COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 116 (2014) 116–122

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

Acceptability of robotic technology in neuro-rehabilitation: Preliminary results on chronic stroke patients

Stefano Mazzoleni[a,b,*], Giuseppe Turchetti[c], Ilaria Palla[c], Federico Posteraro[b,d], Paolo Dario[a]

[a] The BioRobotics Institute, Scuola Superiore Sant'Anna, Polo Sant'Anna Valdera, Pontedera, Italy
[b] Rehabilitation Bioengineering Laboratory, Auxilium Vitae Rehabilitation Center, Volterra, Italy
[c] Institute of Management, Scuola Superiore Sant'Anna, Pisa, Italy
[d] Neurological Rehabilitation Unit, Auxilium Vitae Rehabilitation Center, Volterra, Italy

ARTICLE INFO

Article history:
Received 29 July 2013
Received in revised form
7 December 2013
Accepted 22 December 2013

Keywords:
Rehabilitation
Robotics
Stroke
Upper limb
Technology assessment

ABSTRACT

During the last decade, different robotic devices have been developed for motor rehabilitation of stroke survivors. These devices have been shown to improve motor impairment and contribute to the understanding of mechanisms underlying motor recovery after a stroke. The assessment of the robotic technology for rehabilitation assumes great importance. The aim of this study is to present preliminary results on the assessment of the acceptability of the robotic technology for rehabilitation on a group of thirty-four chronic stroke patients. The results from questionnaires on the patients' acceptability of two different robot-assisted rehabilitation scenarios show that the robotic approach was well accepted and tolerated by the patients.

1. Introduction

Stroke and other neurological injuries cause partial destruction of the cortical tissue and result in the disturbed generation of motor programs through the involvement of sensorimotor areas: a consequence is an impaired arm and hand motor function [1]. After acute brain lesion, training has the potential to drive brain reorganization and to optimize functional performance [2,3].

The main goal of this study is to present preliminary results – from 34 chronic stroke subjects – on the level of acceptability of a robot-assisted upper limb rehabilitation treatment.

An estimated 30–60% of adult patients after stroke do not achieve satisfactory motor recovery of the upper limb despite intensive rehabilitation. Motor reorganization in adults also depends on substantial contributions from the undamaged motor cortex, with functional inhibition by the unaffected arm that has become dominant – a limitation that neuro-rehabilitation should counterbalance after stroke as well as in other pathological conditions (e.g. multiple sclerosis) and in children.

Innovative technologies, such as advanced robotics and virtual reality, have proven applicable in neuro-rehabilitation, their use in the treatment of the paretic upper limb appears promising, and the available evidence supports applicability.

* *Corresponding author at*: The BioRobotics Institute, Scuola Superiore Sant'Anna, Polo Sant'Anna Valdera, Viale R. Piaggio, 34, 56025 Pontedera, Pisa, Italy. Tel.: +39 050883132; fax: +39 050883101.
E-mail address: s.mazzoleni@sssup.it (S. Mazzoleni).
0169-2607/$ – see front matter © 2013 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cmpb.2013.12.017

However, research on efficacy has thus far been unsystematic, and the advantages of robotic-supported rehabilitation compared with conventional treatments remain, to a relevant extent, undocumented. More importantly, a comprehensive scientific rationale and pathophysiological understanding of the mechanisms underlying recovery (with or without robot assistance) still have to be devised. On the other hand, an increasing number of relevant studies on the clinical applications as well as on the effects of robot-assisted treatment can be found in the literature [4,5].

The acceptability of novel technologies depends on their effectiveness, but also on their cost-effectiveness ratio. The economic perspective is becoming more and more relevant in shaping the acceptability and diffusion of new treatment or technology due to the growing economic constraints and budget limitations of healthcare systems in the most industrialized countries.

The field of biomedical technologies is characterized by dynamism and high rate of innovation, its intrinsic feature and fundamental driver. The impact of new technologies in medicine concerns aspects related to clinical efficacy, quality of life of the patient, legal, ethical and economic issues [6–10]. The approach that allows to combine these aspects is represented by Health Technology Assessment (HTA), a multidisciplinary research area aimed at make "informed" health policy decisions [11–14].

The rationale of this study is represented by the need for a comprehensive analysis of different factors affecting the introduction of new technologies in healthcare systems, following an increasing development of promising tools for diagnostics, surgery and rehabilitation and evidence from existing literature, through available methodologies (e.g., HTA procedures) and tools (e.g., acceptability questionnaires).

The patient's needs and the training goals are central to the development of human–machine interfaces (HMIs), as well as the acceptability of new technologies by the patient and his/her family [15–17]. The design of robotic applications in neuro-rehabilitation can benefit from ongoing research on HMIs. The approach would also enhance the patients' commitment to training and extend rehabilitation beyond the mere, often partial and usually compensatory, recovery of motor function.

Optimal recovery of the upper limb function is essential for stroke patients to independently perform activities of daily living (ADLs). Motor learning mechanisms are operative during the spontaneous stroke recovery and interact with rehabilitative training [18]. During the training, repetitive and novel tasks can be effective in reducing motor impairment after stroke [19].

Different robotic systems that can support movement therapy of the upper extremities in subjects with neurological pathologies were recently developed [20]. They can provide a safe and intensive motor therapy which can be highly accurate, intensive and prolonged. Recent systematic reviews showed that upper limb robot-assisted rehabilitation treatments in post-stroke subjects improve short- and long-term motor control, even if no consistent influence on functional abilities was found [21,22]. The studies which demonstrate the motor improvement are based on the analysis of the clinical scales scores: recently only few have proposed a quantitative approach to analyze the mechanisms of motor recovery after stroke [23–26].

The comprehension of such mechanisms assumes great importance in the rehabilitation domain, as it can support the clinical decision process.

The question of whether the nervous system optimizes movements by a kinematic criterion, such as optimization of the trajectory error or smoothness, or a dynamic criterion, such as force or effort optimization, has been investigated in the last decade [27]. Other studies proposed a metric for assessing the forces exerted by post-stroke subjects during robot-assisted rehabilitation treatment [28–30].

The use of robotic systems in the rehabilitation domain changes the interaction between patients and rehabilitation program which can limit acceptability of the new technology.

The novelty of our study relies on the analysis of the acceptability of an innovative rehabilitation treatment based on robotic technology by a group of thirty-four stroke patients.

Two different robot-assisted upper limb rehabilitation treatments were delivered to stroke patients together with a questionnaire to assess the acceptability of robotic technology.

The next section presents the theories related to the acceptability of innovative technologies and the associated barriers.

2. The acceptability of a new rehabilitation treatment

2.1. *The literature related to the acceptability*

The acceptability of a new technology is a field of study analyzed extensively since the 1990s [31]. The acceptability of users is defined as demonstrable availability to use technology [32] and *the way people perceive, accept, and adopt technology use* [33]. The lack of user's acceptance represents a critical obstacle to the success of innovative technologies [34]. In the technology acceptance literature models are used to explain how the users employ or accept the technology. These models derive from disciplines such as psychology, information systems and sociology. The *Theory of Reasoned Action* (TRA) [35] and the *Theory of Planed Behavior* (TPB) [36] have been used to foresee and interpret behaviors and attitudes. Afterwards, other models such as the *Technology Acceptance Model* (TAM) [37] and the *Innovation Diffusion Therapy* (IDT) [38] have been developed. The TAM has been applied to different technologies and tested in several contexts.

The model assumes that perceived usefulness and perceived ease of use represent the main predictors of technology acceptance. Legris et al. affirm that researchers use TAM combined with other constructs [39]. The constructs, in fact, are used to explain acceptance and use of technology.

The *Unified Theory of Acceptance and Usage of Technology* (UTAT model) comprises intention and behavior, performance expectancy, effort expectancy, social influence and facilitating conditions as key constructs for technology usage [40].

Current literature highlights that the user's acceptance is a critical success factor for the adoption of innovative technologies. This factor can be sufficiently explained, accurately predicted, and effectively managed, taking into account the