Kinect-based occupational therapy virtual environment for functional neurorehabilitation of the upper limb

F. Molina[1, 2], C. Gómez[3], J. Ontiveros[1, 2], M.A. Villán-Villán[1, 2], R. Pérez [1, 2], C. Martín[3], E. Opisso[3], J. Medina[3], J.M. Tormos[3], E.J Gómez[1, 2]

[1]Biomedical Engineering and Telemedicine Centre, ETSI Telecomunicación, Universidad Politécnica de Madrid, Spain.

[2]Biomedical Research Networking Center in Bioengineering, Biomaterials and Nanomedicine, Spain.

[3]Institut Guttmann Neurorehabilitation Hospital, Universitat Autónoma de Barcelona, Spain.

[1]*fmolina@gbt.tfo.upm.es*

1. INTRODUCTION

The use of virtual reality technologies has attracted great interest in the area of functional neurorehabilitation [1]. These technologies have a strong ludic component that can increase motivation. Furthermore, Kinect-based motion tracking enables us to individualize the exercises and to generate knowledge [2]. The aim of this research is to perform a proof of concept test of a virtual environment for upper limb rehabilitation. To this end, we have designed two rehabilitation virtual scenarios based on occupational therapy activities. Activities are monitored by a control system based on Microsoft® Kinect sensor [3], for performing bilateral hand coordination and finger dissociation rehabilitation exercises. Both virtual scenarios have been validated by expert therapists at the Institut Guttmann of Nerurrehabilitación and a preliminary evaluation has been performed with four traumatic brain injury patients.

2. METHODS

The virtual environment prototype was developed according to a specific neurorehabilitation process modelling methodology [4]. First, we performed an analysis of the occupational therapy activities that are currently used in the Institut Guttmann Hospital. Next, we chose two activities for their adaptation and implementation on a virtual environment. The first activity is a bilateral hand coordination task in which the patient has to move a wooden disc along a plastic rod. The second is a finger dissociation activity that stimulates the movements of the hand. In this activity the patient has to press specific keys on a piano or keyboard to play a certain pattern. Once these activities were selected, two virtual environments were designed to allow patients to perform rehabilitation tasks. Microsoft® Kinect was chosen as the primary hardware device to monitor and control. Moreover, to develop the control system we used 3GearSystem software [5]. Virtual environments were developed using the Unity development platform [6].

3. RESULTS

The virtual environment for upper limb rehabilitation has been developed. This system allows patients to execute the two designed activities. The first activity has been designed as a car driving game, whilst the second activity represents virtual musical instruments that can be played with arm and finger movements [Figure 1].

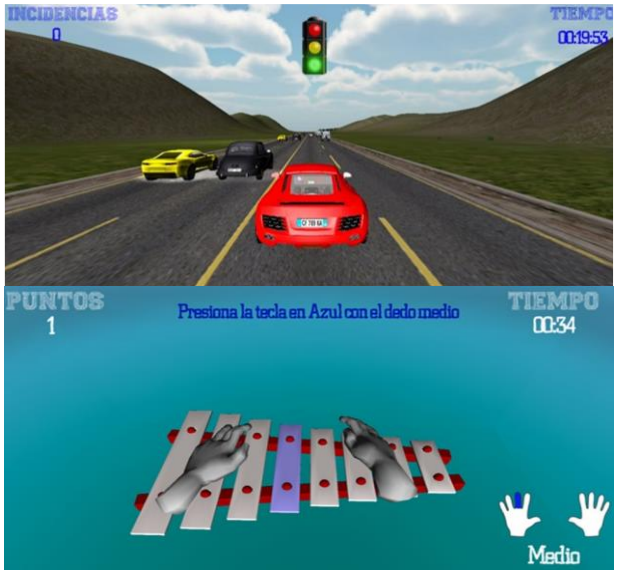

Figure 1. Virtual content graphical interfaces.

The virtual environment has been installed and validated in the Institut Guttmann - Hospital. Four patients participated in the validation process [Table 1]. After performing the activities, patients performed a usability test. The test included a satisfaction questionnaire. The questionnaire was scored from 1 to 5 representing responses from left (worst) to right (best). Test results showed a high level of acceptance for both activities. However, several limitations were identified in the current prototype. The most important limitation is the lack of haptic feedback to help patients perform the finger dissociation activity. Another limitation that must be considered is the lack of a support system to guide patients when they needed help.

Patient	Age	Diagnosis	Motor involvement	Period since injury (Days)	Acceptance level (1-5)
1	27	TBI	Predominantly right tetraparesis	89	4,5
2	29	TBI	Predominantly left tetraparesis	239	4
3	54	TBI	Predominantly left tetraparesis	119	5
4	44	TBI	Predominantly right tetraparesis	204	5

Table 1. Patients' characteristics and acceptance test results.

4. CONCLUSIONS

This research presents a low cost virtual environment prototype for the rehabilitation of the upper limb based on computerized occupational therapy tasks. A proof of concept test has been done and evaluated showing how these tools are widely accepted by patients to perform treatment activities. Furthermore, the usability test allows the identification of main limitations of the current prototype to improve. A new version of the system is under development to be tested in a larger scale of patients.

Acknowledgements: The authors wish to thank the clinicians and therapists in the department of functional rehabilitation, Institut Guttmann – Neurorrehabilitation Hospital, for their invaluable collaboration in this study. This research work was partially funded by Polytechnical University of Madrid, the Spanish Ministry of Economy and Competitiveness (project TP-2012-1063-300000, Sensing Toys; and project TIN2012-38450, COGNITIO), and Mapfre Foundation.

REFERENCES

1. B. Lange, C.-Y. Chang, E. Suma, B. Newman, A. S. Rizzo, and M. Bolas, “Development and evaluation of low cost game-based balance rehabilitation tool using the Microsoft Kinect sensor.” In Conference. Proc. IEEE Eng. Med. Biol. Soc., 2011, pp. 1831–4.
2. Pérez R, Costa Ú, Torrent M, Solana J, Opisso E, Cáceres C, et al. Upper Limb Portable Motion Analysis System Based on Inertial Technology for Neurorehabilitation Purposes. Sensors 2010; 10:10733-51.
3. Microsoft. Kinect for Windows web site. Last Update Date [2015]. Available from: http://www.microsoft.com/en-us/kinectforwindows/
4. Caballero-Hernández R, Gómez-Perez C, Cáceres-Taladriz C, García-Rudolph A, Vidal-Samsó J, Bernabeu-Guitart M, et al. Modelado de Procesos de Neurorrehabilitación. Actas del XXIX Congreso Anual de la Sociedad Española de Ingeniería Biomédica (CASEIB 2011). Cáceres, España, noviembre 2011. P. 125-8.
5. Nimble VR. NimbleVR web site. Last Update Date [2015]. Available from: http://nimblevr.com/
6. Unity Technologies. Unity3D web site. Last Update Date [2015]. Available from: http://unity3d.com/Unity.