Virtual interaction in cognitive neuropsychology

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Abstract Several recent studies have investigated whether knowledge representation turns possible within virtual reality simulated environments. According to these affirmative results different clinical applications were developed in psychology. Among these applications virtual reality seems to have a specific role in assessment and treatment of neuropsychological diseases. This chapter will firstly investigate possibilities and challenges carried from virtual-reality-based neuropsychological application focusing both on patient’s and therapist’s point of view. Afterward it will provide a survey of research and intervention application examples. More in detail a clear explanation of contribution goals will be discussed, in order to place research and applied works within a cognitive neuroscience frame of reference, according with their usefulness and effectiveness in clinical treatment. Fulfilling these objectives neuropsychological virtual reality approaches in memory, motor abilities, executive functions and spatial representation will be shown.

1. Cognitive neuropsychology assessment and rehabilitation

Cognitive neuropsychology can be thought of as a specific discipline within cognitive psychology. In particular:

"Neuropsychology is cognitive to the extent that it purports to clarify the mechanisms of cognitive functions such as thinking, reading, writing, speaking, recognising, or remembering, using evidence from neuropathology" [1].

According to this purpose cognitive neuropsychology will use evidence about the selective breakdown of specific cognitive domains (eg memory, language, visual cognition, praxis) in a variety of neurodegenerative disorders to (a) examine the functional neuroanatomy underpinning those cognitive domains and (b) explore the implications of focal cognitive deficits in neurological patients for models of normal cognitive function.

A variety of central nervous system (CNS) dysfunctions may produce cognitive and functional impairments in human behaviours. Traumatic brain injury is the most frequent causes, and the resulting impairments commonly involve processes of attention, memory, language, spatial abilities, higher reasoning, and functional abilities. Moreover significant emotional and social, components generally co-occur and can also further complicate these areas.

Because of the pervasive nature cognitive dysfunction, the cost to individuals and society is significant.
Neuropsychology, as applied science, has evaluated what are the specific activities in the CNS that are linked with observable behaviours [2]. Furthermore neuropsychological assessment constitutes the fundamental approach for both the treatment and the scientific analysis of any CNS-based cognitive/functional impairment. A neuropsychological evaluation is a comprehensive assessment of cognitive and behavioral functions using a set of standardized tests and procedures. Various mental functions are systematically tested, including, but not limited to reasoning, language and perception. Neuropsychological evaluation can assist greatly in planning a had-hoc rehabilitative strategy in cognitive function recovery after brain injury. A measurement of treatment efficacy is also possible through neuropsychological evaluation in different follow-up periods. Finally it can also be invaluable for disability determination or for forensic (legal) purposes.

Classical approach to neuropsychological assessment was generally based on the use of pencil and paper tests and the measurement of cognitive/functional processes was based on two criteria: reliability and validity. The first is due to the capacity of consistently return the same results in evaluation, the second is concerned with how well an instrument actually measures what it purports to measure. Traditional tests present the neuropsychologist with both reliability and validity problems. The variability of administration procedures, due to differences in examiners or to the difference of stimuli presented can invalidate the reliability of traditional neuropsychological evaluation. Furthermore, the fact that some tests require multiple cognitive domains for successful completion could attenuate the validity of traditional assessment methods because it remains unclear what specific cognitive domain is being evaluated. Finally, “paper and pencil” neuropsychological testing has a limited ecological validity such as the degree of relevance that a test has relative to complex performance in an “everyday” functional environment [3].

In paragraph 2 it will be possible to understand how these problems may be avoided using virtual reality simulation in neuropsychological evaluation and treatment. For concerns clinical treatment, neuropsychological approach to rehabilitation aims to reduce cognitive disability in patients with acquired brain damage. Both cognitive processes and functional activities of daily living are typically targeted with this kind of intervention. Underlying the goals of both of these treatment areas is the concept of neural plasticity, such as the capacity of the brain to reorganize or repair itself following injury.

Brain plasticity is possible through various mechanisms (i.e., axonal sprouting, glial cell activation, denervation supersensitivity, and metabolic changes) and occurs in response to environmental stimulation [4]. If this view is accepted, stimulating training environments would seem able to support rehabilitative process and new approaches to cognitive rehabilitation would be warranted. Consequently, it can be appreciated that the stimulation or “enrichment” provided by neuro-rehabilitation approach may have some effect on the physical brain structure, and hence, training with well suited rehabilitative protocols would be assumed to positively affect brain plasticity.

Cognitive rehabilitation approaches can differ based on a variety of conceptual criteria [5]. According to Rizzo and colleagues [6] these conceptual dimensions can be resumed into two general domains: Restorative approaches that focus on the systematic cognitive processes retraining and Functional approaches that emphasize the training of observable behaviours. Both these approaches to rehabilitation have different methods and goals. The primary objective of the restorative approach is to retrain individuals how to plan and ideate behaviours, whereas the emphasis of the functional approach is to teach individuals how to perform day-to-day activities. Specific weaknesses have been identified in both of these approaches. For restorative methods criticisms are focusing on is the reliance on test materials and on the lack of generalization of ability to the person's real-world situation [7, 8]. The fundamental criticism of functional methods is that the learning
of procedures has to assume that patient lives in a static world where life demands do not change [5].

In paragraph 3 it will be possible to see how the application of VE technology for the rehabilitation of cognitive/functional deficits could serve to limit the major weaknesses of both the restorative and functional approaches, and actually produce a systematic treatment method that would integrate the best features from both methods.

2. Virtual Reality in cognitive neuropsychology

Along with interactive technologies growth, and in particular with virtual reality diffusion, a possible perspectives modification for the assessment and rehabilitation of cognitive functions turns possible. Several researchers agree in underline how virtual reality (VR) should allow the development of suitable and extremely useful virtual environments for cognitive functions rehabilitation [9, 10, 11, 12].

The main innovation carried out from VR is on the possibility in having a new human-interaction type. All user body movements should become potentially very important during the interaction with a virtual environment (VE), within which all the modification in the VE will change back a new action opportunity for the same user. In any case VE doesn’t have to be considered equivalent to the “natural” environments, but environments trough which is possible to have obvious experiences well designed for our goals. A virtual environment even remains something different from a real environment [13].

Determinants that contribute on increasing attention in using interactive-computerized simulations, such as VR, in neuropsychology are various. First of all VR allows the creation of a completely multimodal patient stimulation that will be able to supply patients, by a completely immersive interaction with VE, with a great sense of involvement in action, generally defined presence [14, 15]. Just presence is assumed to be essential for the acquisition and recovery of complex behaviours. According to this, VR interfaces developed for neuropsychology were ideated in order to be able to support a reality judgment or a plausibility impression towards actions that patients are performing within simulated worlds.

Furthermore supporting virtual reality introduction in rehabilitation, several recent studies show how not only knowledge acquisition will be possible in VR but also how this acquired knowledge could be transfer in a real environment [16]. This evidence adds value on VR use in highly social disabling cognitive functions rehabilitation, highlighting how goals reached in controlled settings may be transfer on patients’ everyday life.

2. Why use it and why not

In the last ten years several researches have contributing in develop guidelines for the creation of useful tools in neuropsychological rehabilitation [17, 18]. Among these, applications have left off the use of very expansive and awkward technologically advanced systems in order to focus attention on VR systems and giving the possibility of enhance patient with an high action involvement sense, even through simpler interfaces.

Furthermore, it has spread the inclination on creating ergonomically optimized systems in order to easily use it with cognitive-motor impaired people. Finally it has started to provide for the possibility of create VR systems flexibly conveyable in order to allow a continuous rehabilitative course even out of medical structures without disclaiming in have control possibility on treatment propriety (e.g. tele-assistance).
Main advantages in innovative technology use in cognitive and motor functions assessment and treatment may be resumed in three main aspects. First of all, VR systems allow to potentially have in input all patient actions and are also able to transform these action in different ones within the virtual environment (VE). This aspect turns to be very highly-prized in patients who have the necessity of substitute impaired actions with alternative movement possibilities, such as in hemiparetic patients. Furthermore, VR systems can provide multimodal stimulation that, firstly, avoids in over-stimulate the perceptive system, and also allows to provide patients with behaviour cues on multiple or alternate sensory ways. This will support more accurate knowledge integration and an efficient learning.

Finally, virtual environments give the opportunity of situate patients within settings that in not simulated environment could be unapproachable, dangerous or stressful for them.

More in details VR allows new opportunities for evaluation and treatment of neuropsychological disorders generally not available with traditional methods [19]. Using virtual environments, in fact, it is possible to provide patients with “ecologically-like” situations that could enhance even more efficient goal oriented planning behaviours in rehabilitative tasks performances. Moreover, the immersive experience in VR induces patients in forgetting they are involved in evaluative or training session, supporting a more spontaneous performance. This aspect turns VR-based treatment an effective user-centred training approach, even more because patients may have a detailed monitoring of rehabilitative progresses they are reaching. According to these advances is possible to obtain a congruous therapy modification. VR training settings made able patients in acting within a safety environment firstly avoiding anxiety linked to particular performances, thus enhancing confidence in action execution and finally increasing motivation improving autonomy within everyday-like situation. Moreover acting in a sheltered scenario made patients aware of limitations the pathology cause them and of risk he/she could run up against with and imprudent conduct, such as cross the street or moving around within the kitchen.

If accepted in a focused rehabilitative protocol and not used like entertainment VR tools are able to conciliate a playing aspect spread from computerized interfaces with efficacious treatments enhancing patient’s motivation in pursue therapy.

<table>
<thead>
<tr>
<th>VR Application</th>
<th>Benefits</th>
<th>Challenges</th>
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| Neuro-muscular    | o Improved Compliance  
                   o Fine time resolution  
                   o Rehabilitation at home  
                   o On-line data gathering | o Equipment cost  
                   o Technical expertise  
                   o Safety at home  
                   o Network bandwidth |
| Post-Stroke       | o Engaging/motivating  
                   o Repetitive intensive  
                   o Adaptable to patient condition  
                   o Usable in chronic phase  
                   o Activities of daily living | o Clinical acceptance  
                   o Technical expertise  
                   o Abnormal limb configuration  
                   o Upper functional population applicability |
| Cognitive functions| o More realistic assessment  
                   o Reduced therapy cost  
                   o Increased safety  
                   o Learning transfer | o Equipment cost  
                   o Safety at home  
                   o Psychological factors |

**Figure 1.** Benefit/challenges in VR neurological applications
In spite of its benefits, rehabilitation in VR already shows significant challenges for its adoption. First of all, for the function recovery treatment efficacy, there is a clinical non-acceptance of VR based or VR augmented rehabilitative protocols necessity. Medical and cognitive rehabilitative studies are still underway and not definitive data actually exist on VR rehabilitation effectiveness. However it should be said that in initial data collected with post-stroke chronic patients VR has been shown to improve performances even long after any classical therapy stopped [20]. Another important challenge is supported by the idea that virtual rehabilitation should replace the therapist altogether with computers, whereas VR will be a precious tool for therapists, allowing them to do more with more patients.

Finally there is a technology gap that increases resistances to computer based application. VR interfaces and particular devices are something therapist and users are not generally familiar with, but if “forced” in using VR interfaces patients and their relatives show a clear enthusiasm in embracing such type of rehabilitation.

In spite of VR approaches benefit/challenges comparison, resumed in Figure 1, it seems very important to investigate and develop innovative rehabilitative techniques, supported from advanced technologies, in order to improve the recovery of cognitive and motor functions in neurological patients.

3. How use it

Considering differences with VR interaction in healthy subjects, it is not difficult to understand how rehabilitative approaches had to focus on particular type of VR interfaces that will be able to support motor and cognitive function’s recovery. In doing this VR systems had to be very flexible in order to accommodate themselves according to variety of deficits that could be present among patients and even in patients with same diagnosis.

Up to now evaluative and rehabilitative VR application were, on one site, generally oriented to run an assessment of innovative technologies efficacy and, on the other site, specifically focused on impaired function rehabilitation. From the survey carried out below, it will possible to see how different approaches in VR application were provided.

According with assessment-rehabilitative protocol used it will be possible distinguish between a VR-augmented clinical application (in which patients receive “classical” exercises combined with VR exposure sessions) and a VR-based clinical application (the newer approach in which “classical exercises are eliminated and substituted entirely with VR interactions). These different approaches imply different methodological choices and, how we’ll see afterwards, will conduct researcher to different conclusions on VR efficacy.

VR clinical application will be explained according to cognitive function they are addressed for, such as memory, plan and/or motor abilities, executive functions and knowledge representation.

Table 1 will resume VR application for the evaluation and training of impaired cognitive functions.

4. Memory VR applications

Memory disorders are one of the most disabling consequences of acquired brain injury and according to this cognitive rehabilitation programs had largely focused on it. There are, in fact, many “paper and pencil” neuropsychological assessment tests to measure such cognitive functions. Unfortunately, even if they are specifically devised to measure different forms of memory, they were been criticized as lacking in measure everyday
<table>
<thead>
<tr>
<th>INTERVENTION</th>
<th>APPLICATION</th>
<th>AUTORS</th>
<th>GOAL</th>
<th>CONCLUSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMORY</td>
<td>Assessment</td>
<td>Brooks et al. 2002</td>
<td>Perspective memory evaluation</td>
<td>VR as interesting tool</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Brooks et al. 1999</td>
<td>&quot;Error free&quot; memory recovery approach</td>
<td>VR for errors prevention</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Andrews et al. 1995</td>
<td>Comparison of incidental memory in active/passive interaction</td>
<td>VR as a good instrument for incidental memory assessment</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Gisky et al. 1994</td>
<td>Vanishing cues method for memory rehabilitation</td>
<td>VR provide information that could be reduced according to progresses</td>
</tr>
<tr>
<td>PLAN AND MOTOR ABILITIES</td>
<td>Assessment</td>
<td>Rose et al. 1998</td>
<td>Monitor patient's reaction to specific stimuli</td>
<td>VR for selective motor response evaluation</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Broeren et al. 2002</td>
<td>Haptic stimulation importance</td>
<td>VR as test method for functional motor skills</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Morganti et al. 2003</td>
<td>How VR can support action simulation process in motor rehabilitation</td>
<td>VR can support active construction of motor plans in stroke patients</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Zang et al. 2001</td>
<td>Is VR-based motor rehabilitation transferable to real environment?</td>
<td>VR tools for everyday performance recovery training</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Holden and Todorov, 2002</td>
<td>The importance of augmented feedback in VR rehabilitation</td>
<td>VR training shows a great improvement in motor rehabilitation</td>
</tr>
<tr>
<td>EXECUTIVE FUNCTIONS</td>
<td>Assessment</td>
<td>Lo Priore et al, 2003</td>
<td>Dysexecutive syndrome assessment in VR</td>
<td>VR for training in objects recognition and use</td>
</tr>
<tr>
<td>SPATIAL KNOWLEDGE REPRESENTATION</td>
<td>Assessment</td>
<td>McGee et al., 2000</td>
<td>Comparison between traditional assessment and VR-based one</td>
<td>VR as effective assessment tool for spatial knowledge</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Morris et al 2002</td>
<td>Egocentric/ allocentric spatial memory</td>
<td>VR allow combination of egocentric and allocentric tasks in the same session</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Maringelli et al. 2001</td>
<td>Attention assessment in peripersonal/extrapersonal space</td>
<td>VR highlights asymmetry in stimuli detection generally not detectable in normal subjects</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Holden et al 1999</td>
<td>The importance of observational learning</td>
<td>VR improves complex spatial learning and the possibility of generalize it</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Wann et al 2001</td>
<td>Binocular information in grasping rehabilitation</td>
<td>VR as interesting tool for grasping rehabilitation</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Bertella et al. 2001</td>
<td>Topographical disorientation</td>
<td>VR for training in safety environments</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Myers and Bering, 2000</td>
<td>Neglect syndrome rehabilitation</td>
<td>VR could better simulate eye-patching strategy in neglect recovery</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Weiss et al. 2003</td>
<td>Crossing street ability recovery in Neglect patients</td>
<td>VR enhances careful behaviours in everyday-like situations</td>
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</table>
memory abilities. Several researches assume that this problem may be overcome assessing memory functions in VR.

For example, in assessing prospective memory (remember to perform action in the future), Brooks and colleagues [21] had developed a VR system able to study cue-based, time-based and activity-based memory retrieval. In order to do this they have developed a four-rooms VE, navigable on desktop modality. Patients were requested to remember and classify objects (cue-based task), to remember and use objects (activity-based task) and to remember in performing action in time (time-based task). From this experiment authors were able to conclude that, compared to standard tests, VR was an interesting tool for controlled assessment of prospective memory ability.

In studying incidental memory (the explicit memory of an event encoded without intention), Andrews and colleagues [22] compared memory performances in non-patient subject using both highly interactive and static VR interfaces. Furthermore authors stressed the importance of active negotiating action in VR contexts comparing memory performances of active users in VR with memory performances of a yoked passive observer. Results show how passive participants were more able to memorize events than active ones, which were attentive engaged in interacting with VR. These data could open an important discussion on active-passive dichotomy in object, events and spatial memorization that is actually ongoing. Even in is possible to have an attentive interference in memory process, several authors, in fact, stressed the importance of active participation in planning or execution of action as a fundamental factor for events learning and place memorization [23]. In a second experiment done by the authors, results appear discordant.

Even if passive observers were able to remember object position within an environment, active participants were more able to learn and memorize the entire environment; even if they were engaged in a goal-oriented task during the VR exploration.

If not explicitly requested to participants, spatial layout memory recall seems to be a very useful test for incidental memory in active participants.

In memory function recovery, VR was used both for restore function (repetitive memory exercises in order to improve performance in memory task), both for reorganize memory function (use intact function to aid damaged one). The first approach was generally considered as limited in recovery success and for this reason it was not largely used even with VR. In patients with dementia a PC-based virtual apartment was used in order to increase memory performances [24]. VR application appears to be an interesting tool to creating differentiates memory techniques and increasing patients’ motivation.

In reorganizing memory function an “error-free” learning approach was used with amnesic patients. These patients in fact had generally lost the capacity of distinguish between correct and incorrect responses and show tendencies on use errors as cues for successive performances [25, 26]. Using a VR environment therapists were able to prevent and avoid patient’s errors [27]. Furthermore, Glisky and colleagues [28] used a “vanishing cues” method in which they used a VR system to provide patients with information that could be reduced according with patient progresses. Using this method authors were able to teach amnesic patients in interacting with complex situations. The same author runs an important work in memory and motor remediation with severe amnesiac patients [29]. The study aims to investigate if patient with amnesia could already learn particular motor tasks.

If, for example, an amnesic patient is impaired in verbal memory function he/she generally could be preserved in motor task ability; but is he/she able to learn novel action task? In a VR based system authors investigated if these patients were able to trace a drawing while they are looking at their “mirrored” hand displayed on the screen, and not directly to their real hand. Results show how, even they are not aware in having performed this specific action before, amnesic people were able to learn and perform even complex motor actions.
How easy to understand, virtual reality hold an important role in memory assessment and treatment. Moreover it seems to be able in facing with different cognitive impairment forms in which memory disorder could appear.

5. Plan and motor abilities VR applications

Even in motor planning and execution VR was largely adopted assuming diversified roles according with research and treatment goals. Avoiding in doing a long list of work that have included VR in their protocol, my specific goal in this chapter is on providing some examples of how is possible take advantage in using VR according with strategic objectives in rehabilitation.

A possible approach according to Wilson and colleagues [30], for example, should be in developing a VR tool in order to give patient action possibilities. This becomes possible avoiding physical limitations determined from patients’ own disability. The system allows patients in actively construct and execute action within a simulated environment turning them able in interacting with the environment through sensory channels different from impaired ones. This approach turns patients autonomous in their everyday environment increasing their motivation in performing actions.

According to another point of view Rose and colleagues [31] have developed a VR system able to substitute natural environmental stimulations with artificial stimuli derived from VR system. The aim of their work was in monitoring patient’s reactions to specific categories of sensory stimuli and in assessing if patient’s capacity of make relations among different kinds of stimulation was preserved. This VR use appears to be precious in residual capacities evaluation; in particular when pathology symptoms appear confused. Had hoc VR tools allow to provide patients with specific type of stimulation according with assessment goals. Moreover VR systems were able to monitor all patients’ reactions to such kind of stimuli, in order to determine selective impaired functions. This approach requires innovative technology support and seems to be very difficult to conduct without computer-based systems; Especially because it turns very hard managing and monitoring several different variables contemporaneously. VR systems may allow this complex process on line or even in a post-hoc analysis.

The importance of haptic feedback was investigated in a controlled study [32]. A VR haptic device was used in order to test procedure for the qualitative assessment of motor coordination in post-acute stroke upper limb rehabilitation. Patients involved in this research are requested to make a coordination task such as reach, grasp and move a haptic device to different generated position on the screen. Movement device coordinates were monitored and also targets position, time, and trajectories distances were registered. Results show how, comparing velocity and accuracy, the VR system seems to be able to establish a test method for measurement of upper extremity functional motor skills between healthy individuals and stroke patients. Increasing the complexity of the task authors are satisfied the VR system will be able to lead in motor recovery. The haptic return possibility is an important focus area in VR-rehabilitation-system planning and development. Even if, with simple perceptive stimulation and feedback system, patients were able to derive enough information during motor exercise, haptic modality seems to provide an important added value in correct task execution within VR. Through haptic device VR tools become even more similar to “real” motor execution path. Moreover providing haptic tools during motor performance it is possible to increase sense of presence that seems to be necessary to a good and lasting learning.

Another possible approach to VR rehabilitation is on combining action simulation processes, such as imaginative exercises, with VR stimulation in order to enhance the
recovery of motor function in brain-injured hemiplegics patients [33]. This approach aims in develop egocentric and allocentric upper-limb motor imagery exercises that will be supported from VR multimodal stimulation and feedbacks. Through constructing their own personal image of the motor behaviour that has to be trained, patients were allowed in elaborate their own schema and sequences of movements. This will be possible by displaying highly stylized sketches of the motor behaviour on a computer screen and gradually increasing the perceptual realism of the visualization until optimal learning is achieved. Contrary to the “vanishing cue” technique explained in memory rehabilitation paragraph [34], in this approach VR does not “substitute” perceptual information by depicting all body imagine involved in movement, and decreasing it according to patient’s progress; VR stimulation provided in this protocol should be something like perceptual or auditory action cue able to support active re-creation of movement paths. Inferring on actions schemas relations, actively reasoning about performance execution and contemporaneously being supported by VR multimodal stimulations, patients could individuate their own way to perform actions and learn to execute them in order to reach their goals. Furthermore user-centred portable VR systems could be provided allowing patients in continuing their rehabilitative training at home, according with progresses reached in controlled rehabilitative sessions.

An interesting research was recently run in order to assess if complex motor behaviours acquired in VR environment are transferable to similar not simulated environment [26]. The study implies that several cognitive domains, assessed in VR environment, should be associated with ability to face up with everyday activities and challenges. Within a VR kitchen, fifty-four right and left traumatic brain injured patients were involved in meal preparation tasks that implies multiple action steps. Different kinds of cues are provided when patients turn not able in continuing the task; several feedbacks are given them in order to enhance motor learning. The authors concluded that, with this VR system, there is a good reliability and concurrent validity for assessing patient with brain injury in complex motor tasks and also that VR is a good predictor of the same performances in a not simulated kitchen. According to this research is possible to emphasize once more how there could be a transfer of procedural knowledge from virtual to natural environment, supporting the importance of VR in everyday performances recovery training.

Finally, exploring rehabilitative VR applications in motor function recovery it will be possible to highlight how an interesting use of VR systems could be in enhancing feedback provided to patients. Giving them an “augmented feedback”, in fact, Holden and Todorov [35] had developed a system able to detect patient’s errors and return it to him with an overextended feedback signals, in order to cueing and correcting upper limb motor action. Action task was developed starting from target desired movement (such as putting and envelope into a mailbox slot) and not on specific motor skill (such as reaching, grasping and extending). In stroke patients a rehabilitative harm motion protocol through imitative learning was developed. Patients were requested to perform, in natural and VR environment, a goal oriented movement by imitating action displayed. Results show not only an improvement in virtual task performance but also a transfer of capacity in not simulated environment.

Finally it seems proper to say that according with its highly interactive proprieties, VR was largely used in motor rehabilitation but only selected example of possible application were provided here. This chapter goal, in fact, is in providing cues for assessment and rehabilitative application that could be developed and modified according with different clinical needs.

Furthermore among motor behaviour impairments I’ve not mentioned action deficits due from executive function damage that will be treated in the following paragraph.
6. Executive functions VR applications

The term “executive functions” is generally referred to a group of behavioural skills that includes [36]:

a) the ability of planning a sequence of actions,
b) the ability of maintaining attention in time,
c) the ability of avoiding the interfering stimuli and using the feedback provided by others,
d) the capability of coordinating more activities together at the same time,
e) the cognitive and behavioural flexibility and
f) the other abilities used to cope new situations and stimuli

Loss of executive functions is primarily a consequence of brain injury located in the prefrontal cortex area. As Damasio [37] pointed out, in everyday life patients may show great limits, decisional problems and inability connected with high levels of social inadequacy. In cognitive rehabilitation, traditional protocols are mainly centred to protect or recover the basic instrumental cognitive functions in a clinical or lab setting, but executive function cognitive rehabilitation should require particular attention in relation to their real-life behaviour consequences. According to Damasio it could be underlined four main failures of the laboratory situations to mimic reality: a) choices and decisions are only to be evoked, not to be really performed; b) there is a lack in the normal cascade of events as actions and reactions; c) temporal frame is generally compressed; d) situations are not really presented, but only described through language.

VR was specifically indicated to allow patients in recovering their planning, executing and controlling skills by implementing sequences of actions and complex behavioural patterns that are requested in everyday life [38, 39].

Moreover, both in the assessment and in rehabilitation of dysexecutive symptoms and frontal lobe syndrome, the employment of computer based tools and virtual environments seem to have another fundamental advantage with respect to traditional non-immersive means.

Regarding computer based applications used in the assessment of cognitive functions the Tower of London (TOL) Test [40] has been studied in order to obtain a touch-screen computerized version [41]. With this TOL computerized version there was the possibility to carry on a more detailed performance analysis obtained from the registration of patient movements. Moreover the Wisconsin Carding Sorting Test (WCST) [42] has been studied in order to obtain different computer-based versions [43, 44] such as the Bexley-Maudsley Category Sorting Test [45]. With these tests version it is possible to save time in the scoring step, to simplify all the procedures, to create and show new integrates multi-media scenarios more similar to reality than traditional approaches [46].

Following these assumptions the V-STORE application, depicted in Figure 2, uses a traditional protocol integrated with sessions of Virtual Reality [47].

V-STORE is a close environment within which patients have to reach objects and moving it from one recipient to another according to therapist verbal commands. In this case therapist can even introduce a series of distracting events, such as speed modification, in order to increase difficulty and generate time pressure.

For each trial, the system is able to record accuracy, execution time, movements and planning in subject performances in order to allow further analysis. Furthermore the managing steps taken to face distracters or difficulties encountered during the task, that often constitute the greatest limit for frontal patients could be monitored.

For each trial, the system is able to record accuracy, execution time, movements and
planning in subject performances in order to allow further analysis. Furthermore the managing steps taken to face distracters or difficulties encountered during the task, that often constitute the greatest limit for frontal patients could be monitored. A pilot study conducted in this environment has shown encouraging results on V-STORE applicability with pre-frontal patients.

Using a VR everyday-like environment it was possible to train patients’ abilities in recognizing object and use it within a monitored situation. Further more V-STORE training approach, such as more VR application in rehabilitation, could enhance a playing aspect in function recovery.

7. Spatial Knowledge representation VR applications

Through their 3D graphical sort and their high interactivity possibilities, environments developed in VR were generally used especially for visuo-spatial assessment and treatment.

Among this intervention area, VR applications seem to be varied. VR, in fact, was applied on evaluation and treatment of spatial knowledge in general, topographical disorientation and visuo-attentive deficits such as neglect syndrome.

7.1 General spatial learning

In order to evaluate if a spatial learning is possible in VR simulated environments and if this learning was transferable to not simulated environments several studies were conducted [48, 49, and 50].

Firstly McGee and colleagues [51] ran a comparison between “paper and pencil” assessment tools and computer-based ones. VR interactive scenarios result to be effective in neuropsychological healthy subjects’ spatial abilities assessment. A different VR use in neuropsychology was in evaluating the observational learning of spatial tasks in stroke patients [52]. This application aims in enhance recovery of explorative functions within a complex VE through imitation of action performed by the therapist in natural environment.

At the end of the training, patients were not only able to learn complex exploration behaviour but also to generalize this knowledge to not simulated contexts.
Another VR rehabilitative approach was analyzing the binocular information role in visual amnesic patients involved in a grasping task within a virtual environment [53]. Object depicted in VE could vary in shape, dimension and movement velocity. Furthermore it could be possible to change depth indexes through which it turns possible visualize object in VR. This work allows highlighting how using VR systems is possible to obtain interactive simulation hardly obtainable in natural environments or in laboratory settings.

Finally a research on egocentric/allocentric memory brain correlates was run using VR environments [54]. Anoxing hyppocampal damaged patients were tested in memory tasks within a VE and fMRI study was conducted. According with O’Keef and Nadel study [55] hyppocampal activation was registered only in allocentric memory task. VR gave in this case the opportunity of combining egocentric and allocentric spatial memory tasks in the same experimental session allowing fMRI observation without artefacts.

7.2 Spatial disorientation

Several studies were conducted in order to investigate if VR could be an interesting tool to recover spatial disorientation skills in children who were impaired in mobility by their physical disabilities. In particular they want investigate if a complex spatial performance acquired in VR may be transfer to the same not simulated environment, increasing spatial mobility in disabled people [56]. These studies highlight improvement of spatial abilities in natural environment in patients who had rehabilitative session in VR and stresses the importance of assess memory in VR environments in order to create ecologically situation that are not possible with other assessment forms.

In order to evaluate and recover patients with topographical disorientation a VR based environment was developed [57]. Both patients with topographical agnosia (the incapacity in recognizing places) and topographical amnesia (the incapacity in remember position places) were repetitively immersed in suited VR. The peculiarity in this VR approach is on training disabled patient within a safety environment leaving them to be actively free in exploration.

Finally in Alzheimer disease VR-based rehabilitation seems to give new possibilities in recover orientation functions if linked with auditory devices that could add integrated feedbacks on perceptive experience [58].

7.3 Neglect

Among spatial knowledge representation an important impairment was represented by unilateral spatial neglect syndrome. Persons with right hemisphere stroke are particularly vulnerable to visuo-attentive deficit of the left side of space. After stroke on the right side, not only is detail less readily perceived in the part of space opposite to the lesion site, but in some cases global perception overall is disrupted.

The introduction of VR application in research on neglect syndrome had developed a large range of application areas. Maringelli and colleagues [59], for example, studied egocentric/allocentric based attention orientation using VR tools. Using VR it was possible to authors provide or not provide participants with a body simulation in VE and evaluate if they were able in pay attention on stimulation provided in peripersonal or extrapersonal space.

Results shows how participants were able to detect proximal stimulus when their body was provided in VR and how data are opposite when body was not provided. This kind of asymmetry, optimally derived from VR simulation, results to be present in patient with neglect and not generally evident in normal subjects.

In neglect rehabilitation, VR was firstly used combined with traditional rehabilitative approach stressing how this kind of combination could improve visuo-attentive function
Rehabilitative protocols that used only VR approach were generally focused on the possibility of track patient’s position, and tried to “anchor” attention to neglected spatial area.

According to this approach Myers and Bering [61] developed a VE and presented to patient with a left visual distortion. Some object presented within the environment moved from right to left in order to lead patients in direct attention towards this environment side.

Simultaneously a dark area was presented on 30% right environment area (such as eye patching strategy in natural environment). If patient was able to rotate his head on the left side the dark area decreases until disappear forcing patients in directing attention on the neglected area. Even results appeared not clear this VR application shows the potentiality of interactive scenarios in rehabilitation.

Another important VR use in neglect rehabilitation is on everyday patients’ activities [62]. A safety training VR environment was developed in order to teach patients in crossing streets in a safety manner. Multimodal feedbacks were provided in order to enhance careful behaviours in everyday-like situations. Patients becomes progressively able in manage complex activities not only in VR but also in a real street.

In conclusion it is possible to state how a specific rehabilitative intervention area such as neglect syndrome, and also in general spatial representation, VR stimulation thanks to its high interactivity property may constitute an usable and safety tool for everyday functions recovery.

5. Conclusion

How is possible to note, nowadays VR introduction in neuropsychology seems to be wide and largely consolidated. Among cognitive function evaluation and treatment VR systems application are several, moreover VR approaches in specific cognitive function recovery appear differentiate. This contribution had the intention of point out if it was possible to use VR in cognitive neuropsychology, and also how was the use of this innovative approach in evaluation and rehabilitation of cognition.

As I have pointed out in this chapter, within a VR environment the complexity of stimulus challenges found in naturalistic settings could be delivered while maintaining the experimental control required for rigorous scientific analysis. These results could have greater clinical relevance and direct implications for the development of more effective rehabilitation approaches. Moreover VR systems can provide repeated learning trials and offer the capacity to gradually increase the complexity of tasks while decreasing the support—feedback provided by the therapist. Finally VR can help to address rehabilitative goals by allowing the development of low-cost training environments eventually consistent with the client's home environment.

Lastly I would clarify how it turns important that neuro-rehabilitation works through, not only a passive repetition of behaviours that have to be recovered, but also on active involvement of patients in planning and execution of behaviours. According to this, VR could be considered as a new medium defined in terms of its effect on evaluation and treatment of brain dysfunction within cognitive neuropsychology approach. Patients involved in an active interaction with VR, in fact, were able to create different mental models in order to understand and learn how to correctly perform or recover correct behaviours. VR systems developed according to these objectives could be even graphically simple environments (even 2-dimesional ones) but have to allow a large range of patient’s interaction possibilities. Objects included in a virtual environment have to be partially or totally modified through an active “virtual manipulation” and interaction with the environment have to provide them affordances [63] for new action choice. In a cognitive
neuropsychology approach evaluative and rehabilitative protocol linked with VR should have to make patients able to create new personalized and self-made cognitive strategies in order to improve their independence also to unfamiliar environments. Interacting with VR patients should be able in creating representation of actions and in consolidating representation generalizing learning event to not simulated environments.

The new challenge in cognitive neuropsychology application approach have to be not only in creating a versatile and engaging tool, able to substitute the classical ones, but also on support the growth of a focal instrument. Innovative VR-based applications would be able to ideate a rehabilitative setting customized on specific patient’s need and would allow to project a rehabilitation that can be modified according to patient’s achievement.

Supporting an active self-creation of representative learning strategies, the interaction between patient and VR may enhance the creation of autonomy processes and helps the generalization of learning. More than a playing tool supporting cognitive or motor performances VR simulation has to provide a powerful chance to build personal meaning, map and strategies interacting with it. The possibility of modifying the environment interacting with it will help patients finding themselves new cues for behaviours.

6. References


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Neuropsychology Studies the structure and function of the brain as it relates to psychological processes and behaviors. Lesion studies in humans and animals Neuroimaging studies, EEG studies Behavioral Studies. 5 Neuropsychological Assessment Forms the core of Neuropsychology The means by which Neuropsychologists traditionally assess cognitive functioning Assessment methods Paper and pencil tests Computerized tests Questionnaires.