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Virtual Reality for Intensive Medicine: From Assessment to Rehabilitation

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Summary

1. What is Virtual Reality (VR)?
2. The role of Virtual Reality in Health Care?
3. How can we use it in Neuropsychological Assessment?
4. How can we use it in Neuropsychological Rehabilitation?

Section 1.
What is Virtual Reality

1.What is VR

Virtual Reality (VR) could be defined as a three-dimensional (3D) graphical, interactive and multisensory environment synthesized by a computer from numerical data, where participants can interact with others or with the environment as if they are really inside it (Riva et al., 2015).

1. What is VR

A **VR system** includes the following elements (Burdea & Coiffet, 2003):

- **A 3D graphics rendering system**
- **A modelling software**
- **Input tools**
- **Output tools**

1. What is VR: Output Tools

1. What is VR: Input Tools

1. What is VR

Different types of virtual reality systems, different types of user experience:

1. *Immersive VR*
2. *Computer Assisted Virtual Environment (CAVE)*
3. *Augmented Reality*
4. *Desktop VR*

1. What is VR: Immersive VR

Immersive VR

With this type of solution the user experiences the feeling of being completely immersed into the virtual environment - i.e. the feeling of "**being present**" - thanks to the use of a display device, usually an head mounted display (HMD), which ensures the possibility to visualize in three dimensions the virtual world, and one or more position sensors (trackers), which detect the movements of the subject.

1. What is VR: Non immersive VR

Augmented Reality

A live direct or indirect view of a real-world environment whose elements are *augmented* by computer-generated sensory input

Desktop VR

It replaces the HMD with the standard computer screen, and user interacts with the virtual environment through a joystick or computer mouse.

1. What is VR: CAVE

CAVE

It is a small room, where a computer-generated world is projected to the walls. The projection is made on both the front and side walls. This solution is particularly suitable for virtual collective experiences, as it allows several people to share the same experience at the same time.


ZDNet

How doctors are prescribing VR to help patients cope with real life

One Italian hospital is helping break new ground by using immersive virtual reality to help people deal with neurological problems.

By Raffaele Mastrolonardo for Italy's got tech | September 28, 2016 -- 09:25 GMT (10:25 BST) | Topic: Virtual Reality

1. What is VR: CAVE

CAVE

It is a small room, where a computer-generated world is projected to the walls.

1. What is VR: Technology is ready

- For many years one of the main obstacles to the use of VR was the price of the equipment: a typical VR system in the early '90s required a costly Silicon Graphic workstation in the range of 250000 US$.
- The significant advances in PC hardware are transforming PC-based VR into a reality.
- A simple immersive VR system now may cost less than 2000 €; a professional one 3000/30000 €

3. VR for Neuro Assessment

TECHNOLOGY

Low-cost headsets boost virtual reality's lab appeal

A wave of user-friendly devices is making the technology an attractive research tool.

BY DAVIDE CASTELVECCHI

Devices that have slashed the cost of virtual reality, and transformed its performance, have implications for scientists as well as gamers. Researchers who are experimenting with the head-mounted displays say that they have the potential to find widespread use as a research tool.

Virtual reality (VR), which lets users experience a computer-generated, three-dimensional world, has produced recurring waves of hype since the 1980s — but this time could be different, says Mel Slater, a computer scientist at the University of Barcelona in Spain who has worked in the field for two decades. Thanks to technologies originally developed for smartphones and video-gaming graphics, the performance of these headsets is now comparable to that of high-end devices that cost tens of thousands of dollars. They are sophisticated, affordable and user-friendly enough to become a staple of research labs, says Slater, rather than tools available to only very few researchers.

A gadget that has transfixed technology-news outlets is the Oculus Rift, made by Facebook-owned start-up Oculus VR of Menlo Park, California. It costs US$600 — but operating it also requires a high-end computer that can cost more than $1,000. Similarly priced gadgets made by smartphone-maker HTC and Sony are expected to become available this year. Vastly cheaper sets made by Google and Samsung turn a smartphone into a more basic VR device.

A lab can now buy a VR device without a dedicated equipment grant, says Anthony ▶

1. What is VR: Low End Immersive VR

LOW END VR Systems								
	PC Based		**Mobile Based**			**Console Based**	**Standalone**	
System	Oculus Rift	HTC Vive	Samsung Gear VR	Google Cardboard	Google Daydream	Playstation VR	AllWinner VR	Snapdragon 820 VR
Cost	599 US$	799 US$	99 US$	10-50 US$	69-149 US$	399 US$	99-249 US$	399-450 US$
Hardware Requirements	High End PC (>1000 US$)	High End PC (>1000 US$)	High End Samsung Phone (>600 US$)	Middle/High end Android phone or iPhone (>299 US$)	High End Android Phone (>499 US$)	PS4 (299 US$) or PS4 Pro (399 US$)	None	None
Resolution	2160x1200	2160x1200	2560x1440	Depends from the phone (minimum 1024x768)	Depends from the phone (minimum 1920x1080)	1920x1080	1920x1080	2560x1440
Refresh Rate	90Hz	90Hz	60Hz	60Hz	90Hz minimum	120Hz	60Hz	70Hz
Field of View	110 degrees	110 degrees	101 degrees	from 70 degrees	96 degrees	100 degrees	90 degrees	
Body Tracking	Medium/High: head tracking (rotation) and positional tracking (forward/backward)	High: head tracking (rotation) and volumetric tracking (full room size – 15ft x15ft - movement)	Medium: head tracking (rotation)	Medium: head tracking (rotation)	Medium: head tracking (rotation)	Medium/High: head tracking (rotation) and positional tracking (forward/backward)	Medium: head tracking (rotation)	Medium/High: head tracking (rotation) and positional tracking (forward/backward)
User Interaction with VR	High (using a joystick or controllers)	High (using controllers)	Medium (using gaze, a built in pad or joystick)	Low (using gaze or a button)	Medium (using gaze or joystick)	High (using a joystick or controllers)	Medium (using gaze, a built in pad or joystick)	Medium (using gaze, a built in pad or joystick)
Software Availability	Oculus Store	Steam Store	Oculus Store	Google Play or IOS Store	Google Play	Playstation Store	Google Play	Google Play

Section 2.
Virtual Reality in Health Care

2. VR in Health Care

Photograph by Susan Plageman

- 1989: First VR company (VPL Research) founded
- 1991: Virtuality Game System
- 1993: Suggested the use of VR in psychological treatment
- 1993: Suggested the use of VR in surgical simulation
- 1995: First research papers on VR in neuro-psychological assessment and treatment
- 1997: First research paper on VR in eating disorders
- 2016: more than 6000 papers in MedLine and 3000 in PsycInfo

2. VR in Health Care

The 27 meta-analyses and systematic reviews available for VR support the use of this technology in the treatment of anxiety disorders, stress-related disorders, obesity and eating disorders, and pain management. But still, there is no clear good quality evidence for or against using VR for the treatment of depression and schizophrenia.

In most pathologies, VR is used as simulative tool for controlled exposure to critical/fearful situations. The possibility of presenting realistic controlled stimuli and, simultaneously, of monitoring the responses generated by the user offers a considerable advantage over real experiences. More, the possibility of designing targeted VR experiences with different difficulty levels – from easy performances to very difficult ones – offers an important source of personal efficacy.

However, the use of VR in pain management and in the treatment of obesity and eating disorders suggest a different rationale: VR can also be used as an embodied technology able to alter our experience of the body and space. If most VR applications to date have been used to simulate external reality, it is also possible to use VR for the simulation of our internal reality including the perception and ownership of our body. The final outcome may be a new generation of transformative experiences that provide knowledge that is epistemically inaccessible to the individual until he or she has that experience, while at the same time transforming the individual's worldview and pushing him/her to an immediate and irreversible personal or clinical change (25, 159). More, it may offer a scientific path to improve the level of well-being in non-clinical subjects by inducing positive emotions, improving attitudes, and helping individuals in understanding and controlling the signals of their body.

frontiers in Psychiatry

REVIEW
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Transforming Experience: The Potential of Augmented Reality and Virtual Reality for Enhancing Personal and Clinical Change

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During life, many personal changes occur. These include changing house, school, work, and even friends and partners. However, the daily experience shows clearly that, in some situations, subjects are unable to change even if they want to. The recent advances in psychology and neuroscience are now providing a better view of personal change, the change affecting our assumptive world: (a) the focus of personal change is reducing the distance between self and reality (conflict); (b) this reduction is achieved through (1) an intense focus on the particular experience creating the conflict or (2) an internal or external reorganization of this experience; (c) personal change requires a progression through a series of different stages that however happen in discontinuous and non-linear ways; and (d) clinical psychology is often used to facilitate personal change when subjects are unable to move forward. Starting from these premises, the aim of this paper is to review the potential of virtuality for enhancing the processes of personal and clinical change. First, the paper focuses on the two leading virtual technologies – augmented reality (AR) and virtual reality (VR) – exploring their current uses in behavioral health and the outcomes of the 28 available systematic reviews and meta-analyses. Then the paper discusses the added value provided by VR and AR in transforming our external experience by focusing on the high level of personal efficacy and self-reflectiveness generated by their sense of presence and emotional engagement. Finally, it outlines the potential future use of virtuality for transforming our inner experience by structuring, altering, and/or replacing our bodily self-consciousness. The final outcome may be a new generation of transformative experiences that provide knowledge that is epistemically inaccessible to the individual until he or she has that experience, while at the same time transforming the individual's worldview.

Keywords: virtual reality, augmented reality, personal change, anxiety disorders, eating disorders, acute pain, post-traumatic stress disorder, body swapping

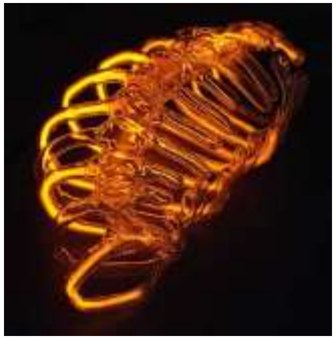
2. VR in Health Care

Research papers show that VR has come of age for **clinical and research applications**:

- *exposure therapy:* the patient is gradually confronted with the virtual simulation of feared stimuli while allowing the anxiety to attenuate
- pain distraction: VR reduces acute pain
- body image modification: VR modifies the bodily experience: it may be used in eating disorders
- *neuropsychological testing and rehabilitation:* VR allows to deliver interactive 3D stimuli in a variety of forms and sensory modalities
- *cognitive neuroscience:* researchers carry out experiments in an ecologically valid situation, while still maintaining control over all variables

2. VR as Cognitive Technology

Different visions from cognitive sciences – *Situated Cognition, Embodied Cognition, Enactive Approach -* suggest that:



- Cognition is no more the simple performance of formal operations on abstract symbols, but has instead **deep roots in sensorimotor processing**.
- this is allowed by a common coding – **the motor code** – shared by perception, action and concepts.

2. VR as Cognitive Technology

Our conceptual system dynamically produces contextualized representations (**simulations**) that support grounded action in different situations. These simulations include not only sensory, motor and mental states:

"We maintain that what integrates these sensory modalities is action simulation. Because sound and action are parts of an integrated system, the sight of an object at a given location, or the sound it produces, automatically triggers a "plan" for a specific action directed toward that location. What is a "plan" to act? We claim that it is a simulated potential action." (Gallese and Lakoff, 2005, p. 460).

2. VR as Cognitive Technology

On one side, the vision of an object immediately activates the appropriate hand shape for using it (canonical neurons; Rizzolatti, 1999): seeing a red apple activates a precision grip for grasping and turning.

On the other side, thinking an apple produces the simulation of an action related to the apple in a specific context of use.

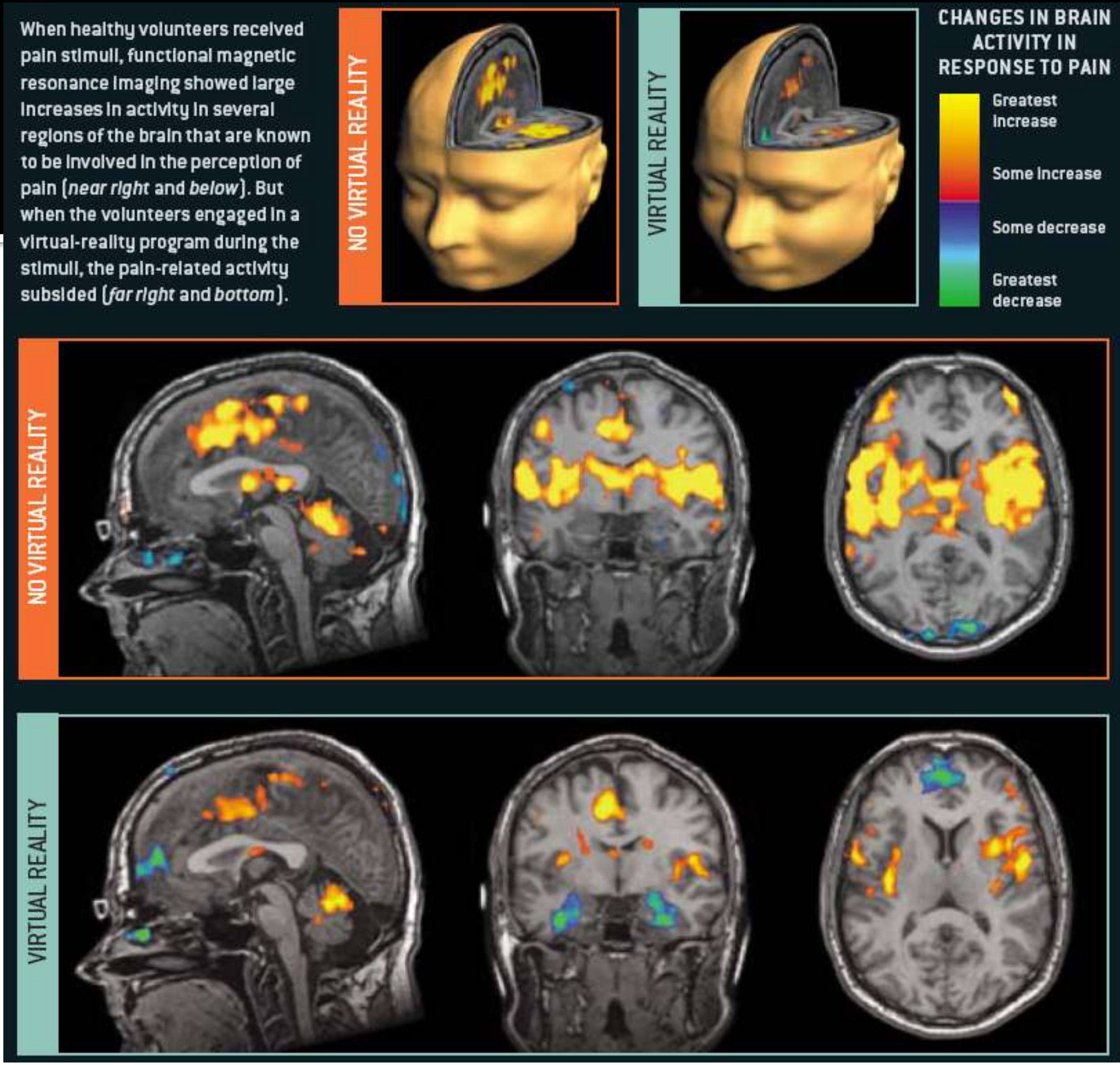
VR as Cognitive Technology (2)

On one side, **concepts** are embodied simulations of actions

On the other side **virtual reality** allows embodied simulations of actions.

The **main idea** is to use **virtual reality** for **assessing cognitions** and modifying **concepts** through **embodied simulations** => behavior and cognitions are tied together

Immersive VR modifies the neural areas of pain (measured using a **PET**): No effects with videogame



Hoffman, H. Scientific American, April 2004

2. VR in Health Care

VR in **neuro assessment and rehabilitation: The FIVE advantages**

1. It offers several requirements for cognitive neurorehabilitation interventions: repetitive practice, feedback about performance, multimodal stimulation, and controlled, secure and ecologically valid environments (Bohil et al., 2011);
2. VR exposes patients to computer-generated virtual environments providing a sensation of "presence" or "being there," (Riva, 2009);

1. What is VR (10)

3. It is possible to control and manipulate tailored exercises within **meaningful and motivating** environments using virtual environments (Riva, Gaggioli & Castelnuovo, 2009);

4. A growing number of **interactive devices** are available today (e.g., joysticks, gloves, surfaces, etc.), facilitating the design of complex rehabilitative protocols.

5. It is an **altered** "**egocentric space**" where individuals can train their ability to translate between different spatial representations (Serino and Riva, 2013).

Section 3.
Virtual Reality for Neuropsychological Assessment

3. VR for Neuro Assessment

A world away from reality

FLAVIO DONATO & EDVARD I. MOSER

Technology that involves VR has obvious advantages for studies of simple sensorimotor computations, in which a defined set of inputs, such as those corresponding to an animal's movement, is associated linearly with neural output. However, some pressing concerns are raised when VR technology is used to study higher-order computations such as spatial navigation. Navigation reflects the integration of many sensory inputs. The resulting outputs are not linearly related to sensory perception, but rather express cognitive abstractions.

Goal-driven navigation relies on several cell types in the brain, including place cells (which fire when an animal is in a particular location), grid cells (which fire at periodically spaced positions across the entire environment) and border cells (which fire selectively along local borders)[7,8]. By fixing an animal's head in place, investigators can monitor the activity of these neurons at high resolution while the animal runs between specific locations in virtual space. But do animals navigate in the same way in VR as in real life?

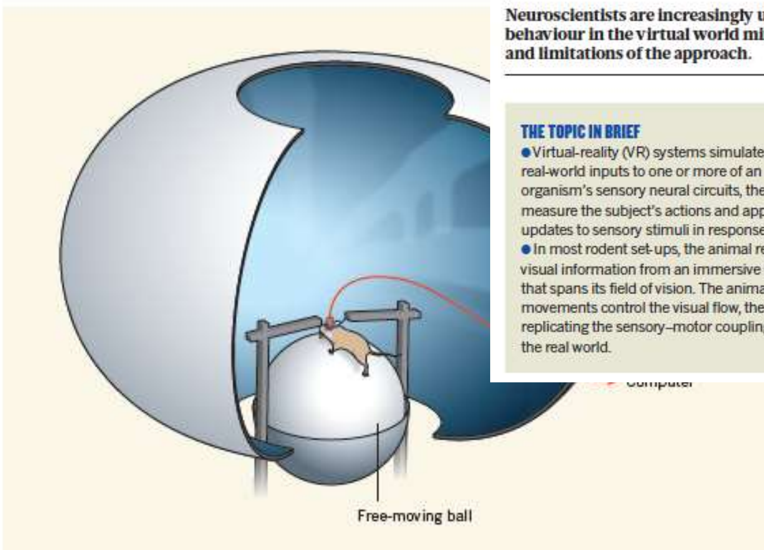


Figure 1 | A mouse explores a virtual world. In most typical virtual-reality experiments, a mouse is head-fixed above a ball. Its legs are free, allowing it to move the ball in all directions. By moving the ball, the mouse navigates around a virtual world that is projected onto a 270° doughnut-shaped screen in front of it. Head fixing enables neural activity to be measured and correlated with the motor actions that drive movement.

Indeed, if movement is unrestrained, the position-coding activity of place and grid cells

John O'Keefe changed our understanding of the physiology of navigation by studying rats

NEWS & VIEWS

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FORUM Neuroscience

Virtual reality explored

Neuroscientists are increasingly using virtual reality to facilitate studies of animal behaviour, but whether behaviour in the virtual world mimics that in real life is a matter for debate. Here, scientists discuss the strengths and limitations of the approach.

THE TOPIC IN BRIEF

- Virtual-reality (VR) systems simulate real-world inputs to one or more of an organism's sensory neural circuits, then measure the subject's actions and apply updates to sensory stimuli in response.
- In most rodent set-ups, the animal receives visual information from an immersive screen that spans its field of vision. The animal's movements control the visual flow, thereby replicating the sensory–motor coupling of the real world.
- Typically, movement is restricted by fixing the rodent's head in position; this allows precise measurements of neural activity to be taken and correlated with motor actions in animals that are awake, rather than anaesthetized (Fig. 1).
- Many researchers think that VR is a valuable tool for studying both navigation and sensory systems.
- However, a body of work[1–3] indicates that the way in which mice navigate in real and virtual worlds is different.

Furthermore, studies[1–3] that remove key sensory inputs such as vestibular stimuli reveal which aspects of navigational neural activity depend on vestibular input and which can be supported by visual cues alone. Therefore, VR can recapitulate neural activity in real environments, and VR experiments can be designed to create informative differences between neural function in real and virtual worlds.

Overall, VR has yielded many insights into sensorimotor integration, decision-making and navigation[6]. But it is important to remember that, like all reductionist approaches, VR requires a trade-off between improved

3. VR for Neuro Assessment

simulations of real world contexts. Historically, this work has relied on simple and static stimuli (e.g., Stroop for clinical; IGT for affective, and schematic faces for social neuroscience) lacking many of the potentially important advantages in advanced technology and characteristics of real world activities and interactions. The current review suggests that the promise of the approach described here has already started to be realized. For example, in the clinical neurosciences virtual environment-based neuropsychological assessments allow for real-time assessment of a participants cognitive and affective processing in a manner that more closely resemble real-world functional abilities (Matheis et al., 2007; Parsons and Rizzo, 2008). In affective neuroscience, virtual environments are also being used to assess "Hot" processes of affective arousal both clinical (Parsons and Rizzo, 2008) and nonclinical (Armstrong et al., 2013; Parsons et al., 2013) studies. Finally, for social neuroscience, virtual environments offer the social neuroscientist the ability to induce a feeling of "presence" in participants as they experience emotionally engaging background narratives to enhance affective experience and social interactions (Gorini et al., 2011; Diemer et al., 2015).

It is important to reiterate that the use of virtual environments advocated here does not seek to minimize the contribution of traditional (paper-and-pencil and computerized) neuropsychological assessments that use static stimuli. The neuropsychological assessment measures in clinical neuroscience and the static stimuli in social neuroscience have numerous benefits for researchers as evidenced by the progress made using such tests and stimuli. The approach advocated here calls for the "addition" (not replacement) of virtual environments to neuropsychological batteries in situations where researchers desire to have some idea of real world functioning. Another important note is that in some neuroimaging research, the approach suggested will present methodological challenges. While this is a challenge, there is no reason to abandon such an effort. Understanding the neural correlates of Cold and Hot processing using virtual environments represents an important advance in clinical, affective, and social neuroscience. This pursuit faces challenges given the complex nature of real world interactions. This review presents one viable way to meet some of the challenges. Given that virtual environments allow for precise presentation and control of dynamic perceptual stimuli, they can provide ecologically valid assessments that combine the control and rigor of laboratory measures with emotionally engaging background narratives to enhance assessment of cognition, affect, and social interactions.

frontiers in Human Neuroscience

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CrossMark

Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences

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An essential tension can be found between researchers interested in ecological validity and those concerned with maintaining experimental control. Research in the human neurosciences often involves the use of simple and static stimuli lacking many of the potentially important aspects of real world activities and interactions. While this research is valuable, there is a growing interest in the human neurosciences to use cues about target states in the real world via multimodal scenarios that involve visual, semantic, and prosodic information. These scenarios should include dynamic stimuli presented concurrently or serially in a manner that allows researchers to assess the integrative processes carried out by perceivers over time. Furthermore, there is growing interest in contextually embedded stimuli that can constrain participant interpretations of cues about a target's internal states. Virtual reality environments proffer assessment paradigms that combine the experimental control of laboratory measures with emotionally engaging background narratives to enhance affective experience and social interactions. The present review highlights the potential of virtual reality environments for enhanced ecological validity in the clinical, affective, and social neurosciences.

Keywords: neuropsychological tests, social neuroscience, ecological validity, virtual reality, neuropsychology

3. VR for Neuro Assessment

An example: The Virtual Multiple Errand Test (VMET) for the assessment of Executive Functions

frontiers in Behavioral Neuroscience

‹ Archive

THIS ARTICLE IS PART OF THE RESEARCH TOPIC
Executive function(s): Conductor, orchestra or symphony? Towards a tra
and practice across development, in normal and atypical groups

ORIGINAL RESEARCH ARTICLE
Front. Behav. Neurosci., 05 December 2014 | http://dx.doi.org/10.3389/fnbeh.2014.00405

Virtual multiple errands test (VMET): a virtual reality-based tool to detect early executive functions deficit in Parkinson's disease

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3. VR for Neuro Assessment

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Barbara Poletti
Barbara Corra
Davide Sangalli
Vincenzo Silani

Validating the Neuro VR-Based Virtual Version of the Multiple Errands Test: Preliminary Results

Abstract

The purpose of this study was to establish ecological validity and initial construct validity of the virtual reality version of the Multiple Errands Test based on NeuroVR software as an assessment tool for executive functions. In particular, the Multiple Errands Test is an assessment of executive functions in daily life which consists of tasks that abide by certain rules and is performed in a shopping mall-like setting where there are items to be bought and information to be obtained. The study population included three groups: post-stroke participants ($n = 9$), healthy young participants ($n = 10$), and healthy older participants ($n = 10$). The general purpose of the study was investigated through the following specific objectives: (1) to examine the relationships between the performance of three groups of participants in the Virtual Multiple Errands Test (VMET) and in the traditional neuropsychological tests employed to assess executive functions; and (2) to compare the performance of post-stroke participants to those of healthy young and older controls in the Virtual Multiple Errands Test and in the traditional neuropsychological tests employed to assess executive functions. Correlations between Virtual Multiple Errands Test variables and some traditional executive functions measures provide preliminary support for the ecological and construct validity of the VMET; further performance obtained at the Virtual Multiple Errands Test provided a distinction between the clinical and healthy population, and between the two age control groups. These results suggest a possible future application of such an ecological approach for cognitive assessment and rehabilitation of

Stud Health Technol Inform. 2011;163:8-10.

Sleep dysfunctions influence decision making in undemented Parkinson's disease patients: a study in a virtual supermarket.

Albani G[1], Raspelli S, Carelli L, Priano L, Pignatti R, Morganti F, Gaggioli A, Weiss PL, Kizony R, Katz N, Mauro A, Riva G.

Author information

Abstract
In the early-middle stages of Parkinson's disease (PD), polysomnographic studies show early alterations of the structure of the sleep, which may explain frequent symptoms reported by patients, such as daytime drowsiness, loss of attention and concentration, feeling of tiredness. The aim of this study was to verify if there is a correlation between the sleep dysfunction and decision making ability. We used a Virtual Reality version of the Multiple Errand Test (VMET), developed using the NeuroVR free software (http://www.neurovr2.org), to evaluate decision-making ability in 12 PD not-demented patients and 14 controls. Five of our not-demented 12 PD patients showed abnormalities in the polysomnographic recordings associated to significant differences in the VMET performance.

PMID: 21335749
[PubMed - indexed for MEDLINE]

Stud Health Technol Inform. 2014;199:40-4.

Cognitive Assessment of OCD Patients: NeuroVR vs Neuropsychological Test.

La Paglia F[1], La Cascia C[1], Rizzo R[1], Cangialosi F[1], Sanna M[1], Riva G[2], La Barbera D[1].

Author information

Abstract
This study aimed to evaluate the reliability and validity of the Neuro-Virtual Reality as tool for the neuropsychological assessment in OCD patients. We used the neuropsychological battery and a virtual version of the Multiple Errand Test (V-MET), developed using the NeuroVR software, in order to evaluate the executive functions, the ability to plan ahead on complex problem solving tasks in daily life in 30 obsessive compulsive disorder (OCD) patients and 30 healthy controls. The results showed the presence of difficulties of OCD patients: lower levels of divided attention and higher levels of errors; higher mean rank of inefficiencies, interpretation failures and rule breaks and longer time of execution of the whole task. By contrast, controls have higher level of efficiency and better performance. In addition, a significant correlation was found between the V-MET and the neuropsychological battery which confirms and supports the ecological validity of neurocognitive assessment through NeuroVirtual Reality.

PMID: 24875687
[PubMed - in process]

3. VR for Neuro Assessment

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Effects of traumatic brain injury on a virtual reality social problem solving task and relations to cortical thickness in adolescence

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Brain structure

A B S T R A C T

Social problem solving was assessed in 28 youth ages 12–19 years (15 with moderate to severe traumatic brain injury (TBI), 13 uninjured) using a naturalistic, computerized virtual reality (VR) version of the Interpersonal Negotiations Strategy interview (Yeates, Schultz, & Selman, 1991). In each scenario, processing load condition was varied in terms of number of characters and amount of information. Adolescents viewed animated scenarios depicting social conflict in a virtual microworld environment from an avatar's viewpoint, and were questioned on four problem solving steps: defining the problem, generating solutions, selecting solutions, and evaluating the likely outcome. Scoring was based on a developmental scale in which responses were judged as impulsive, unilateral, reciprocal, or collaborative, in order of increasing score. Adolescents with TBI were significantly impaired on the summary VR-Social Problem Solving (VR-SPS) score in Condition A (2 speakers, no irrelevant information), $p = 0.005$; in Condition B (2 speakers + irrelevant information), $p = 0.035$; and Condition C (4 speakers + irrelevant information), $p = 0.008$. Effect sizes (Cohen's D) were large ($A = 1.40$, $B = 0.96$, $C = 1.23$). Significant group differences were strongest and most consistent for defining the problems and evaluating outcomes. The relation of task performance to cortical thickness of specific brain regions was also explored, with significant relations found with orbitofrontal regions, the frontal pole, the cuneus, and the temporal pole. Results are discussed in the context of specific cognitive and neural mechanisms underlying social problem solving deficits after childhood TBI.

2.2. Virtual reality social problem-solving task (VR-SPS)

Social problem-solving was assessed using a VR task in which participants were presented scenarios portraying a social conflict and then asked questions relating to the scenario just viewed in a semi-structured interview to address four problem-solving steps (Yeates, Schultz, & Selman, 1990). Responses were audiotaped, transcribed, and scored.

The original INS was developed to marry the strengths of two theoretically distinct approaches to social development, the structural approach (Kohlberg, 1969), grounded in Piagetian developmental theory, and the functional approach (Dodge, 1985), grounded in description of information processing steps, and the use of those steps in action selection. Reliability for the INS has been demonstrated in several studies, with a test–retest reliability of $r = .68$ across a four month interval (Yeates et al., 1990). Validity was provided for key elements of the INS model with developmental studies that found significant relationships between children's ages or intellectual development and the INS measurement techniques (Yeates et al., 1990). In one study, for example, the overall adaptive functioning of adolescents with affectively disordered parents was related to their overall level of INS development (Beardslee, Schultz, & Selman, 1987).

In the virtual task, participants were asked to watch six computerized, virtual reality scenarios involving four people, two of whom were in conflict. There were two possible scenario types: the Parent–Youth scenario and the Youth–Peer scenario. In the Parent–Youth scenario, a parent and youth were involved in the disagreement. For example, a girl asks her mother if she can go out for the evening, but her mother asks her to babysit instead. In the Youth–Peer scenario, two friends are involved in a disagreement (i.e., two boys are both interested in the same girl). Male and female participants received gender-matched scenarios in which the characters involved in the argument were the same gender as the participant. In addition we wished to explore the possibility that cognitive processing load might have a disproportionate effect on youth with TBI in the context of social problem solving as compared to typically-developing youth.

3. VR for Neuro Assessment

3.3. *Summary of results for VR-SPS*

In general, the results on this task parallel our findings for the narrative version of the INS, in that adolescents with TBI showed impairment in social problem solving across several problem-solving steps relative to typically-developing adolescents. We also manipulated the complexity of the social interaction, varying the dialog between two people exchanging information about a single conflict to four people exchanging information both relevant and tangential to the conflict. This manipulation revealed that in Condition C, the most complex condition, group differences were significant for analysis of the Summary Score and for each of the four problem solving steps. For Conditions A and B, groups differed on the Summary Score, but significant differences were inconsistent among problem solving steps. Only the Defining Problem step was sensitive to group differences in all three Conditions. In previously reported studies of social problem solving using the original, narrative form of the INS, injury group differences were more apparent at the more complex stages of social problem solving (GS, SS, EO) than at the initial stage of defining the problem (Hanten et al., 2008; Yeates et al., 2004). In the current study using the VR version, group differences were apparent even at the DP stage, suggesting the VR-SPS may prove to be slightly more sensitive to deficits in identifying the social problem. Processing load did not appear to have an effect on TD adolescents, but adolescents with TBI showed poorer scores in the most complex scenarios.

Appendix A. Example of social conflict scenarios and responses at each developmental (scoring) level by problem-solving step. Taken from the INS (Yeates et al., 1990).

Scenario: Randy and Tom are friends. They have been assigned to work together on a science project in school and only have two days to finish the project. They meet after school and Randy says he wants to start working on the project right away, but Tom wants to play softball first.

Steps/interview query	Impulsive: 0 pts	Unilateral: 1 pt	Reciprocal: 2 pts	Collaborative: 3 pts.
Step 1: Defining the problem (DP)	Physical terms only:	Self or other's needs *They're not going to finish on time if Tom doesn't work with Randy.*	Contrasting both self and other's needs *One of them wants to play softball and the other one wants to get going on the project.*	Mutual goals & long-term relationships *Two friends have a project to work on and don't agree when to start working on it. They might agree to work on the project first and decide to play after finishing the project because both are important but they don't want to argue and stop being friends.*
"What is the problem here?"	*They have a project to finish in two days.*	*Because it is a grade.*	*So, they need to figure out what they're going to do first and then go do the other thing.*	
"Why is that a problem?"				
Step 2: Generating alternative strategies (GAS)	Physical, with little difference between impulse and action	Emphasize assertion of power or appeasement, conformity	Satisfying both participants in a 'just' fashion	Collaboration with shared goals
"What are the things you can think of that Randy can do to solve the problem?"	*Poison him; break his leg or something. . .be like, 'no you can't play softball'*	*Just tell the reasons why they should go ahead and do the project now*	*He can flip a coin...So they can choose whether they start on the project or play softball*	*Ask Tom to help him with the project first and then promise to play softball with him the rest of the week so that both get what they want*
Step 3: Selecting specific strategy (SSS) *"What would be the best way to solve the problem?"*	For immediate gratification or self- protection *Go ahead and do the project as fast and as early as you can*	To please self or other in the short-term *Both work on it because a project is a test grade, and a zero on that is really going to hurt you*	To satisfy self, other, and relationship *Do half the project each day and play softball the other half*	To optimize collaboration, sustain relationship *To sit down with his partner and say, 'Hey, you know we need to work on this. What's a good time for you to work on this and have no distractions?'*
Step 4: Evaluating outcomes	Based on immediate needs of self	Based on personal satisfaction of either self or other	Based on balance with emphasis on a fair exchange	Based on long-term effects of relationship
(EO)	*By asking a grown-up that he knows*	*They get an 'A' on the project*	*They'd finish the project, and Tom and Randy played softball, too.*	*He'll know because they'll both be playing together, and they would be friends and want to play again and again.*
"How would Randy know if he had really solved the problem?"				

1. Picture Interpretation Test (1)

Neurol Sci (2005) 25:322–330
DOI 10.1007/s10072-004-0365-6

ORIGINAL

C. Rosci · D. Sacco · M. Laiacona · E. Capitani

Interpretation of a complex picture and its sensitivity to frontal damage: a reappraisal

Received: 19 July 2004 / Accepted in revised form: 4 December 2004

Abstract A.R. Luria introduced the interpretation of a meaningful picture as a tool for assessing pre-frontal impairment. We gave this test to 196 normal adults, who were asked to communicate what was happening in the portrayed scene (a boy chases a mouse hidden under a cupboard, while three frightened girls assist). The same subjects were given two other frontal tests (verbal fluency on phonemic cue and Trail Making Test (TMT)) and Raven's Matrices. Twenty-three normal subjects (12%) failed to correctly interpret the picture. We also examined 20 patients whose brain lesion encroached upon pre-frontal areas, in order to check if this version of the test could be easily administered to this type of patient, and if its difficulty level was appropriate for avoiding ceiling and floor effects. Twelve patients were unable to interpret the picture (60%). A similar failure rate was observed with the same subjects on verbal fluency and TMT, while Raven's Matrices were less impaired (35%). Some dissociation was found between Picture Interpretation and the TMT. The Italian version of the Picture Interpretation Test is suitable for the examination of pre-frontal patients.

Key words Frontal lesions · Visual exploration · Problem solving

Introduction

Over the last 10 years, neuropsychological investigation of pre-frontal functions has markedly improved our understanding of this fascinating region of the brain. Most of the new data available have been acquired with the help of functional imaging, an approach that has led to the modification of some earlier statements about the finer localisation of cognitive skills within the frontal lobes (for example, see [1, 2]). Despite these exciting advances, however, the bedside assessment of frontal lobe functions remains somewhat elusive and, in some cases, even disappointing. A huge number of tasks have been suggested [3], but a standardised clinical battery for the detection of various types of frontal impairment is still lacking, and the sensitivity and specificity of the commonly used tests are not always known. Among pre-frontal functions, many authors have contrasted the ability to comply with a strategy, ascribed to dorso-lateral cortex, with the general activation or initiation of a task, that would be more dependent on the integrity of mesial structures. However, in most cases both aspects are needed in order to grant the normal efficiency, and the same task may be affected for different reasons. For instance, when frontal patients are given a verbal fluency task, a lower

Fig. 1 The painting by Giacomo Favretto used in this study. Participants were shown the coloured picture reported in [10]. The picture can also be obtained from the Brera Gallery, Milan

What is happening in this painting?

They are trying to catch a mouse…

Prefrontal patients do not understand it

1. 1. Picture Interpretation Test (2)

1. 1. Picture Interpretation Test (3)

Indexes measured

1. *Correct interpretation*: It is the time in seconds registered from the moments in which the experimenter says the words "Open your eyes" until the participant provides a correct interpretation" (i.e., "mouse", "snake", etc.). The maximum time allowed was 180 seconds, consequently if the participants fails in the interpretation a time of 180 seconds was assigned as the outcome (as suggested by (Rosci et al., 2005);
2. *Number of scene elements for correct interpretation*: It is the sum of the elements of scene verbalized during the description before the correct interpretation. Only successful recognition are considered;
3. *Number of scene elements*: It is the sum of the elements of scene verbalized during the during the interpretation, independently by the correctness of the interpretation.

1. 1. Picture Interpretation Test (4)

57 subjects (Paper Submitted):

16 patients suffering from Parkinson's Disease (PD group)

41 cognitively healthy individuals (CG, control group).

Montreal Cognitive Assessment (MoCa, (Santangelo et al., 2015**).**

Trail Making Test (TMT, (Giovagnoli et al., 1996**).**

F.A.S. Verbal Fluency Task (Carlesimo et al., 1996**).**

Traditional Neuropsychological Tests

Logistic Regression

		Predicted		
		1.0	2.0	Σ
Actual	1.0	75.0 %	40.0 %	41
	2.0	25.0 %	60.0 %	16
	Σ	52	5	57

Random Forest

		Predicted		
		1.0	2.0	Σ
Actual	1.0	82.2 %	33.3 %	41
	2.0	17.8 %	66.7 %	16
	Σ	45	12	57

Support Vector Machines

		Predicted		
		1.0	2.0	Σ
Actual	1.0	80.0 %	41.7 %	41
	2.0	20.0 %	58.3 %	16
	Σ	45	12	57

vs.

PIT 360°

Logistic Regression

		Predicted		
		1.0	2.0	Σ
Actual	1.0	79.2 %	33.3 %	41
	2.0	20.8 %	66.7 %	16
	Σ	48	9	57

Random Forest

		Predicted		
		1.0	2.0	Σ
Actual	1.0	78.3 %	45.5 %	41
	2.0	21.7 %	54.5 %	16
	Σ	46	11	57

Support Vector Machines

		Predicted		
		1.0	2.0	Σ
Actual	1.0	78.0 %	28.6 %	41
	2.0	22.0 %	71.4 %	16
	Σ	50	7	57

1. 1. Picture Interpretation Test (4)

PLANNED CONTROLLED TRIAL:
The potential of virtual reality for the assessment and treatment of traumatic brain injury

Elisa R Zanier, MD
Laboratory of Acute Brain Injury and Therapeutic Strategies, Head
Dept of Neuroscience
IRCCS-Mario Negri Institute for Pharmacological Research

120 subjects

60 (TBI patients with post-stabilization GCS: 4-8)
60 cognitively healthy individuals (CG, control group).

Montreal Cognitive Assessment (MoCa, (Santangelo et al., 2015).
Trail Making Test (TMT, (Giovagnoli et al., 1996).
F.A.S. Verbal Fluency Task (Carlesimo et al., 1996).

3. VR for Neuro Assessment

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Volume 26, Issue 18, p2463–2468, 26 September 2016

Report

Switch to Standard View

Neural Representations Integrate the Current Field of View with the Remembered 360° Panorama in Scene-Selective Cortex

Caroline E. Robertson[5], Katherine L. Hermann, Anna Mynick, Dwight J. Kravitz, Nancy Kanwisher

[5] Lead Contact

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Article Info

These results demonstrate neural representations of the scene within the current field of view are imbued with our memory for the broader panoramic environment. We hypothesized that this association might serve an important functional role in scene perception, causing non-overlapping views of a learned panoramic environment to automatically prime each other in perception. We tested this hypothesis in a final behavioral experiment

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Our findings dovetail with predictions from integrative encoding models of memory, which posit that memory representations of prior related events are reactivated during encoding of novel events, contextualizing ongoing experience [21–23]. Neural support for such models derives from associative inference paradigms, where discrete stimuli (e.g., a baseball and a hat) are paired via mutual association with a third stimulus (e.g., a car)

Summary | Full Text | Images/Data | References | Related Articles | Comments

Highlights

- Visual experience of a 360° panorama forges memory associations between scene views
- Representations of discrete views of a 360° environment overlap in RSC and OPA
- The scene currently in view primes associated views of the 360° environment

Summary

We experience our visual environment as a seamless, immersive panorama. Yet, each view is discrete and fleeting, separated by expansive eye movements and discontinuous views of our spatial surroundings. How are discrete views of a panoramic environment knit together into a broad, unified memory representation? Regions of the brain's "scene network" are well poised to integrate retinal input and memory [1]: they are visually driven [2, 3] but also densely interconnected with memory structures in the medial temporal lobe [4]. Further, these regions harbor memory signals relevant for navigation [5–8] and adapt across overlapping shifts in scene viewpoint [9, 10]. However, it is unknown whether regions of the scene network support visual memory for the panoramic environment outside of the current field of view and, further, how memory for the surrounding environment influences ongoing perception. Here, we demonstrate that specific regions of the scene network—the retrosplenial complex (RSC) and occipital place area (OPA)—unite discrete views of a 360° panoramic environment, both current and out of sight, in a common representational space. Further, individual scene views prime associated representations of the panoramic environment in behavior, facilitating subsequent perceptual judgments. We propose that this dynamic interplay between memory and perception plays an important role in weaving the fabric of continuous visual experience.

Section 4.
Virtual Reality for Neuropsychological Rehabilitation

4. VR in Neuro Rehabilitation

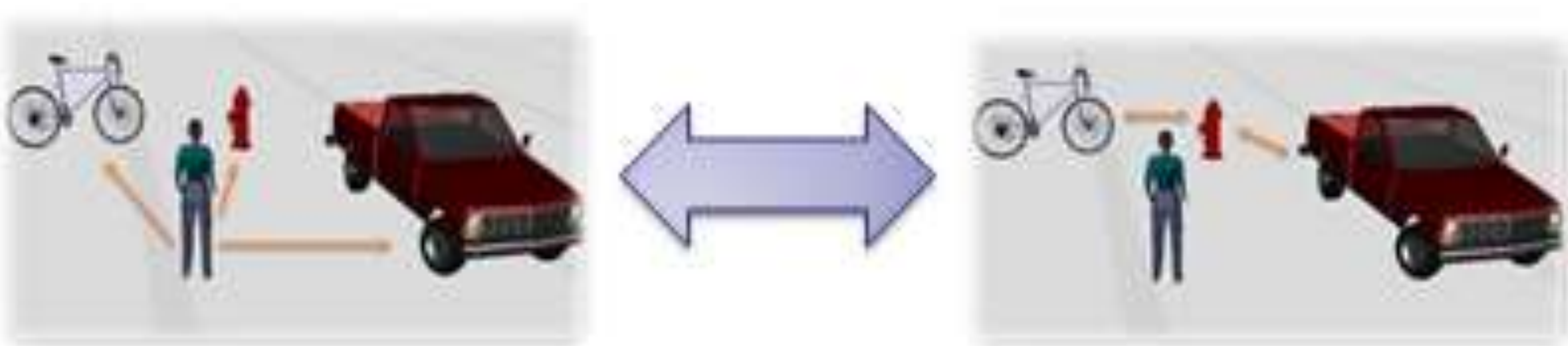
Getting lost is not just common in Alzheimer's disease (AD), but is one of its earliest clinical manifestations.

This reflects a deficit in **spatial memory**, i.e the ability to encode, store, and retrieve spatial information in order to build an internal representation of the environment (a "cognitive map") (O'Keefe & Nadel, 1978) .

4. VR in Neuro Rehabilitation

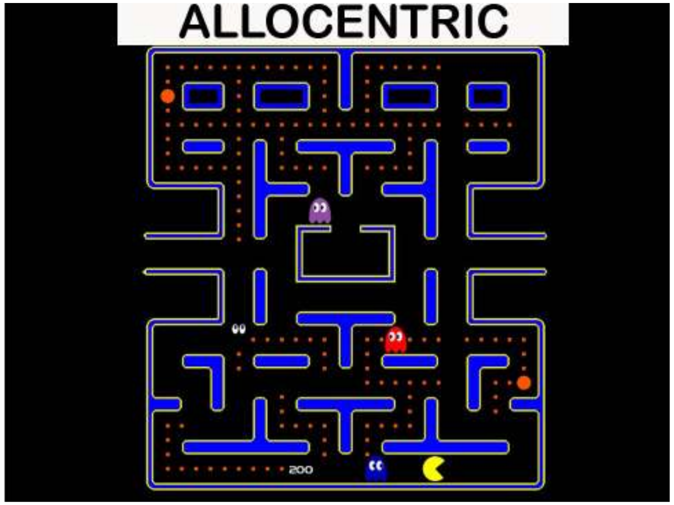
Two spatial references frames (Klatzky, 1998)**:**

- "**egocentric**" reference frame: object locations are represented relative to the individual's orientation
- "**allocentric**" reference frame: object locations are represented irrespective of the individual's orientation



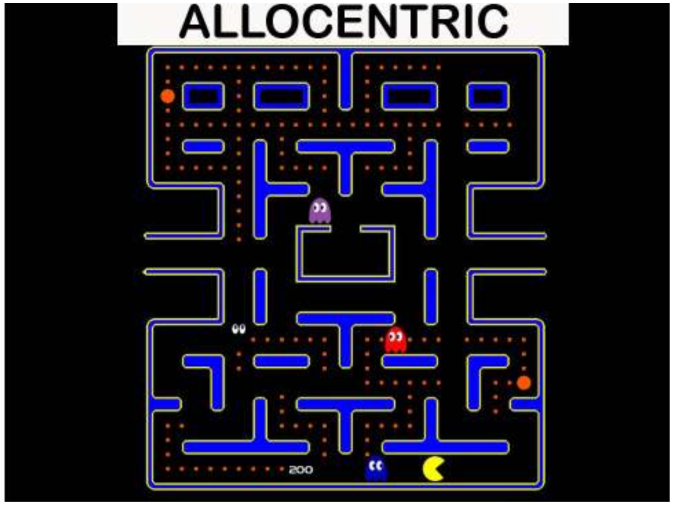
4. VR in Neuro Rehabilitation

- When we adopt an **egocentric stance** the position of an object changes when we move. All the objects are located in relation to ourselves.



4. VR in Neuro Rehabilitation

- When we adopt an **allocentric stance** the object is represented independently of our own current relation with it. All the objects are located in relation to a space external to the perceiver.



4. VR in Neuro Rehabilitation

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Review

The role of egocentric and allocentric abilities in Alzheimer's disease: A systematic review

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ABSTRACT

A great effort has been made to identify crucial cognitive markers that can be used to characterize the cognitive profile of Alzheimer's disease (AD). Because topographical disorientation is one of the earliest clinical manifestation of AD, an increasing number of studies have investigated the spatial deficits in this clinical population. In this systematic review, we specifically focused on experimental studies investigating allocentric and egocentric deficits to understand which spatial cognitive processes are differentially impaired in the different stages of the disease. First, our results highlighted that spatial deficits appear in the earliest stages of the disease. Second, a need for a more ecological assessment of spatial functions will be presented. Third, our analysis suggested that a prevalence of allocentric impairment exists. Specifically, two selected studies underlined that a more specific impairment is found in the translation between the egocentric and allocentric representations. In this perspective, the implications for future research and neurorehabilitative interventions will be discussed.

3. VR for Neuro Assessment

COGNITIVE NEUROSCIENCE, 2013, http://dx.doi.org/10.1080/17588928.2013.854762

Rout
Taylor &

From allo- to egocentric spatial ability in early Alzheimer's disease: A study with virtual reality spatial tasks

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The ability to orient in space constitutes a main sign of cognitive impairment in Alzheimer's disease (AD). Presently, a peculiar aspect of topographical disorientation in AD linked with spatial reference frame congruence appears to have been only minimally investigated. We aim to study whether there is a decline in performing the allo- to egocentric translation of spatial knowledge during different types of wayfinding in AD patients. We introduced two virtual reality tasks, the VR-Maze and VR-Road Map tasks, in which we compared 26 AD and 26 healthy, elderly subjects. The results emphasize that there is a specific reduction in performing allo- to egocentric spatial tasks in AD, whereas this reduction is not as evident in equivalent allocentric spatial tasks. The data are consistent with the neurological results regarding the early degeneration of the hippocampus and retrosplenial cortex in AD, which underlies the ability to translate between these two reference frames.

TABLE 1
The statistical differences between AD and CG in the neuropsychological assessment

Neuropsychology test	*Between-groups analysis (t-test)*	*Alzheimer*	*Healthy*
Mini Mental State Exam	$F(.872)\ p < .023$	*M* 21.57 *SD* 2.52	*M* 28.55 *SD* 1.23
Trail Making Test (*A* + B)	$F(.004)\ p < .001$	*M* 129. 36 *SD* 45.14	*M* 68.15 *SD* 41.58
Tower of London	$F(8.79)\ p < .020$	*M* 28.00 *SD* 3.94	*M* 32.83 *SD* 1.6
Corsi's span	$F(16.99)\ p < .001$	*M* 3.6 *SD* .94	*M* 7.61 *SD* 2.87
Corsi's supra span	$F(77.47)\ p < .001$	*M* 3.55 *SD* 1.27	*M* 20.59 *SD* 9.64
Benton Line Orientation (H)	$F(3.02)\ p < .001$	*M* 14.33 *SD* 6.43	*M* 28.83 *SD* .98
Manikin's Test	$F(3.86)\ p < .001$	*M* 17.05 *SD* 3.23	*M* 29.61 *SD* 2.47

TABLE 2
The means and standard deviation values for AD and CG in the VR-MT task

					Int Conf 95%	
Group	*Task*	*Maze*	*Mean*	*SD*	*Inf.*	*Sup.*
AD	PP-MT	1	.923	.053	.816	1.030
		2	.923	.038	.847	.999
		3	.654	.067	.519	.789
		4	.769	.065	.638	.901
		5	.808	.067	.673	.943
	VR_MT	1	.346	.097	.150	.542
		2	.231	.065	.099	.362
		3	.077	.080	−.084	.237
		4	.038	.074	−.110	.187
		5	.000	.071	−.142	.142
CG	PP-MT	1	.923	.053	.816	1.030
		2	1.000	.038	.924	1.076
		3	1.000	.067	.865	1.135
		4	.962	.065	.830	1.093
		5	.923	.067	.788	1.058
	VR_MT	1	.538	.097	.343	.734
		2	.962	.065	.830	1.093
		3	.538	.080	.378	.699
		4	.615	.074	.467	.764
		5	.462	.071	.320	.603

TABLE 3
The ANOVA main results for VR-MT (Bonferroni's adjustment)

Variable	*F value*	*Sig.*	*Effect size*	*Power*
Task	383.45	.000	.885	1.00
Mazes	7.643	.000	.388	.994
Task * Mazes	4.52	.038	.083	.550
Group	89.22	.000	.641	1.00
Task * Group	42.60	.000	.460	1.00
Mazes * Group	2.17	.147	.042	.304
Task * Mazes * Group	.007	.933	.000	.051

4. VR in Neuro Rehabilitation

We **used VR** to explore the egocentric/allocentric transformation:

frontiers in Aging Neuroscience

ORIGINAL RESEARCH
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Detecting early egocentric and allocentric impairments deficits in Alzheimer's disease: an experimental study with virtual reality

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Several studies have pointed out that egocentric and allocentric spatial impairments are one of the earliest manifestations of Alzheimer's Disease (AD). It is less clear how a break in the continuous interaction between these two representations may be a crucial marker to detect patients who are at risk to develop dementia. The main objective of this study is to compare the performances of participants suffering from amnestic mild cognitive impairment (aMCI group), patients with AD (AD group) and a control group (CG), using a virtual reality (VR)-based procedure for assessing the abilities in encoding, storing and syncing different spatial representations. In the first task, participants were required to indicate on a real map the position of the object they had memorized, while in the second task they were invited to retrieve its position from an empty version of the same virtual room, starting from a different position. The entire procedure was repeated across three different trials, depending on the object location in the encoding phase. Our finding showed that aMCI patients performed significantly more poorly in the third trial of the first task, showing a deficit in the ability to encode and store an allocentric viewpoint independent representation. On the other hand, AD patients performed significantly more poorly when compared to the CG in the second task, indicating a specific impairment in storing an allocentric viewpoint independent representation and then syncing it with the allocentric viewpoint dependent representation. Furthermore, data suggested that these impairments are not a product of generalized cognitive decline or of general decay in spatial abilities, but instead may reflect a selective deficit in the spatial organization. Overall, these findings provide an initial insight into the cognitive underpinnings of amnestic impairment in aMCI and AD patient exploiting the potentiality of VR.

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4. VR in Neuro Rehabilitation

Evaluation

A total of 45 participants allocated to three groups were included in the study:

- 15 **AD patients** [(11 F; age: 82.93 (5.61); education: 6.60 (3.83); MMSE: 23.06 (1.50)],
- 15 **aMCI patients** [(11 F; age: 77.53 (5.52); education: 7.73 (4.48); MMSE: 22.46 (1.95)]
- 15 **cognitively healthy individuals** [9 F; age: 73.87 (7.38); education: 12.27 (3.88); MMSE:27.52 (1.48)].

(*Serino, Morganti, Di Stefano, Riva, 2015*)

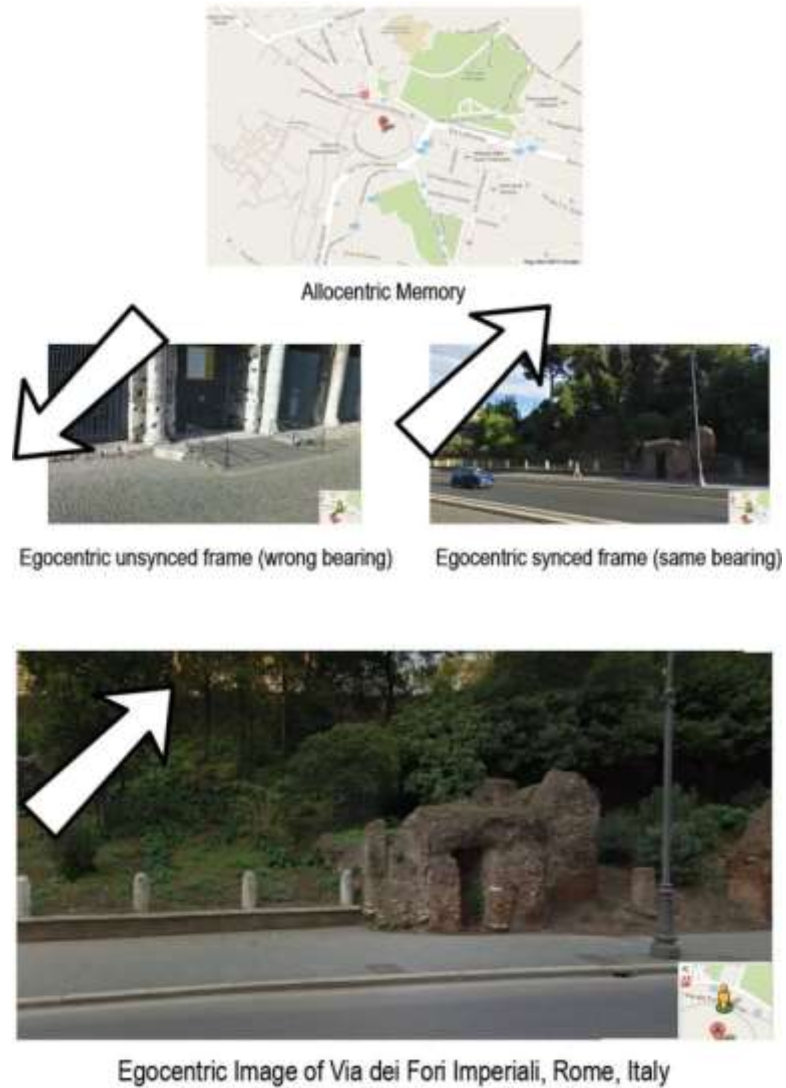
4. VR in Neuro Rehabilitation

Participants were asked to indicate on a real map (**Enconding phase)** the position of the object they had memorized, and then to retrieve its position from an empty version of the same virtual room, starting from a different position (**Retrieval phase**).

The entire procedure was repeated across three different trials, depending on the object location in the encoding phase.

4. VR in Neuro Rehabilitation

- These data indicated the presence of a deficit in storing an **allocentric viewpoint-independent representation** in aMCI patients.
- A profound deficit **was found in AD patients in the storage of an allocentric viewpoint-independent** representation and, consequently, in its synchronization with the allocentric viewpoint-dependent representation.



4. VR in Neuro Rehabilitation

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Getting lost in Alzheimer's disease: A break in the mental frame syncing

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A B S T R A C T

Despite the clinical significance of topographical disorientation in Alzheimer's disease, it is not clear which cognitive spatial processes are primarily impaired. Here, we argue that a deficit in "mental frame syncing" between egocentric and allocentric spatial representations causes early manifestations of topographical disorientation in AD. Specifically, patients show impairment in translating from an allocentric hippocampal representation to an egocentric parietal one for the purpose of effective spatial orientation and navigation. We suggest that a break in "mental frame syncing", underpinned by damage to the hippocampus and retrosplenial cortex, may be a crucial cognitive marker both for early and differential diagnosis of AD. Identification of these spatial deficits could facilitate the development of early cognitive rehabilitation interventions and the possibility of identifying individuals most at risk for progression to AD during the preclinical stages.

4. VR in Neuro Rehabilitation

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Hippocampal tauopathy in tau transgenic mice coincides with impaired hippocampus-dependent learning and memory, and attenuated late-phase long-term depression of synaptic transmission

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ABSTRACT

We evaluated various forms of hippocampus-dependent learning and memory, and hippocampal synaptic plasticity in THY-Tau22 transgenic mice, a murine tauopathy model that expresses double-mutated 4-repeat human tau, and shows neuropathological tau hyperphosphorylation and aggregation throughout the brain. Focussing on hippocampus, immunohistochemical studies in aged THY-Tau22 mice revealed prominent hyper- and abnormal phosphorylation of tau in CA1 region, and an increase in glial fibrillary acidic protein (GFAP) in hippocampus, but without signs of neuronal loss. These mice displayed spatial, social, and contextual learning and memory defects that could not be reduced to subtle neuromotor disability. The behavioral defects coincided with changes in hippocampal synaptic functioning and plasticity as measured in paired-pulse and novel long-term depression protocols. These results indicate that hippocampal tauopathy without neuronal cell loss can impair neural and behavioral plasticity, and further show that transgenic mice, such as the THY-Tau22 strain, might be useful for preclinical research on tauopathy pathogenesis and possible treatment.

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Behavioral/Systems/Cognitive

Human Hippocampal CA1 Involvement during Allocentric Encoding of Spatial Information

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A central component of our ability to navigate an environment is the formation of a memory representation that is allocentric and thus independent of our starting point within that environment. Computational models and rodent electrophysiological recordings suggest a critical role for the CA1 subregion of the hippocampus in this type of coding; however, the hippocampal neural basis of spatial learning in humans remains unclear. We studied subjects learning virtual environments using high-resolution functional magnetic resonance imaging (1.6 mm × 1.6 mm in-plane) and computational unfolding to better visualize substructural changes in neural activity in the hippocampus. We show that the right posterior CA1 subregion is active and positively correlated with performance when subjects learn a spatial environment independent of starting point and direction. Altogether, our results demonstrate that the CA1 subregion is involved in our ability to learn a map-like representation of an environment.

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Cognitive training (paper submitted)

- **VR-AD**: 10 AD patients were involved in <u>10 VR-based biweekly training sessions</u> [age: 86.6 (6.13); education: 9.8 (3.97); MMSE:22.05 (1.63)]
- **NONVR-AD**: 10 AD patients patients were involved in <u>10 traditional paper and pencil biweekly cognitive training sessions </u>[age: 88.7 (3,59); education: 7 (3.50); MMSE: 20.79; (1.47)].

No initial significant differences between the groups

4. VR in Neuro Rehabilitation

Participants were required to **find an object in a virtual city** (encoding phase).

Then to train their ability in the "mental frame syncing", **starting from another position in the city** they were invited to **retrieve the position of the object** they had memorized (retrieval phase) with an initial help of the right current heading to take.

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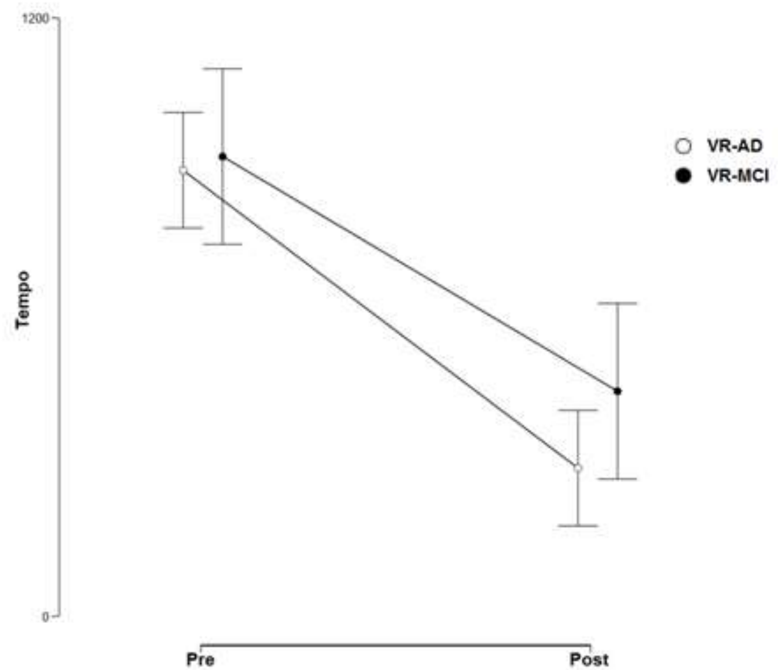
1. It emerged a significant decrease in the time needed to retrieve the object in the retrieval phase between the first and last session [$F(1, 14) = 12{,}829$, $p = ,003$, $\eta^2 p = ,478$].

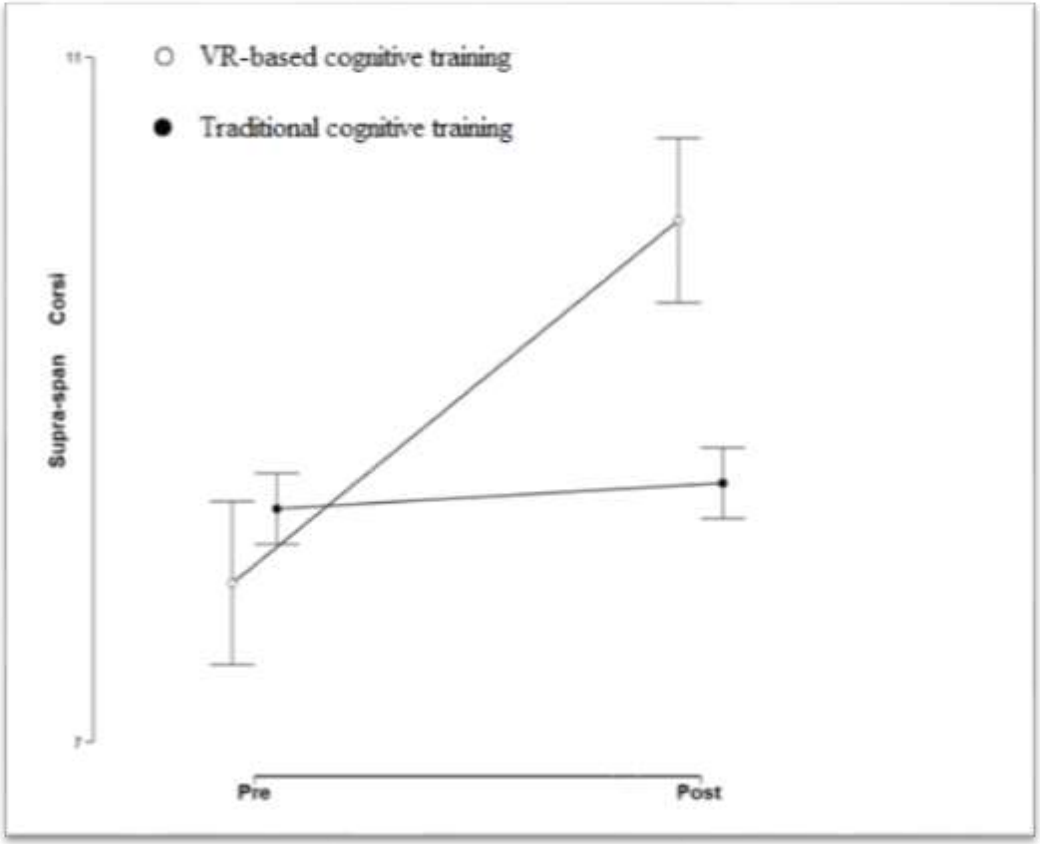
This may suggest a progressive increase in the ability to **functionally organize spatial knowledge**.



4. VR in Neuro Rehabilitation

2. It emerged a significant **improvement in spatial memory abilities** for participants involved in VR-based cognitive training [F(1, 22) = 4.798, p = 039, η2 p= ,179].

No improvement in CTRs



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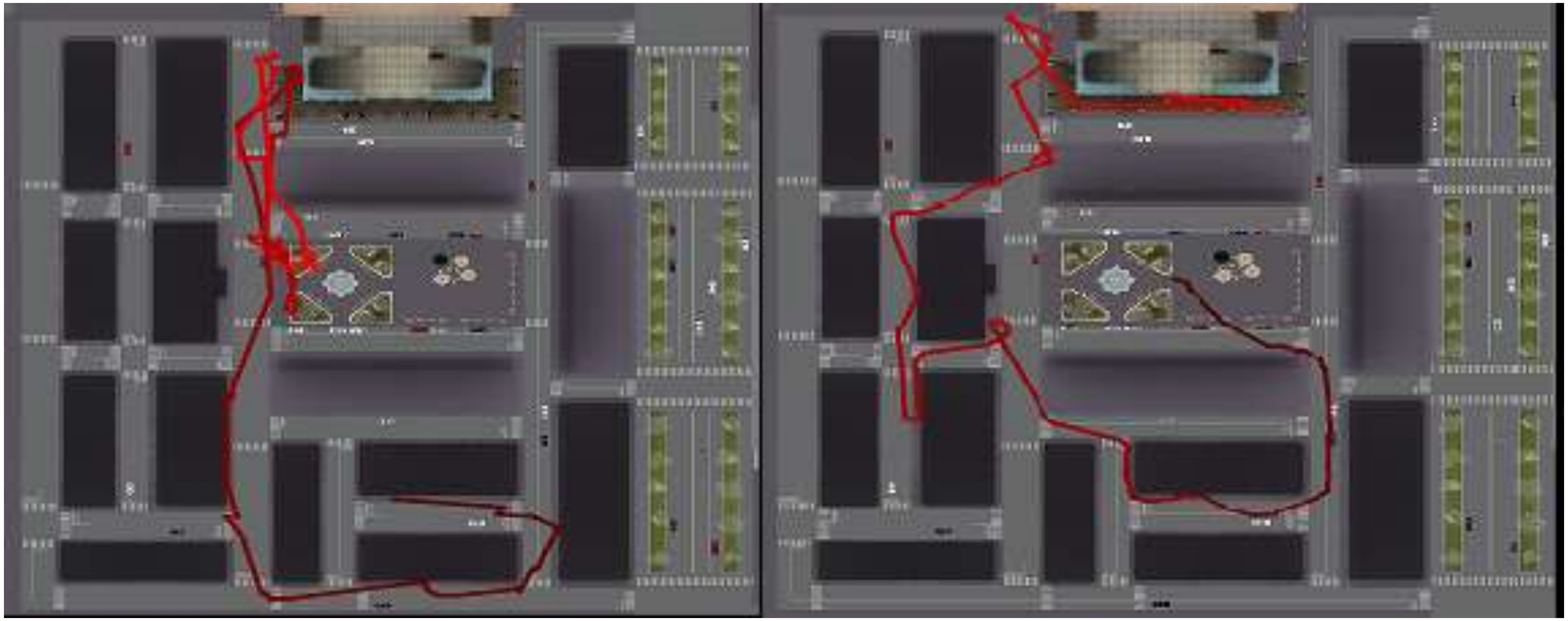
3. Navigation and search strategy improved significantly

Before **After**



4. VR in Neuro Rehabilitation

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Traumatic brain injury memory training: a virtual reality online solution

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Abstract

This study aims at assessing an online portal where patients with traumatic brain injury (TBI) can carry on memory and attention exercises outside clinic premises. The training took place in a virtual reality (VR) setup where one TBI patient had to complete a set of 10 online VR sessions. The neuropsychological evaluation was carried out with the PASAT (Paced Auditory Serial Addition Task) at pre-, during and post-treatment assessments. The results showed an increase in working memory and attention levels from the first to the final assessment, which can suggest that VR applications may promote the autonomy and increase in overall quality of life of these patients. The average time for task conclusion was 5 min.

Keywords: memory training; telerehabilitation; traumatic brain injury.

Results

PASAT data were analyzed for the corrected responses on each assessment (PTA, ITA, POSTA) for both trials, PASAT 3s and PASAT 2s (3 and 2 s inter-stimulus intervals, respectively). Values were considered significant for $p<0.05$.

Non-parametric pairwise comparisons were carried out by the χ^2 adjustment statistic to analyze the percentage of correct responses between assessments for both PASAT trials. For the first trial, data showed a significant increase in the percentage of correct responses between PTA and ITA [χ^2 2(1, 59)=23.438; $p<0.001$], and between ITA and POSTA [χ^2 2(1, 59)=41.667; $p<0.001$].

Regarding the second trial, data also revealed a significant increase in the percentage of correct responses between PTA and ITA [χ^2 2(1, 59)=4.356; $p<0.05$], and between ITA and POSTA [χ^2 2(1, 59)=5.689; $p<0.05$]. This means that the memory and attention exercises conducted in the VR world led to an improvement of the working memory and attention of this patient.

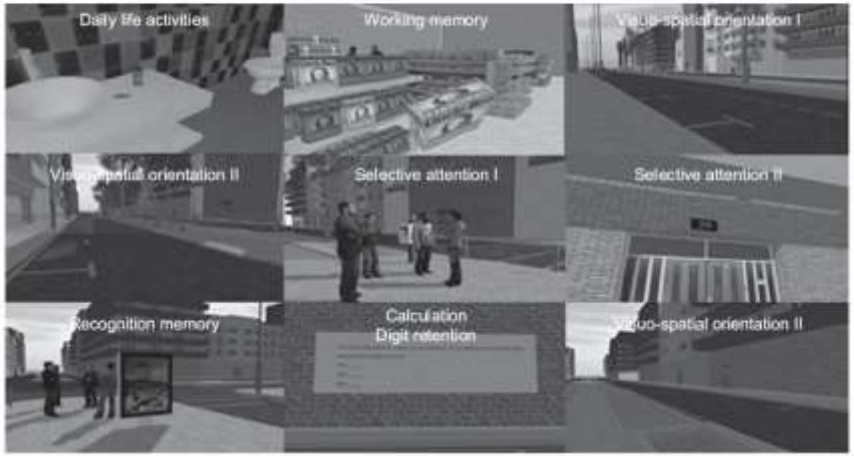
Descriptive analysis showed that the average completion time for each task was approximately 5 min.

Conclusions

The main goal of this study was to assess an online VR platform for cognitive telerehabilitation of TBI patients. A preliminary VR session was conducted in order to evaluate possible navigation and interaction issues with the environment. The patient was able to achieve a satisfactory level of performance after some practice, with an average time for each task of 5 min. These data revealed a significant increase in working memory and attention levels, suggesting an improvement on patient cognitive function, which is in line with other studies that used VR platforms to increase memory and attention (20).

The VR-based tasks consisted of 10 VR online sessions, as follows (see Figure 1):

- Session 0: training interaction;
- Session 1: daily life activities, such as morning hygiene and breakfast, and working memory task, such as finding the way to the minimarket and buying one item);
- Session 2: session 1+working memory task: finding the way to the minimarket and buying several items;
- Session 3: visuo-spatial orientation task I: finding the way from the minimarket back home;
- Session 4: session 1+visuo-spatial orientation task II: finding a different way to the minimarket;
- Session 5: session 1+a selective attention task I: finding a yellow dressed virtual character;
- Session 6: session 1+a selective attention task II: finding the door number 29;
- Session 7: session 1+a recognition memory task: retention of outdoor advertisements;
- Session 8: session 1+calculation and digit retention tasks: Mini-Mental State Examination (23) and Short test of Mental Status (24) tasks along the way;
- Session 9: visuo-spatial orientation task III: spawned on a different local of the VR world, the patient had to find his way back home with an item bought at the minimarket.



Conclusion

- There is a ‘**window of possibility**” to develop cognitive rehabilitation interventions by detecting and targeting earliest spatial deficits in “mental frame syncing”.
- VR appears to be an effective tool for **assessing and improving** the cognitive mechanism underlying **spatial memory**.
- Future studies are needed (i.e., other populations, improvements in other cognitive functions, follow-up, ecc.).