Virtual Reality for the Upper Limb Motor Training in Stroke: A Case Report

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Abstract. In this report we describe the effects of a virtual reality (VR) training addressed to the upper limb of a stroke patient. After 20 days of rehabilitation sessions consisting of physical therapy and VR rehabilitation, the subject was evaluated by means of kinematics and clinical scales. Results showed the improvement of paretic arm mobility, in terms of quantitative parameters and clinical scales, suggesting that VR training could represent a valuable tool to supplement the traditional rehabilitation provided by the physical therapist.

Keywords. Rehabilitation, virtual reality, upper limbs, stroke, kinematics

Introduction

Stroke disease impairs motor functions of survivors and it is estimated that 50% to 75% of individuals who experienced a stroke have persistent impairment of the affected upper limb (UL). Rehabilitation intervention is a critical part of the recovery and recent studies reported that intensive repeated practice might be necessary to modify neural organization [1,2] and to effectively favor recovery of functional motor skills [3].

Virtual Reality (VR) is a promising rehabilitation technique even though until now evidence about its effectiveness in UL rehabilitation of stroke patients is very limited [4]. Moreover, to evaluate the real efficacy of motor training in a virtual environment, it is important to determine whether the skills gained in that environment transfer to real-world conditions. Thus, in our opinion, before recommending the use of VR rehabilitation techniques in clinical practice, it is mandatory to assess its effectiveness not only in VR environment but also in real-world conditions. In this report we describe a rehabilitation protocol integrating standard physiotherapy and VR training, aimed to treat right upper limb paresis in a stroke patient. The results of this treatment were evaluated in the real world using a quantitative kinematic analysis and by means of clinical scales. To our knowledge this is the first study integrating VR rehabilitation and quantitative biomechanical evaluation of the obtained results.
1. Materials and Methods

BA was a 35-year old man with right hemiparesis following an ischemic stroke. Clinical picture included: preserved cognitive functions, ability to stay in standing position without any assistive device, ability to perform postural transfers, and spastic muscle hypertone on the right upper limb.

The treatment consisted of 1 daily session, 5 days a week, for 4 consecutive weeks. Each therapeutic session included 30 minutes of standard therapeutic physiotherapy plus 30 minutes of selective treatment for the upper limb: patient was asked to grasp and throw virtual targets (Fig. 1) that appeared randomly on the computer screen using P5 virtual glove (Essential Reality, U.S.).

Quantitative kinematic analysis of pointing task (Fig. 2) was performed according to Menegoni et al., [5], before and after treatment, using an optoelectronic system (Vicon, UK). Specifically, we focused on the following kinematic parameters to characterize the functional limitation of the paretic arm: movement execution time and precision parameters (adjustments performed in the last phase of pointing and minimum distance from target).

The following validated clinical scales were administered before and after treatment: Nine-Hole Peg Test (NHPT) a quantitative test for upper extremity fine coordination [6], Frenchay Arm Test (FAT) [7], Medical Research Council (MRC) [8], Motricity Index (MI) [9], and the Motor Evaluation Scale for Upper Extremity in Stroke Patients (MESUPES) [10].

Figure 1. VR treatment unit.
2. Results

After the treatment, the kinematic analysis of the paretic arm, showed a diminished time of movement execution (-11%), more pronounced in the last part of pointing (-20.8%), together with accuracy improvements: less finger excursions (-10%) and more precision (-13% error) in target localization (Fig. 3). Clinical scales confirmed quantitative improvements: MRC of fingers (pre: 4; post: 5), MESUPES - orientation part (pre: 2/6; post: 3/6), and NHPT time (pre: 25 s; post: 21 s). No significant changes were recorded in MI (pre: 76/100, post: 76/100) and FAT (pre: 5/5, post: 5/5).

3. Discussion and Conclusion

The effectiveness of the proposed rehabilitation protocol, integrating VR treatment and standard rehabilitation therapy, was demonstrated by a careful quantitative analysis in real world. Furthermore the treatment was well tolerated and
allowed the administration of intensive training without need to increase allocation of human resources.

Improvements were assessed by clinical scales in terms of enhanced arm mobility (MESUPES), in terms of dexterity and movement velocity (NHPT), and in terms of muscle power (MRC). Conversely no effects were found in terms of MI, and FAT. While the latter was suffering of ceiling effect, the unchanged MI could depend on the scale itself, not specifically designed to take into account arm-hand improvements.

The implicit limitations affecting clinical scales (e.g.: semi-quantitative, operator dependent) lead us to assess upper extremity movement by quantitative methods. The quantitative kinematic analysis, which represents a valuable and sensitive tool to detail different aspects of improvements, confirmed the results provided from clinical scales. Specifically, after treatment, our patient showed a clear improvement in terms of movement time together with better precision and less finger excursion in the last phase of the movement. The diminished time can be associated to the better values of MRC, i.e.: having more muscle power it is easier to perform the movement in less time. In addition, precision and finger excursions can be associated to movement control: the rehabilitation treatment could have caused a better organization of the movement, thus providing the right path and direction to the target, decreasing finger displacements in the last phase of the movement (i.e.: diminishing movement corrections), and augmenting the final precision. It is clear that better movement control can also influence the movement time, since less trajectory corrections means less time spent in performing them.

This study suggests that VR training could represent a useful tool to integrate and complete the traditional rehabilitation provided by the physical therapist.

References