flow),

Piano Tiles 2 (https://play.google.com/store/apps/details?id=com.cmplay.tiles2),

Chrooma (https://play.google.com/store/apps/details?id=com.gamelounge.chrooma.android),

etc.

9.2. Neuro training approach in healthy adults

Simulating and training cognitive processes in the context of an active ageing approach is easily linked to the concept of *empowerment*. According to Antonietti and colleagues

(Antonietti, Balconi, Catellani, & Marchetti, 2014), empowerment has four fundamental objectives:

- helping the elderly to maintain their current levels of mental functioning as high as possible;
- preventing possible decay in their skills;
- coping with adverse events experiences;
- exploiting the possible latent resources.

For this reason, although the complex notion of active ageing does not refer to motor or cognitive abilities only (social/cultural participation and one's own life management are important too), numerous studies and technologies were developed in order to support the healthy elderly to preserve and improve their cognitive abilities. Indeed, some cognitive abilities are usually maintained unaltered during physiological ageing, while others are at risk of decline/impairment, or better *vulnerable*: those are marked with the V letter in the next list (Boulton-Lewis, 2010; Horn & Hofer, 1992):

- knowledge derived from acculturation;
- fluency of retrieval of knowledge;
- visualizing capabilities;
- auditory capabilities;
- quantitative capabilities;
- reasoning capabilities (V);
- processes of maintaining immediate awareness (V);
- processes in speed of apprehension (V);
- processes for quickly arriving at decisions or decision making (V).

9.2.1. Examples of Memory exercises:

Pinball Recall (Lumosity) you have to memorize the bumpers, which briefly appear on the screen, to predict the ball's path and tap where the ball will exit. (Working Memory)

In *Memory Matrix* (Lumosity) a pattern of tiles briefly appears in the grid. You have to remember the pattern and recreate the pattern by tapping the correct tiles. (Spatial Recall)

In the game *Memory recall* (Freebrainagegames) you have to click on the buck balls that you see light up in the order that they appear (Memory recall)

9.2.2. Examples of Attention exercises:

In *Lost in Migration* (Lumosity) a flock of birds appear on the screen; you have to swipe in the direction the middle bird is facing, without letting the direction of the other birds distract you (Selective attention)

The goal of *Train of Thought* (Lumosity)*t* is to switch the tracks to get the colored train in the station of the appropriate color. (Divided attention)

In *Eagle Eye* (Lumosity) you have to pay attention to multiple things at the exact same time; a number will appear in the box at the center of the screen, and a picture of a bird will also appear elsewhere on the screen. You are supposed to move your camera mouse pointer to

where the bird was and click. Then, a new screen will come up with a list of five numbers. You need to hit the letter which you saw in the center square. (Field of view)
In *Stroo* (Freebrainagegames) you test your ability to focus while processing information; you have to name the color of the word, (not the name of the word). This game is a variation on the famous Stroop effect. (Attention)

9.2.3. Examples of exercises for cognitive processing speed:
Speed Match (Lumosity) in which you have to determine whether each card is the same as the last one. (Information Processing)

Spatial Speed Match (Lumosity) it is similar to the previous one except it has three circles and you have to guess if the blue dot is on the same circle as it was in the previous match) (Information Processing)

Speed Match Overdrive (Lumosity) is an advanced and harder version of *Speed Match*. This introduces the method of knowing if the current shape or color of shape matches the one shown on the previous card. (Information Processing)
In the game *Reaction pounce* (Freebrainagegames) you have to click on as many yellow icosahedrons as can in 30 seconds (Reaction time)

9.2.4. Examples of exercises for Reasoning and decision making
The object of *by The Rules* (Lumosity) *is* to figure out the hidden rule by sorting cards according to their shape, color or other properties. You start by making an initial guess, then you try to figure out the hidden rule through a process of elimination.

In *Raindrops* (Lumosity) you have solve math problems written on the drops before they hit the water. (Numerical Calculation)

In *Pet Detective* (Lumosity) you have to find out the best way to complete the task (returning pets to their houses) observing a defined number of moves(Planning)

Examples of exercises for spatial cognition
The game *Visual Blink* (Freebrainagegames) tests how good you are at spotting the difference between two images that appear on the screen one after the other (visual cognition)

10. Conclusions and indications.

The present paper has the objective to identify available technologies on the market on order to create a rehabilitation platform for healthy aged people.

According to the first part of this paper Authors found that in the literature review VR starts to become a topic of interest also for health care purposes.

The interest of protectionists in VR as an instrument for rehabilitation starts to exists, nonetheless the literature review highlights some open questions related to the effective use of VR in rehabilitation approaches.

A SWOT analysis has been presented in the first part of the document that underlines threats and opportunity coming from the health care system that have not still found matching with strengths and weaknesses.

Starting from those considerations the paper shifted to the core objective. Thanks to a mixed methodology (desk analysis, quantitative research), Authors proceeded in scouting the technologies for the fruition, interaction and creation of a Virtual Reality Environment.

Some keywords (See sections 6.1.2) and parameters (See sections 7.1.1, 7.2.1 and 7.3.1) have been identified in order to screen the huge number of possible alternatives.

A cut of the technologies found has been deemed not suited for this project thanks to restrains set by the Exclusion parameters.

For what concerns the hardware technologies for the fruition of Virtual Reality Oculus Rift seems to the most promising hardware for immersive VR that overtakes sensory inputs, while Traditional display of the more modern tablet could provide an experience that could fall short in immersion compared to the RIFT but offer undeniable advantages of safety, user acceptance, sustainability and affordability. A special mention should go to the innovative and non-invasive paradigm of exploration of Virtual environments offered by tablets (Window On World)

Between the hardware devices scouted for providing an interaction with the VR environment, MS Kinect, now at its second iteration, seems to outshine other products, leaving the comparable DS525 behind by far. Similarly, to what happens with the hardware devices for the fruition of VR, affordability and diffusion bring devices like smartphones and tablets to the same level of devices more aimed to specific purpose.

In the evaluation of available development framework for VR, Unity seems to be highlighted as the most suited one, with parameters of cost well within the parameters proposed and a massive amount of support and available resource and integrations when compared to other solutions.

An additional goal of the present paper was to analyze currently available solutions for cognitive training and rehabilitation in order to highlight the approaches used to promote a moving and active life.

Starting from the conclusions of the fist deliverable, Attention and Memory emerged as the main focus areas for cognitive rehabilitation and the analysis conducted in the 10th chapter provided examples and explanations of available exercises for this specific cognitive functions.

Brain@home:

Moving and enhancing brain training for an active life

The Brain@HOME platform in order to be sustainable and affordable, will have to be adapted to the specific target under analysis, that is a non-pathological elderly population. Therefore, from a technological point of view must be flexible and adaptable to the dynamic lifestyle of this target, from the point of view of the training exercise it will have to provide a variety of tasks, stimuli and difficulties in order to engage the user with a rising challenge and avoid boredom.

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