New Methodologies for Patients Rehabilitation

H. M. Fardoun¹; A. S. Mashat¹; B. Lange２
¹Faculty of Computing and Information Technology, King Abdulaziz University (KAU), Jeddah, Saudi Arabia; ²USC Institute for Creative Technologies, University of Southern California, Playa Vista, CA, USA

Keywords
Virtual rehabilitation, multi-user systems for user interaction, virtual humans, communications aids, training tools for rehabilitation, rehabilitation robotics

Summary
Objective: The present editorial is part of the focus theme of Methods of Information in Medicine titled “New Methodologies for Patients Rehabilitation”, with a specific focus on technologies and human factors related to the use of Information and Communication Technologies (ICT) for improving patient rehabilitation.

Methods: The focus theme explores different dimensions of empowerment methodologies for disabled people in terms of rehabilitation and health care, and to explores the extent to which ICT is a useful tool in this process.

Results: The focus theme lists a set of research papers that present different ways of using ICT to develop advanced systems that help disabled people in their rehabilitation process.

1. Introduction
Building an inclusive society and improving the quality of life of disabled people by applying technology that meets their needs, must be a key point in the evolution of today’s technology [1]. Disability is the consequence of an impairment that may be physical, cognitive, mental, sensory, emotional, developmental, or some combination of these. It is an umbrella term, covering impairments, activity limitations, and participation restrictions. Impairment is a problem in terms of bodily function or structure. An activity limitation is a difficulty encountered by an individual in executing a task or action, while a participation restriction is a problem experienced by an individual with regard to involvement in life situations. Assistive technology is a field that involves encouraging a better understanding of all aspects of disability and promoting rehabilitation science and practice [2].

Over the past few years there has been an increasing interest in the application of Virtual Reality (VR) and ICTs in the field of rehabilitation [3], with clinical results that demonstrate their potential. This proves that ICT solutions and new health technologies have been developed to support disabled people living at home, to facilitate the integration of home and hospital care services, and to promote the integration of public and private sector services [4]. In addition, VR has been increasingly used in physical rehabilitation to provide individualized treatments, facilitate learning, increase motivation, and provide patients with pleasant and enjoyable exercises in the home. This can be done, for example, by applying the use of the Ninten-
The main focus of this research is the use of humanoids in rehabilitative care, where the automated judgment functionality determines how the rehabilitation exercise matches the pre-programmed correct sequence (i.e. pulmonary rehabilitation in chronic obstructive pulmonary disease “COPD” patients). To prove this, the authors apply the use of humanoids in rehabilitative care (rehabilitation robotics). This requires the capability to localize patients, to move in the proximity of, to persuade, to present the activity, and to judge the quality of the human-made exercises at run time. The authors investigate the computationally efficient methods for the support of real-time use by:

- implementing pulmonary rehabilitation using humanoid robots;
- inducing elderly patients to undertake humanoid-driven rehabilitation exercise;
- evaluating the human actions against the correct template using easiest automated comparison techniques.

So, while the patient is performing an action, the humanoid is recording and processing the human's movements. The artificial cognitive function uses pattern matching to elaborate input data (stream of motion pictures) in order to determine if the rehabilitation exercise matches the pre-programmed correct sequence.

As the one-fits-all exercise does not exist, the valuable rehabilitative care by mobile robots is a complex mission articulated in a number of interlinked tasks. The personalize rehabilitation program should be offered depending on the patient's current status. To become an effective rehabilitation therapy means that the robot has to use the repeatable and quantifiable metrics that are going to be used during the assessment of the patient's performance [7]. The authors try to define a function to measure the motion in near real time using industrial motion sensors, Microsoft Kinect, and Nintendo Wii Remote to assist physicians and patients in implementing rehabilitation exercises. They also adopt Aldebaran NAO joints to implement the correct body motion sequences and present them to patients.

The simulation of the experimental results of this research cover almost all possible situations in which patients repeat the rehabilitation program, and the monitoring of the activities performed by patients following the robot are made by using fully scaled robots, without additional and/or specialized sensors [8, 9]. The proposed approach shows that it could enable better sustainable rehabilitative care services in remote residential settings because of lowering the need of human care.

2.2 Assessing Frontal Lobe Functions in Patients with Alcohol Dependence Syndrome

The research work of Gamito et al. [10] proposes a new approach to neuropsychological assessment that takes advantage of the benefits of new technologies, allowing for a more effective and reliable evaluation process by using a task similar to those that are usually performed by the patient in their real-life settings [11]. Accordingly, the authors develop a test that combines all the characteristics of a well-established neuropsychological test for frontal functions with a context where these functions could be naturally assessed.

In order to do this, the authors develop a test – the Virtual Kitchen Test (VKT) – that emulates the paper-and-pencil Trail Making Test (TMT), but with the advantages that new technologies have to offer. These include 3D interaction, which may be important to assess neuropsychological performance under ecologically valid contexts. The test, which simulates the baking of a cake, reproduces food preparation tasks that are an important domain of instrumental activities of daily living (IADL) [12] that may be compromised in cases of mild to severe cognitive impairments [13]. The neuropsychological evaluation carried out, in this research, confirms poorer cognitive ability in alcoholics in comparison to healthy volunteers on both traditional and VR-based measures of the presented VKT; thus, this supports the authors’ assumption, which was that alcohol abuse has a negative effect on attention and cognitive flexibility, among other cognitive functions located in the frontal lobe.

The results reveal negative and moderate to strong, significant associations between errors, as well as execution time, in the VKT’s total scores, which indicates that poorer cognitive abilities are related to more errors and longer execution times in the VKT. What is more, the results from different statistical procedures seem to support the validity of the VKT in evaluating neuropsychological functions, particularly those related to the frontal lobes. However, further studies are needed with clinical samples of brain-injury patients in order to broaden the application of the VKT to other contexts of cognitive impairment. There are, however, several limitations in the current study that need to be addressed. The main limitation is related to the differences found between the sample of patients and controls in potential confounders of neuropsychological testing. Although age and education were controlled statistically in the comparisons between patients and controls, the effects of age on execution time were not possible to isolate in the Receiver Operating Characteristic Curve (ROC) analysis due to the small sample size. Thus, additional validation studies with age and education-matched control samples are needed in order to provide further support for the use of the VKT in neuropsychological testing. Another limitation concerns the concurrent neuropsychological measures used in our study to assess frontal lobe abilities.

2.3 A Novel Virtual Motor Rehabilitation System for Guillain-Barré Syndrome: Two Single Case Studies

Albiol-Perez et al. [14] present a novel and customizable tool that is applied to two Guillain-Barré patients (GBS) [15 –18], to test a balance disorder aimed at improving the patients’ motor recovery using Virtual Motor Rehabilitation (VMR). To apply the test the authors use a low-cost force platform (the Nintendo Wii Balance Board) and the specific Virtual Environment tool Active Balance Rehabilitation system (ABAR); this is a system composed of cusu-
tomizable virtual games to perform static and dynamic balance rehabilitation. The most important and representative characteristics of the ABAR system are as follows:

- flexible system for the recovery of postural control and for reducing fractures and the risk of falls;
- suitable system that improves the patient’s motivation and treatment adherence;
- reinforcement system that allows the results obtained in each session to be monitored and the appropriate action taken;
- robust system that is able to make a good recovery in parameters such as balance, postural control, muscle tone, and stability in the standing/sitting position in GBS;
- portable system that can be used at home to reinforce the acute and sub-acute stages;
- customizable system that offers multiple levels of difficulty that is based on the patients’ progression.

Finally this research work presents a study using ABAR, carried out in the San José Metropolitan Hospital. The results show improvements in tested patients. In general, the results show less improvement for the dynamic clinical balance test than for the static clinical balance test. The results confirm that, after the development of a specific treatment using VMR, the recovery of balance control is a reality.

3. Conclusions

In the last decades there has been a growing interest in employing ICT in patients’ rehabilitation processes, both for clinical activity and for research purposes. ICT shows that it can be employed from different perspectives, it can help in the assessment and evaluation of patients’ functional impairments (allowing the development of new methods to evaluate more objectively behavioural and functional deficits), and it can also be employed to support patients’ daily activities, playing a key role in the patients’ treatment, stimulation, and rehabilitation. The three papers discussed here present varied solutions using ICT for different patients’ problems, and show how the use of ICT has resolved or improved their rehabilitation process. Simove et al. [6] show how artificial cognitive software can judge in almost real-time the correctness of rehabilitative exercises performed by patients following the robot’s indications. Alternatively, the paper of Gamito et al. [10] develops a new test for patients – the VKT – devised to evaluate frontal brain functioning in cognitively impaired individuals, and to capture frontal lobe abilities during a more ecologically valid task. Finally the last paper, by Albiol et al. [14], performs a test and analysis of a new system that is focused on the rehabilitation of GBS, following intensive training program using the ABAR system.

These studies prove the effectiveness of employing ICT in patients’ rehabilitation processes, and it is important to chart the field, and to open the dialogue between the different professionals working within it (e.g., researchers, clinicians and engineers).

Acknowledgments

We want to thank the editors of Methods of Information in Medicine for supporting us by publishing this focus theme.

References