Acceptance Model of an innovative Assistive Technology by neurological patients with a motor disability of their upper limb

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Abstract. This study develops a novel theoretical model that clarifies the main determinants of the acceptance of an innovative Assistive Technology by neurological/neuromuscular patients with upper limb motor disability. The model has been developed through a three stage method: Literature Review, Expert Judgement Elicitation and a pilot test of the model involving fourteen patients. The theoretical model organizes the most relevant determinants of patient acceptance along two dimensions, that reflect different perspectives. On the one hand, there is vertical dimension that is characterized by the distinction between functional vs. emotional perspectives. On the other hand, there is a horizontal dimension that is characterized by the distinction between individual vs. relational perspectives. This study has both theoretical and practical implications towards design and diffusion of rehabilitation/assistive devices with the intent to improve patients' independence and quality of life.

Keywords: Assistive Technology · Acceptance Model · Exoskeleton

1 Introduction

This study develops a novel theoretical model that clarifies the main determinants of the acceptance of an innovative Assistive Technology by neurological/neuromuscular patients with upper limb motor disability.

This model takes origin from the emerging field of Precision Medicine, where understanding socio-demographic variables that explain the intention to use over time a healthcare technology is critical to guarantee, at first, patient adherence and high clinical outcomes and quality of life.

The development of innovative technologies for upper limbs rehabilitation and assistance has gained momentum in the last years as result of the growing incidence of acquired cerebrovascular traumas (e.g., stroke) and neuromuscular diseases and the opportunities offered by robotics and Internet of Things (Industry 4.0).

In particular, cerebrovascular events are rapidly growing in terms of number, ranking first among the causes of disability acquired in adulthood in the USA and Europe with significant individual, social and economic impact. Moreover, as longevity increases, it is easy to assume a further considerable increase of stroke cases, and consequently upper limb dysfunction in the near future [1]. The mobility alterations resulting from the stroke acute event, in fact, involve in 93% of cases contralateral limb to the affected cerebral hemisphere affected, leading, every year, to about 150,000 new diagnoses of hemiplegia and hemiparesis characterized by muscle weakness, abnormal muscle tone, functional adjustment, and synergy of pathological movements, lack of mobility and loss of coordination. Only between 5% and 20% of patients with hemiplegic stroke can achieve partial or complete functional recovery of the affected limb. In particular, the reduced arm dexterity of neurological and neuromuscular patients has a huge impact on the personal independence and quality of life of stroke survivors and their families [2]. This is the reason why assistive technologies such as exoskeletons have the potential to provide enhanced quality of life and independence [2].

Over the past decade, major technological advances in robotics, actuators and control systems have led to an increasing development of assistive exoskeleton systems in which kinematic joints correspond to human joint centers [3], [4, [5]. In this direction, policy-makers of the most developed countries agree that developing technologies and interventions aimed at improving arm assistance is a priority. In this view, a key issue is to facilitate the effective transition from the Labs to the every-day clinical practice.

Past studies gathered evidence that the continuative use of assistive technologies is highly dependent on their acceptance by patients [6]. The acceptance of these assistive technologies cannot be taken for granted and understanding the factors that might promote or inhibit patient acceptance is a priority for both theory and practice.

When it comes to assistive technologies, although user-centered design theories gave a great contribution to the identification of factors that could influence their acceptance, to the best of authors' knowledge, there are not comprehensive models that explain patient acceptance in the specific case of assistive technologies – while there is a variety of acceptance models for general healthcare technologies.

This paper aims at developing a comprehensive model that clarifies the determinants of patient acceptance of a technology like robotic exoskeleton for upper limb. In doing this, the authors aim at contributing to both theory and practice.

The rest of the paper is organized as follows: Section 2 discusses the study methodology; Section 3 summarizes and discusses the findings, in particular the model developed. Finally, Section 4 draws conclusions and suggests directions for future research.

2 Study Methodology

We developed a theoretical model that explains the acceptance of an assistive technology by neurological/neuromuscular patients with upper limbs motor disability. The model has been developed through a three-stage method, detailed briefly in the followings.

STEP1: Literature Review. The literature search was limited to the field of "acceptance models of technology in healthcare". Since acceptance theory and practice was first developed in the Computer Science and only in recent years has been transferred and applied in health technologies, the search fell at the intersection between engineering scientific literature and medical, social science. Thus, the scope of the analysis covered both domains. Different literature sources were thus explored: one database covering medical literature (Pubmed) and two non-medical databases (Scopus, ISI Web of Knowledge). The literature search process was organized as follows: (i) screening process to identify descriptive articles and commentaries (examination of title and abstract); (ii) selection of the papers matching the following inclusion criteria: i) Theoretical knowledge of acceptance models; ii) Applications of acceptance models for technology in healthcare with particular focus on assistive technologies. The final aim was the **identification of determinants** of acceptance in the specific case of assistive technology.

STEP2: Expert Judgement Elicitation. Results from STEP1 have been shared with a panel of senior physicians specialized in neurological/neuromuscular patients and knowledgeable about assistive technologies, to elicit their expert judgement. Based on their expertise, we identified the determinants to be included in the acceptance model, balancing comprehensiveness and parsimony.

STEP3: This step dealt with a **pilot test of the model** crystallized at STEP2. This was performed by applying the model through questionnaire method during technological design concept testing of an upper limb exoskeleton for patients. Approval for the study was obtained from the relevant local research ethics authorities. The informal nature of this methodology facilitated an interactive discussion and reflection about their perception of the acceptance determinants. Participants were recruited within an ongoing research project aimed at the clinical test of an upper limb exoskeleton (Villa Beretta Rehabilitation Hospital, Northern Italy). Fourteen patients took part in our pilot test and have been individually interviewed. The informed consent was obtained from each participant.

3 Results

The first type of findings deals with the identification of the constructs on acceptance based on the literature review. The starting point was the study of the traditional acceptance models. In particular: Theory of reasoned action [7]; Theory of planned behavior [8]; Technology acceptance model [9], [10], [11]; Unified theory of acceptance and use of technology [12]. The literature review about the acceptance models in healthcare revealed that there is an emerging stream of acceptance models derived from the traditional ones. A critical issue underlined by the authors is the proper application or suitability of the existing models, since they were primarily designed and developed for other contexts [13], [14]. In fact, the studies dedicated to specific targets took into account the peculiarities of the specific context, as the case of the Almere model [15] designed for senior adults, and Senior technology acceptance model – STAM [16]. Some scholars are investigating the patients' opinions on using lower limb exoskeletons for older adults, or assistive robots in general, for daily tasks [17], but, to the best of our knowledge, no previous study has been found about upper limb exoskeleton.

Among the attempts to develop specific acceptance models for target applications, the studies of Shore et al. stand-out [13], [17]. In particular, Shore et al. 2018 [13] discussed a selection of TAMs, displaying a chronology that highlights their evolution, and indicates two TAMs— Almere [15] and STAM [16] —as the two models which merit consideration when attempting to understand acceptance and use of assistive robots by older adults. They emphasized the need for a deep adaptation and translation of these models to the specific needs [13], [17].

As result of the literature review, a preliminary list of relevant determinants – and relative constructs – have been identified. The review of the extant literature on acceptance models in healthcare (Almere and STAM) reveals that the models derived from traditional models (TAM; TPB; UTAUT), even if they consider contingent variables related to the characteristics of the object of analysis, they are focused on the analysis of determinants according to a **functional perspective** without focusing on **no-rational** determinants linked more to an **emotional perspective**. Although there is an emerging interest in developing acceptance models for assistive technologies, to the best of our knowledge there is not an ad-hoc model which isolate factors related to the emotional perspective and investigate relationships with determinants related to functional perspective.

We propose a theoretical model (Fig. 1) that organizes the most relevant determinants of patient acceptance along two dimensions, that reflect different perspectives. On the one hand, there is vertical dimension that is characterized by the distinction between **functional vs. emotional** perspectives. On the other hand, there is a horizontal dimension that is characterized by the distinction between **individual vs. relational** perspectives. We assume that acceptance is reflected by the intention to repetitively use the assistive technology. We include the selected constructs in this two-dimension framework. In particular, **perceived ease of use** and **perceived usefulness** as **individual determinants** according to a **functional perspective**.

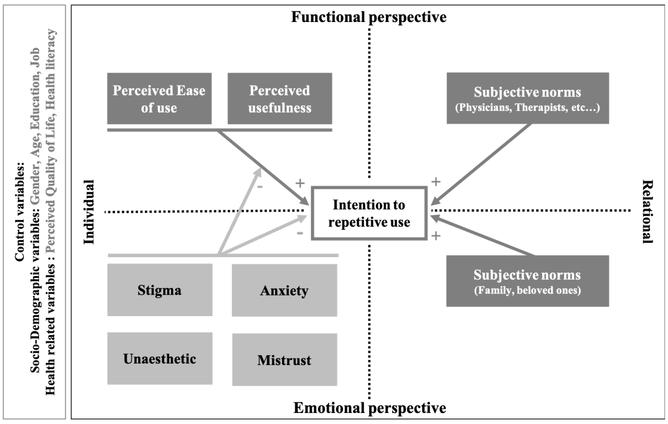

Fig. 1. Acceptance Model for upper limb exoskeleton

The relational "Subjective norms" by relevant influencers belongs to the functional perspective if referring to people related to the cure of patients (e.g., physicians, therapists, etc.) and to the emotional perspective if referring to people related to the care of patients (e.g., family, beloved ones, etc.). According to the **emotional perspective**, individual determinants have been organized in anxiety, unaesthetic, stigma and mistrust to assistive technology. These constructs might affect indirectly the intention to repetitive use of assistive technologies as (negative) moderators of the perceived ease of use and perceived usefulness. Control variables refer to two groups. On the one hand, there are socio-demographic variables: gender, age, education, type of job. On the other hand, there are health-related variables: perceived quality of life and health literacy.

The second type of findings concerns the expert judgment elicitation about the level of awareness of those determinants as influential on neurological patient acceptance. All the determinants proposed for evaluation were confirmed as relevant by interviewees. They agreed with the need to isolate the emotional determinants and functional ones to better understand how they may impact or change the person's intention to repetitive use. Beside the validation of each single determinant, some useful information about the perception of the influence of them on intention to repetitive use also emerged from the interviewees. In particular, interviewed physicians clearly revealed a personal ranking among determinants, by openly claiming that the individual and emotional determinants have negative influence on the individual functional determinants as perceived usefulness and perceived ease of use; and the relational "Subjective norms" by relevant influencers according to emotional perspective referring to people related to the care of patients (e.g., family, beloved ones, etc.) have positive influence on the intention to repetitive use. What was actually positively valued by the clinicians involved is its main potentialities to be extended to other context of assistive technologies.

The third type of findings regards the pilot test of the initial version of the model by the fourteen patients who took part in the studies. They confirm the relevance of irrational emotional determinants of the intention to repetitive use of the exoskeleton.

As result, investigating factors according to emotional perspective that determine acceptance by neurological patients is of paramount relevance for theory and practice. This study offers – to the best authors' knowledge – the first theoretical contribution towards an explanatory model of assistive technology acceptance by neurological/neuromuscular patients with upper limbs disability.

4 Conclusions

We developed a novel theoretical model that crystallizes the main determinants of the acceptance of upper limb exoskeletons by patients with neurological disease. This study provides a model to support the technological design process as a means to optimize patients use, acceptance of the upper limb robotic assistive technologies. The model presents a clear separation between the **individual** and the **relational** perspectives and between the **functional** and **emotional** perspectives.

Upper limb exoskeletons that are trusted, useful, and enriching to assisting with day-to-day tasks, offer important value and quality-of-life experience for users of these emerging technologies.

The development of this innovative theoretical model has both theoretical and practical implications towards design and diffusion of rehabilitation/assistive devices with the intent to improve patients' independence and quality of life. To the best of the authors' knowledge there is not much literature available about validated acceptance model for the upper limb exoskeleton. In this regard, this study is a first contribution.

The study has relevant practical implications as well. While ongoing studies have essentially been technology-driven, meaning that they primarily have aimed towards the development of new assistive technology, they neglect issues of acceptance, in the contexts where specific technologies would be implemented. In this regard, assessing the acceptance during the design phase of the technology would be a strong contribution for the real use of the technology.

Future work is necessary to apply the model and collect further data with a large sample of end users to validate any such determinant.

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References

1. Kwakkel, G., Kollen, B. J., van der Grond, J., & Prevo, A. J.: Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke. Stroke, 34(9), 2181-2186 (2003).
2. Dalla Gasperina, S., Gandolla, M., Manti, A., Aquilante, L., Longatelli, V., D'Angelo, M. G., …, Puchinger, M.: Upper-limb actuated exoskeleton for muscular dystrophy patients: preliminary results. In 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). pp. 4431-4435. IEEE (2019).

3. Ambrosini, E., Zajc, J., Ferrante, S., Ferrigno, G., Dalla Gasperina, S., Bulgheroni, M., ..., Gfoehler, M.: A Hybrid Robotic System for Arm Training of Stroke Survivors: Concept and First Evaluation. IEEE Transactions on Biomedical Engineering, 66(12), 3290-3300. (2019).
4. Ambrosini, E., Ferrante, S., Zajc, J., Bulgheroni, M., Baccinelli, W., d'Amico, E., ... & Puchinger, M.: The combined action of a passive exoskeleton and an EMG-controlled neuroprosthesis for upper limb stroke rehabilitation: First results of the RETRAINER project. In 2017 International Conference on Rehabilitation Robotics (ICORR). pp. 56-61. IEEE (2017).
5. Gandolla, M., Costa, A., Aquilante, L., Gfoehler, M., Puchinger, M., Braghin, F., & Pedrocchi, A.: BRIDGE—behavioural reaching interfaces during daily antigravity activities through upper limb exoskeleton: preliminary results. In 2017 International Conference on Rehabilitation Robotics (ICORR). pp. 1007-1012. IEEE (2017).
6. Steinke, F., Bading, N., Fritsch, T., & Simonsen, S.: Factors influencing trust in ambient assisted living technology: a scenario-based analysis. Gerontechnology, 12(2), 81-100, (2014).
7. Ajzen, I.; Fishbein, M.: Understanding Attitudes and Predicting Social Behaviour; Prentice-Hall: Englewood Cliffs, NJ, USA, (1980).
8. Ajzen, I.: From intentions to actions: A theory of planned behavior. In Action Control: From Cognition to Behavior; Kuhl, J., Beckmann, J., Eds.; Springer: Berlin, Germany, (1985).
9. Davis, F.D.: A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results. Ph.D. Thesis, Massachusetts Institute of Technology, MA, USA, 20 December (1985).
10. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q., 13, 319–340 (1989).
11. Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D.: User acceptance of information technology: Toward a unified view. MIS Q, 27, 425–478 (2003).
12. Venkatesh, V. Davis, F.D. A theoretical extension of the technology acceptance model: Four longitudinal field studies. Manag. Sci., 46, 186–204 (2000).
13. Shore, L., Power, V., De Eyto, A., O'Sullivan, L., W.: Technology acceptance and user-centred design of assistive exoskeletons for older adults: A commentary. Robotics, 7(1), 3 (2018).
14. Onofrio, R., Trucco, P.: Human reliability analysis (HRA) in surgery: Identification and assessment of Influencing Factors. Safety science, 110, 110-123 (2018).
15. Heerink, M., Kröse, B., Evers, V., Wielinga, B.: Assessing acceptance of assistive social agent technology by older adults: The almere model. Int. J. Soc. Robot. 2, 361–375 (2010).
16. Chen, K., Chan, A.H.S.: Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). Ergonomics, 57, 635–652. (2014).
17. Shore, L., Power, V., Hartigan, B., Schülein, S., Graf, E., de Eyto, A., O'Sullivan, L.: Exoscore: a design tool to evaluate factors associated with technology acceptance of soft lower limb exosuits by older adults. Human factors, 0018720819868. (2019).