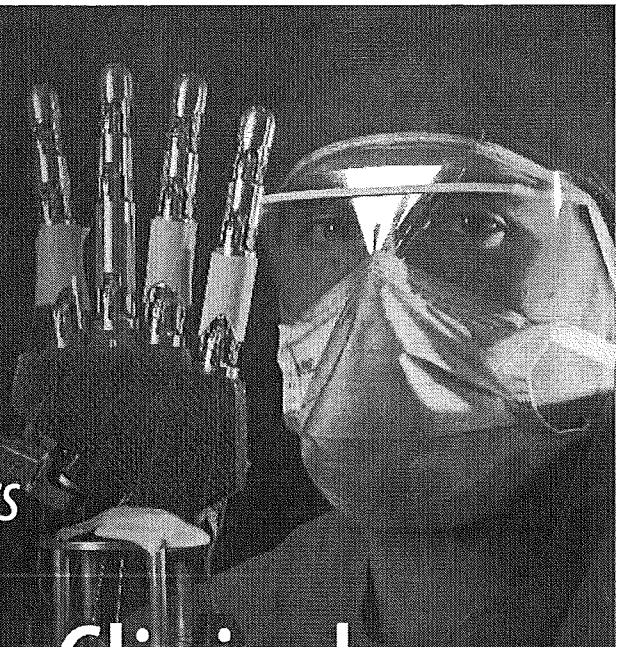
Biosystems & Biorobotics



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Converging Clinical and Engineering Research on Neurorehabilitation III

Proceedings of the 4th International Conference on NeuroRehabilitation (ICNR2018), October 16–20, 2018, Pisa, Italy

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Biosystems & Biorobotics

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Aims & Scope

Biosystems & Biorobotics publishes the latest research developments in three main areas: 1) understanding biological systems from a bioengineering point of view, i.e. the study of biosystems by exploiting engineering methods and tools to unveil their functioning principles and unrivalled performance; 2) design and development of biologically inspired machines and systems to be used for different purposes and in a variety of application contexts. The series welcomes contributions on novel design approaches, methods and tools as well as case studies on specific bioinspired systems; 3) design and developments of nano-, micro-, macrodevices and systems for biomedical applications, i.e. technologies that can improve modern healthcare and welfare by enabling novel solutions for prevention, diagnosis, surgery, prosthetics, rehabilitation and independent living.

On one side, the series focuses on recent methods and technologies which allow multiscale, multi-physics, high-resolution analysis and modeling of biological systems. A special emphasis on this side is given to the use of mechatronic and robotic systems as a tool for basic research in biology. On the other side, the series authoritatively reports on current theoretical and experimental challenges and developments related to the "biomechatronic" design of novel biorobotic machines. A special emphasis on this side is given to human-machine interaction and interfacing, and also to the ethical and social implications of this emerging research area, as key challenges for the acceptability and sustainability of biorobotics technology.

The main target of the series are engineers interested in biology and medicine, and specifically bioengineers and bioroboticists. Volume published in the series comprise monographs, edited volumes, lecture notes, as well as selected conference proceedings and PhD theses. The series also publishes books purposely devoted to support education in bioengineering, biomedical engineering, biomechatronics and biorobotics at graduate and post-graduate levels.

About the Cover

The cover of the book series Biosystems & Biorobotics features a robotic hand prosthesis. This looks like a natural hand and is ready to be implanted on a human amputee to help them recover their physical capabilities. This picture was chosen to represent a variety of concepts and disciplines: from the understanding of biological systems to biomechatronics, bioinspiration and biomimetics; and from the concept of human-robot and human-machine interaction to the use of robots and, more generally, of engineering techniques for biological research and in healthcare. The picture also points to the social impact of bioengineering research and to its potential for improving human health and the quality of life of all individuals, including those with special needs. The picture was taken during the LIFEHAND experimental trials run at Università Campus Bio-Medico of Rome (Italy) in 2008. The LIFEHAND project tested the ability of an amputee patient to control the Cyberhand, a robotic prosthesis developed at Scuola Superiore Sant'Anna in Pisa (Italy), using the tf-LIFE electrodes developed at the Fraunhofer Institute for Biomedical Engineering (IBMT, Germany), which were implanted in the patient's arm. The implanted tf-LIFE electrodes were shown to enable bidirectional communication (from brain to hand and vice versa) between the brain and the Cyberhand. As a result, the patient was able to control complex movements of the prosthesis, while receiving sensory feedback in the form of direct neurostimulation. For more information please visit http://www.biorobotics.it or contact the Series Editor.

More information about this series at http://www.springer.com/series/10421

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Preliminary Development of Two Serious Games for Rehabilitation of Spinal Cord Injured Patients

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Abstract. The upper limb function is affected in more than 50% of spinal cord. The upper limb motor recovery can be promoted by providing high intensity, repetitive and task-orientated training by means of using virtual reality applications and motion capture technologies. The objective of the present study is to present the preliminary development of two serious games for rehabilitation purpose of patients who have suffered tetraplegia. The technology used for registering hands movements is the Leap Motion Controller. The results on 8 people (4 healthy and 4 tetraplegic patients) have shown that the performance of patients is minor than healthy people, reaching a less number of goals. As conclusion these versions of both serious games are feasible in the rehabilitation of gross manual dexterity and the pinching motor skills of the fingers in tetraplegic patients.

1 Introduction

Loss of motor function is a consequence after spinal cord injury (SCI) and the upper limb (UL) is affected in more than 50% of cases [1].

In the clinical context, the rehabilitative process that patients receive has to be orientated to reach functional tasks. Moreover, considerable amounts of practice are required to induce neuroplastic changes and functional recovery of neurological motor deficits. One proposed method to improve rehabilitation is to complement conventional

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therapy with the use of virtual reality (VR) [2]. The UL motor recovery can be promoted by providing high intensity, repetitive and task-orientated training by means of using VR environments [3].

In this sense, the Playground virtual applications based on Leap Motion Controller (LMC; Leap Motion Inc., San Francisco, CA) [4] involve the performance of functional tasks developed for an entertainment purpose, such as robot-assembly and petal-picking games. These applications have been used for the UL rehabilitation in subacute stroke patients, without providing feedback sources to the patient [5]. However, feedback is essential because it allows patients to monitor their performance, promote errorless learning and avoid compensatory movements.

In this study the concept of serious game is used for a videogame with a rehabilitation purpose. Until now, studies conducted in SCI patients are scarce. In this sense, the objective of the research project cited above is to develop a set of serious games manipulated by means of the LMC device taking into account the clinical requirements and the rehabilitation objectives, providing the visual feedback necessary to enhance the motor learning and increase the motivation in patients. Specifically, the aim of the present work is to present the preliminary development of two of them for the UL rehabilitation of SCI patients: the virtual simulation of the Box and Block Test and a new version of the petal-picking game for the LMC, adapting the virtual objects to manipulate them by SCI patients and providing the necessary visual feedback in relation to the motor performance within the virtual environment. After an iterative development, the games versions shown in this work are those that SCI patients with UL affectation can manipulate in a more successful way (Fig. 1).

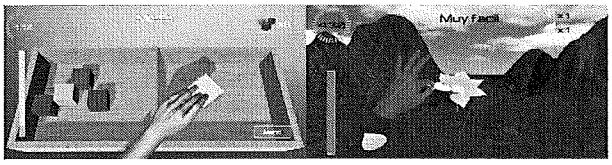

Fig. 1. Images of the virtual applications developed for the rehabilitation of the manual dexterity.

2 Methods

2.1 Participants

In this concept proof 8 people had participated: 4 healthy subjects and 4 tetraplegic patients between the metameric levels C5–C8 (Table 1). All the participants had to fulfill the inclusion criteria and sign the corresponding informed consent. The level and severity of the SCI, in relation to the ASIA scale, were determined by a neurological exam [6]. The study was approved by the Local Ethical Committee.

Table 1. Injury characteristics and motor performance in both virtual applications

Participants	Injury level and ASIA	Box and block	Picking petals
H1	-	51	105
H2	-	48	76
H3	-	47	99
H4	-	43	66
P1	C4 ASIA D	46	58
P2	C5 ZPP C7 ASIA A	15	27
P3	C6 ASIA D	9	68
P4	C7 ASIA A	13	85

2.2 Leap Motion Controller and Serious Games

The LMC is a low-cost device that has been designed to control application by hand gestures and movements, It contains three infrared lights and two cameras. The device is small, rectangular and its weight is 45 g. The LMC is connected to the computer via USB connection.

The games were developed and adapted to SCI patients' condition by using the Unity3D game engine and C# programming language. In this study, the characteristics of the computer used are a i7 processor running under Windows 10, 12 GB RAM memory and a NVIDIA graphic card.

A preliminary version of two serious games were developed: (a) a virtual simulation of the Box and Block Test to evaluate the gross manual dexterity, following the design criteria of the real clinical scale [7]; (b) petal-picking game for LMC allows to develop the pinching motor skills of the fingers. Our main contribution in this work is the proposal of several difficulty levels with the aim of adapting this virtual application to the patients' conditions varying the placement of the flowers on the screen, increasing the petals size to pinch to and allowing the virtual flower stalk as an undeformable object to improve the patients performance within the task. All the levels proposed providing visual feedback in relation to the motor performance.

2.3 Experimental Procedure

The iterative development implied several experimental sessions with patients to analyze the feasibility of manipulating the virtual objects within the serious games proposed.

Each participant had to pass with the dominant arm the maximum number of cubes during 2 min within the virtual Box and Block and to pick the maximum number of petals within the new adapted version of the petal-picking application during 5 min. Both games provided to the user visual feedback in relation to the UL motor performance. Previously, each participant performed a proof for acclimatation to the virtual environments.

3 Results and Discussion

After the iterative development, the results shown in Table 1 allow considering these versions of both serious games as a release candidates. All the patients could manipulate the applications in a successful way and the results shown correspond to the last experimental session that each patient performed. Healthy participants passed a mean number of 47.25 cubes and picked a mean of 86.50 petals.

These results were lower in patients, 20.75 cubes and 59.50 petals. However, the number of cubes passed was 46 for the patient 1. This patient presented an UL motor index of 18, with a punctuation of 4 for the finger flexors and abductors muscles, related to a good hand function.

Previous experiences with virtual versions of the Box and Block Test have been conducted in stroke patients [8, 9]. However, there is no evidence about similar studies for the rehabilitation of SCI patients.

4 Conclusion

The versions of both serious games proposed in this concept proof seem to be feasible for the rehabilitation of gross manual dexterity and the pinching motor skills of the fingers in tetraplegic patients. The virtual simulation of the Box and Block Test will be validate with the real clinical scale and a correlation between both versions will be made.

This experience is addressing the development of other novel virtual games for UL rehabilitation purposes in SCI patients involving different aspects of motor control, dexterity and hand-eye coordination within bimanual tasks and following the hand trajectory.

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