User Centered Design in Practice
Adapting HRI to Real User Needs

Eleni Efthimiou†
Embodied Interaction and
Robotics Group
Institute for Language and Speech
Processing (ILSP)/ATHENA RC
Maroussi Athens Greece
eleni_e@ilsp.gr

Stavroula-Evita Fotinea
Embodied Interaction and
Robotics Group
Institute for Language and Speech
Processing (ILSP)/ATHENA RC
Maroussi Athens Greece
evita@ilsp.gr

Anna Vacalopoulou
Embodied Interaction and
Robotics Group
Institute for Language and Speech
Processing (ILSP)/ATHENA RC
Maroussi Athens Greece
avacalop@ilsp.gr

Xanthi S. Papageorgiou
Embodied Interaction and
Robotics Group
Institute for Language and Speech
Processing (ILSP)/ATHENA RC
Maroussi Athens Greece
xpapag@ilsp.gr

Alexandra Karavasili
DIAPLASIS Rehabilitation Center
Kalamata Greece
akaravasili@gmail.com

Theodore Goulas
Embodied Interaction and
Robotics Group
Institute for Language and Speech
Processing (ILSP)/ATHENA RC
Maroussi Athens Greece
tgoulas@ilsp.gr

ABSTRACT

Here we present the methodological principles and technologies, which compose the backbone of designing the i-Walk platform Human Robot Interaction (HRI) environment. The reported work builds upon experience gained from previous engagement with development of the multimodal HRI communication model of the MOBOT assistive robotic rollator and its end-user evaluation, leading to our enhanced methodology for identifying and prioritizing user needs as applied in our current HRI design approach. Emphasis is placed on adopting multimodal communication patterns from actual human-human interaction in the context of mobility rehabilitation, which may enrich human-robot communication by increasing the naturalness in interaction from the side of the robotic device by adding more "human" characteristics both in respect to understanding and reaction capabilities of the robot.

CCS CONCEPTS

• Human-centered computing • Human computer interaction (HCI) • HCI design and evaluation methods • Computer systems organization → Robotics

KEYWORDS

Human-Robot Interaction, Multimodal HRI design, User centered design, User validation, Intelligent assistive robotic systems, Assistive HRI, Mobility assistance

1   The i-Walk Project Concept

One of the greatest challenges that the modern developed societies are facing, is the rapid change in demographic data associated with the aging of their populations. A direct consequence is the increase of the population percentage that faces different degrees of mobility and cognitive problems apart from those caused by chronic related diseases and/or accidents.

The need to improve the quality of daily living by supporting mobility and vitality, as well as enhance independent living of elderly individuals with motor limitations [1] has inspired technological solutions towards developing intelligent active mobility assistance robots for indoor environments, providing user-centered, context-adaptive and natural support [2-5].

Figure 1: The i-Walk platform concept.

The i-Walk project aims at developing and testing a new pioneering robotic system that will provide a range of mobility and cognitive support functions for people belonging to the aforementioned population groups, building upon experience gained from research in the framework of the previously accomplished MOBOT[1] project. The goal is to develop a flexible platform of robotic technologies adapted on a rollator walker aiming to provide active assistance and with the ability to acquire knowledge and adapt to the environment, personalized to each individual user, in order to support mobility and enhance health and vitality. To achieve this goal, a number of methodologies are currently been developed, which are foreseen to be synergistically utilized. These include:

- Processing of multi-sensory and physiological signals and identification of actions for the monitoring, analysis and prediction of human gait and other actions of the user
- Behavioral and user-adaptive robot control and autonomous robot navigation for the dynamic approach of the user and the interactive co-occurrence combined also with voice guidance
- Human-robot communication, including speech synthesis and recognition technologies and a virtual assistant (avatar) to enhance the naturalness of communication.

The i-Walk project is researching the enhancement of these technologies and their application to meet major social needs. One of the project's major characteristics is the synergy of the technological achievements with medical services that concern rehabilitation, aiming at interacting with target populations (patients) in order to design and integrate systems based on the needs of potential users.

Overall, the i-Walk project aims to support elderly people and patients with mobility and/or cognitive inabilities, by achieving:

- More effective patient mobilization in the clinical environment of a rehabilitation center, reducing the burden on clinical staff and increasing the efficiency of rehabilitation programs, and
- Continuous support at home through technologies monitoring patients' progress, but also their mobilization through interfaces of cognitive and other

support, increasing their degree of independence and improving their quality of life.
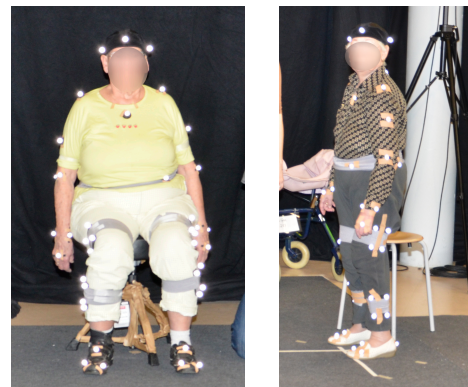
Figure 2: The body sensors set applied for acquisition of the MOBOT multimodal corpus.

2   Lessons Learnt from the MOBOT Rollator User Evaluation

The MOBOT project has envisioned cognitive robotic assistants that act proactively by realizing an autonomous and context-specific monitoring of human activities and by subsequently reasoning on meaningful user behavioral patterns, as well as adaptively and interactively, by analyzing multi-sensory and physiological signals related to gait and postural stability. To address these targets, a multimodal action recognition system has been developed in order to monitor, analyze and predict user actions with a high level of accuracy and detail [6].

Parallel to the enhancement of computer vision techniques with modalities such as range sensor images, haptic information and command-level speech and gesture recognition, data-driven multimodal human behavior analysis has been conducted in order to extract behavioral patterns of elderly people. The aim was to import the basic elements of these behavioral patterns into a multimodal human-robot communication system [7], involving both verbal and nonverbal communication conceptually and systemically synthesized into mobility assistance models after taking into consideration safety critical requirements.

The first evaluation phase of the MOBOT rollator-type mobility assistant was conducted at the BETHANIEN-Hospital/Geriatric Centre at the University of Heidelberg from end of October 2014 to beginning of December 2014. The final evaluation of the MOBOT prototypes was conducted in two phases: from April 22 to May 12 2016 at the BETHANIEN-Hospital/Geriatric Centre of the University of Heidelberg, Germany and from July 15 to 27 at the DIAPLASIS rehabilitation center in Kalamata, Greece [8].   The final evaluation phase performed at DIAPLASIS (Fig. 2), included a relatively extensive number of end users towards an overall benchmark verification of the developed intelligent mobility assistants [9].

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[1] http://www.mobot-project.eu/.

Figure 3: End-user evaluation of the MOBOT robotic rollator.

A total of 30 subjects participated in this evaluation study completing all foreseen scenarios of the experiments. Technical functionalities were assessed with respect to accuracy, validity and reliability of technical function. Clinical evaluation targeted at the interaction between a human and the device [10]. The scenarios implemented in validation studies aimed at assessing the performance of an audial cognitive assistance mode of operation and a set of audio-gestural human-robot interactions, aiming to evaluate the mechanisms implemented in order to build a close to natural human-machine communication.

Though all trials have been positively assessed in terms of feasibility and adequacy to the user needs, especially regarding the basic walking assistance, and the subjective user perception of the MOBOT device and its assistance systems [11], the "human" like characteristics of interaction have been the features which have received the highest scores in respect to user trust and user satisfaction in the subjective user evaluation, which took place as part of the evaluation procedures.

Such results are revealing regarding user expectations from devices, which are designed to be intensively used in a variety of home and clinical/rehabilitation contexts and demand a long-term user engagement [12].

These findings have driven the design of the human-robot interaction model in i-Walk. Thus, the i-Walk communication ecosystem incorporates a set of multimodal interaction options which intent to raise user trust and engagement on the basis of knowledge gained from end user evaluation results of a similar assistive device, but also through a thorough study of the target group needs and interaction parameters as described next.

3 User-Centered Design in Practice

In order to succeed in applying user-centered design, most system developers put emphasis in gathering user specifications by means of interviews, questionnaires or mocap demonstration to groups of intended users. Following this kind of methodology may prove successful in what concerns assembling the necessary functionalities for a system to address its goals. However, designing the human-machine communication model and interaction environment of an assistive device is crucially related to the degree to which the latter incorporates features of natural human interaction in similar situations, along with an in depth study of technologies selected to provide user access to device functionalities and system information to users.

With this in mind, when designing assistive interfaces, it is crucially important to concentrate on human communication situations, which include the use of embodied signals and language, taking into account the whole spectrum of options engaged to express a single linguistic message. This means that in the ideal case, the device's artificial intelligence capacity should be extended significantly, in order to become able to successfully handle communication situations not easy to predict, based on a rather robust underlying dialogue management system. Furthermore, incorporation of various features such as i.e. the use of touch screen, avatars or multimodal means of communication should serve specific needs towards better end-users support rather than be added just for the fun of variety, or because the technology is available.

In designing the i-Walk HRI model, the following parameters have been studied in detail:

1. The targeted user group(s) as regards rehabilitation needs to be supported by the platform
2. The symptoms which are expected to be supported as defined by a group of experts, including physicians, physiotherapists, ergo-therapists and psychologists
3. The combination of available and missing physical/mental functionalities of the patient target groups
4. The rehabilitation procedures followed in each case
5. The communication patterns used during rehabilitation process, including linguistic and embodied signal exchange between patient and therapist.

The designed communication model can, thus, be characterized as user-centered because it is built considering all the above parameters. Furthermore, the built in language communication model that is incorporated in the dialogue management system of the platform, makes use of intuitive human language characteristics and the variation met in real human-human communication.

The design of the language communication model has been based on the observation of several on-the-spot sessions between patients and physiotherapists/ergotherapists/psychologists in DIAPLASIS rehabilitation center. The observed sample consisted of both male and female inpatients and outpatients between the ages of 50 and 80 who attended pre-scheduled sessions. These were audio-recorded and transcribed, resulting in a corpus which was tokenized and lemmatized using NLP tools developed by ILSP.

lemma	frequency	lemma	frequency	lemma	frequency
go	4,013%	he	1,043%	open	0,778%
nice	2,740%	other	1,043%	alright	0,760%
am	1,627%	now	0,902%	foot	0,725%
well	1,414%	do	0,902%	lift	0,690%
little	1,220%	very	0,831%	beautiful	0,636%
there	1,149%	want	0,831%	high	0,601%
here	1,149%	hand	0,813%	step	0,583%

Figure 4: Excerpt of frequencies analysis of the real use cases token corpus.

The acquired 6,350-token corpus underwent quantitative and qualitative analysis, which revealed (a) specific high-frequency word/phrase patterns used in this type of interaction (Fig. 4) and (b) recurring communication strategies such as the use of uncomplicated vocabulary and the tactical repetition of certain key words. Adoption of real use case patterns of language communication in the i-Walk linguistic model aims at providing for a more natural and easier to adopt human-machine interaction, where the goal is set to increased user trust and acceptance, targeting engagement with the platform for a longer period.

4   The i-Walk HRI Components

The i-Walk experimental platform used for the development of the project's HRI module, consists of a sensorised passive rollator prototype, equipped with the necessary HRI components, as depicted in Fig. 1. The platform design incorporates HRI equipments in a portable and non-intrusive way. The system incorporates multimodal information from a camera and a microphone in order to capture the area of the torso, waist, hips and the upper part of the limbs, as well to communicate verbally with the user. The main goal is to interact and advice the user during the walking actions and during the execution of various rehabilitation exercises arranged in sessions. The main issue is to capture the upper body motion information and therefore to analyze the stability of the users' motion and assist them accordingly. In addition, through audio communication and avatar performance, the i-Walk system "naturally" interacts with the user at each phase of executed actions, by using simple instructions in order to guide and control the procedure and at the same time to provide reinforcement feedback in order to encourage and help the patient accomplish the executed task.

Furthermore, the platform incorporates visible and easy to use touchable buttons appropriate for the elderly people. Such buttons are very useful not only for emergencies, but also for platform mode selection, while making communication with the system highly accessible for the aged user. Finally, a screen is attached to the platform to provide visible instructions to the user by means of appropriately designed avatars.

In addition, the platform is equipped with biosensors, attached at the handles, in order to capture basic but comprehensive bio signals like heart signals, pulses, etc. This information is important to continuously monitor the users' status and to relax and protect them from fatigue and stress during execution of the foreseen rehabilitation activities.

4   Concluding Remarks

Cognitive and robotic architectures may be able to provide advanced interactive capabilities with humans and influence the usability and functionality of a resulting system, thus, contributing to its quality of services. Such systems may not only integrate multiple advanced cognitive abilities, but also employ methods that are extendible to various other robotic and non-robotic applications required in assisting humans with mobility disabilities [13]. Since, systems failing to address the requirement of high user trust [14] and acceptance seem to fail in respect to user engagement, user-centered system design incorporating 'natural' "intelligent" ways of human-machine communication is becoming obligatory.

The MOBOT rollator end user evaluation process has highlighted the importance of the "human" like system characteristics for user acceptance and engagement. In parallel, it has also pointed out the weaknesses of the initial design, especially focusing on the preset options of the multimodal interaction component of the evaluated prototype as regards the system's HRI options.

The current goal is to bring HRI modeling further by: (i) fully exploiting information derived from patients' everyday routines both as regards the range of their available physical and mental functionalities and tasks to be accomplished, and (ii) augmenting the device's communication capabilities by building an intelligent dialogue management system that entails lexically and semantically extended knowledge based on the actual linguistic and embodied interaction patters used by the targeted user group in real use environments while interacting with other humans including their therapists.

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