An Innovative Virtual Reality-Based Training Program for the Rehabilitation of Cognitive Frail Patients

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Abstract. Cognitive Frailty is one of the most common age-related disabilities in elderly. The two most damage cognitive domain in these patients are memory and executive functions. An innovative virtual reality-based training program for the rehabilitation of cognitive frail patients are proposed. The training is focused both on memory and executive functions and is possible to combine the two tasks according to the needs of the patients. The program could be done both with low-end (personal computer) and high-end (CAVE) virtual reality systems to guarantee the continuity of treatment from the hospital to home.

Keywords: Cognitive rehabilitation · Memory · Executive functions Virtual reality · CAVE

1 Introduction

1.1 Cognitive Deficit in Elderly

Cognitive impairment in the elderly is one of the most common age-related disabilities and, to prevent the negative consequences of this decline, it is usually accepted how it is important to act promptly by targeting rehabilitation programs. Accordingly, the focus of intervention should be in the pre-clinical or early stage of the cognitive impairment. Prompt interventions could improve the ability of the elderly individuals and preserve their autonomy, thus avoiding an early hospitalization.

Recently, the International Consensus Group composed of the International Academy on Nutrition and Aging (IANA) and the International Association of Gerontology and Geriatrics (IAGG) [1] proposed the identification of the Cognitive Frailty (CF) to better describe elderly individuals who are at a preclinical stage.

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The two main criteria was used to correctly recognize this syndrome:

- the presence of cognitive impairment and physical frailty;
- the exclusion of any other types of dementia.

Physical Frailty could be diagnosed when patients show at least 3 of these 5 physical criteria: (1) slow gait speed, (2) unintentional weight loss, (3) weak muscle strength, (4) exhaustion, and (5) sedentary behavior [2].

However, there are no clear indications about battery for the assessment of CF. Understanding the unique cognitive profile of patients with CF could lead to a prompt diagnosis and a timely rehabilitative intervention which is crucial for the potential reversibility and prevention of CF [1–3].

Delrieu and colleagues [3] have made a first attempt to define a neuropsychological profile of patients with CF. Specifically, they found deficits in processing speed, selective attention, free recall, and mental flexibility. Impairment in Executive Functions (EF) is the most common outcome of studies about the neuropsychological profile of CF [3–5].

Beside impairments in EF, another common deficit in elderly individuals may be found in a very specific domain: Spatial Memory (SM). Specifically, topographical disorientation is one of the most common deficits in the early stage of dementia, especially in Alzheimer Disease (AD) [6–8]. A recent study indicated that long-term allocentric representation may become inaccessible for a successful retrieval in patients with AD.

Both EF and SM deficits are complex phenomena that the classical assessment and rehabilitation protocols are not able to detect and manage adequately. A more ecological and customized procedure could help clinicians to improve the quality of the clinical practice.

1.2 Virtual Reality and Neurorehabilitation

Virtual Reality (VR) is a useful technology for neurorehabilitation, thanks to its peculiar characteristics. Using a virtual environments for the assessment and rehabilitation allows to increase the ecological validity and to control and manipulate the tasks according to the needs of patients, to adapt the difficulty levels of a task, and to engage patients in their training [9]. Moreover, by using VR, it is possible to drive and control the patients' performances in a functional, purposeful and motivating way, specifically for the rehabilitation protocols [10].

Specifically, for the treatment of EF, the goal is to create a task that allows patients to deal with every-day life situations. These situations require a more complex series of abilities compared to classic protocols: patients have concrete goals to achieve and a high degree of cognitive flexibility is required to elaborate different strategies to solve the problems and to inhibit inappropriate behaviors [11].

Moreover, VR is a useful tool to analyze impairment in the ability to manage spatial representations. Thanks to this technology, the therapist can induces interference in the egocentric representation and forces the use of long-term allocentric representation using a strategy known as "virtual disorientation," [12].

In summary, VR is an important technology for the improvement and amelioration of the classical paper and pencil protocol used in clinical settings. In the last decade, VR-based protocols have been developed for many neurological diseases, for both motor [13] and cognitive [14] impairments.

2 Virtual Rehabilitation Protocols

2.1 Cognitive Stimulations for the Elderly

Here, we present two different highly-ecological virtual rehabilitation protocols for EF and SM developed specifically for frail patients. Both protocols could be implemented using low-end and high-end virtual reality systems.

2.1.1 Executive Functions

In order to stimulate the executive functions, we developed a VR-based training in a virtual supermarket. The protocol is based on the Virtual Multiple Errands Test (VMET), a VR-based assessment for the EF developed by Riva and colleagues [11, 15], itself inspired by the Multiple Errands Test (MET) [16, 17]. During the task, patients are able to move around in the supermarket and they are requested to select several products on shelves following precise rules. For the VR-based rehabilitation protocol, 10 different tasks with increasing difficulty are developed. Each task has different rules and different goals and may require a different aspect of the executive function domain to be solved. At the beginning of each session, the patient and the clinician analyze the task and the rules in order to understand and plan the different steps needed to solve the task. The clinician helps the patient during all the tasks in order to avoid the main errors and, at the end of the task, conducts a brief discussion about the outcome of the task. The software automatically records every object taken from the shelves and the path taken by the patient.

2.1.2 Spatial Memory

In the virtual city developed for the training, patients can move around with a common joypad. As in the protocol for the rehabilitation of EF, 10 different tasks are created for the rehabilitation of SM. Each task is divided in two phases: encoding and retrieval. In the encoding phase, patients are asked to search for one, two or three objects located in some predefined place in the city. In this first phase, the exploration always starts from the center of the city.

In the retrieval part, patients are asked to remember and reach the place where the objects were located before. Here, the starting point is different for each session and is one of the cardinal points where the patient does not return.

Between the two phases of the first five tasks, the clinician shows an allocentric map of the city and shows the patient the starting point of the retrieval phase in order to simplify the use of allocentric representation.

If the patient has problems in remembering the target point, the software provides a cue, a green path that connects the present position of the subject to the forgotten point. The software automatically records the path taken by the patient, when all target points have been achieved, and if the cue has been used. This task is developed accordingly with the “Mental Frame Syncing” theory [9].

Before the rehabilitation training patient underwent to a complete neuropsychological and physical assessment in order to evaluate the CF. Only eligible patients are selected and started with the rehabilitation program.

Accordingly with the cognitive profile every sessions could include one or both protocols. After the 10 sessions a new cognitive assessment were done.

3 Discussion

Both the proposed protocols for cognitive rehabilitation are in the test phase with low-end and high-end virtual reality systems. The preliminary results are very encouraging and convince us to continue with the experiment.

An important aspect of neurorehabilitation that will be implemented in our innovative system is motor rehabilitation, because several studies show the efficacy of the virtual rehabilitation programs for many physical impairments [13]. Balance and prevention of falls are two main aspects of the therapeutic plan for frailty patients on which to focus attention [18]. Both of these goals are easily manageable within the CAVE system, but the development of new protocols is still in progress.

Thanks to this advanced technology, the possibility exists to create complex and integrated protocols to maximize the efficacy of the treatment plan. An increasing number of studies showed that the effectiveness of a treatment that combines the cognitive and motor aspects [19, 20].

Another important aspect is the assessment of both cognitive and motor deficits. VR is an important tool because it allows ecological and standardized environments for a more precise and valid assessment. Many studies have analyzed the use of VR-based assessment protocols for cognitive impairment with very positive results [14, 15]. Clearly, a more precise assessment method allows an early diagnosis and a prompt rehabilitation treatment aimed at increasing the autonomy and the health of frail patients.

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References

1. Kelaiditi, E., et al.: Cognitive frailty: rational and definition from an (IANA/IAGG) international consensus group. J. Nutr. Health Aging **17**(9), 726–734 (2013)
2. Fried, L.P., et al.: Frailty in older adults evidence for a phenotype. J. Gerontol. Ser. A Biol. Sci. Med. Sci. **56**(3), M146–M157 (2001)
3. Delrieu, J., et al.: Neuropsychological profile of “cognitive frailty” subjects in MAPT study. J. Prevent. Alzheimer’s Dis. **3**(3), 151 (2016)
4. Montero-Odasso, M.M., et al.: Disentangling cognitive-frailty: results from the gait and brain study. J. Gerontol. Ser. A Biol. Sci. Med. Sci. (2016). glw044

5. Shimada, H., et al.: Impact of cognitive frailty on daily activities in older persons. J. Nutr. Health Aging, pp. 1–7
6. Iachini, T., et al.: Visuospatial memory in healthy elderly, AD and MCI: a review. Curr. Aging Sci. **2**(1), 43–59 (2009)
7. Guariglia, C.C., Nitrini, R.: Topographical disorientation in Alzheimer's disease. Arq. Neuropsiquiatr. **67**(4), 967–972 (2009)
8. Aguirre, G.K., D'Esposito, M.: Topographical disorientation: a synthesis and taxonomy. Brain **122**(9), 1613–1628 (1999)
9. Riva, G., Gaggioli, A.: Rehabilitation as empowerment: the role of advanced technologies. In: Gaggioli, A., et al. (eds.) Advanced Technologies in Rehabilitation - Empowering Cognitive, Physical, Social and Communicative Skills Through Virtual Reality, Robots, Wearable Systems and Brain-Computer Interfaces, pp. 3–22. IOS Press, Amsterdam (2009)
10. Bohil, C.J., Alicea, B., Biocca, F.A.: Virtual reality in neuroscience research and therapy. Nat. Rev. Neurosci. **12**(12), 752–762 (2011)
11. Raspelli, S., et al.: Validation of a Neuro Virtual Reality-based version of the Multiple Errands Test for the assessment of executive functions. Stud. Health Technol. Inform. **167**, 92–97 (2011)
12. Bosco, A., et al.: Assessing human reorientation ability inside virtual reality environments: the effects of retention interval and landmark characteristics. Cogn. Process. **9**(4), 299–309 (2008)
13. Mirelman, A., et al.: Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk in older adults (V-TIME): a randomised controlled trial. Lancet **388**, 1170–1182 (2016)
14. Pedroli, E., et al.: Assessment and rehabilitation of neglect using virtual reality: a systematic review. Front. Behav. Neurosci. **9** (2015)
15. Cipresso, P., et al.: Virtual multiple errands test (VMET): a virtual reality- based tool to detect early executive functions deficit in Parkinson's disease. Front. Behav. Neurosci. **8** (2014)
16. Alderman, N., et al.: Ecological validity of a simplified version of the multiple errands shopping test. J. Int. Neuropsychol. Soc. **9**(01), 31–44 (2003)
17. Shallice, T., Burgess, P.W.: Deficits in strategy application following frontal lobe damage in man. Brain **114**(2), 727–741 (1991)
18. de Labra, C., et al.: Effects of physical exercise interventions in frail older adults: a systematic review of randomized controlled trials. BMC Geriatr. **15**(1), 1 (2015)
19. Wang, X., et al.: Cognitive motor interference for preventing falls in older adults: a systematic review and meta-analysis of randomised controlled trials. Age Ageing **44**(2), 205–212 (2015)
20. Schoene, D., et al.: The effect of interactive cognitive-motor training in reducing fall risk in older people: a systematic review. BMC Geriatr. **14**(1), 1 (2014)