Application of a User-Centered Design Approach to the Development of XoSoft – A Lower Body Soft Exoskeleton

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Abstract. The objective of this research was to apply a user-centered design approach to the development of a soft exoskeleton for lower limb assistance. There has been a clear shift from hard to soft robotic exoskeletons in recent years. Soft exoskeleton technologies typically comprise sensors and actuators embedded in fabric/technical textiles. This approach to physical assistance offers benefits in usability for wearers, but also presents challenges e.g. how the concepts are put on/off and worn for long durations considering the personal needs of the wearer. Presented is a structured three-cycle development approach which considers user-centered design principles, but also a participatory user-driven design-test-redesign methodology. Target users for the concept (older adults, individuals post-stroke or incomplete spinal cord injury) were involved in concurrent design evaluation and development throughout the design process.

1 Introduction

User-centered design (UCD) – or human-centered design – is defined in ISO 9241-210 as "an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques" [1]. For wearable systems such as assistive exoskeletons, the rationale for adopting a UCD approach is clear: to ensure that the system is effective and efficient, to promote successful uptake and continued use, to improve user satisfaction and acceptance, to enhance user well-being, and to mitigate safety risks and other adverse effects.

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XoSoft (www.xosoft.eu) is a soft modular biomimetic lower body exoskeleton which aims to assist people with mobility impairments (e.g. older adults, people with stroke, incomplete spinal cord injury). UCD is a core feature of XoSoft, as clearly-defined user groups have played key roles throughout the project to inform the design of the system.

The current paper describes the application of UCD principles and methods to the development of XoSoft. Findings in relation to the practical benefits and challenges of applying a UCD approach are also discussed.

2 User-Centered Design of XoSoft

2.1 User-Centered Design Principles

A set of core principles underpin UCD [1, 2]:

1. The design is based upon a clear understanding of the requirements of the intended users, tasks and environments;
2. Users are actively involved throughout design and development;
3. The design is driven and refined by user-centered evaluation, facilitated by early prototyping;
4. The design process is iterative, with cyclical design, evaluation and redesign processes repeated as often as required;
5. The design addresses the whole user experience, including parallel development of training and support services, organizational structures etc.;
6. The design team is multidisciplinary, offering a variety of skills, expertise and insights.

These principles are of distinct value to the design of assistive exoskeletons, as novel, complex systems for which achieving usability and user acceptance are vital [3].

2.2 XoSoft Design Process and Methods

The principles of UCD were adopted to guide the structure and content of the XoSoft design process. This ensured that users and their needs were the driving forces for technology development. A variety of appropriate methods were used to achieve the desired aims of each stage of the process: (1) planning the UCD process, (2) specifying the context of use, (3) specifying user/organizational requirements, (4) producing designs and prototypes, and (5) carrying out user-based evaluations [4].

Figure 1 presents an overview of the XoSoft UCD process. A three-cycle iterative design approach was taken. A defined timeline for completion of specific prototypes (α, β, γ) and associated testing/user evaluation campaigns acted as milestones in the project.

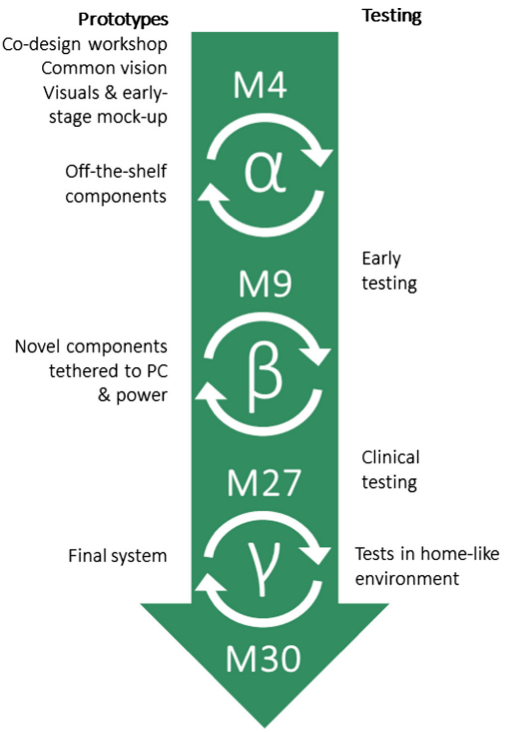

Fig. 1. Overview of the XoSoft UCD process. The prototypes developed (α, β, γ) are summarized in the left column. The nature of testing scheduled for each prototype is listed in the right column. The timeline is presented according to project months e.g. Month 4 = M4.

At the outset of the project (Months 1–4), a cross-sectional mixed-methods study was carried out to define prioritized user requirements for three target primary user groups [5]:

1. Older adults who require light to moderate physical assistance to perform activities of daily living;
2. Individuals post-stroke who would benefit from unilateral stability and assistance;
3. People with incomplete spinal cord injury who are mobile but would benefit from physical assistance.

The study also elicited the requirements of secondary users (professional and non-professional caregivers).

Prioritized user requirements were used to inform a design brief and technical specifications, which were developed via collaborative multidisciplinary discussions. This led to the first design cycle, in which the α prototype was rapidly developed using off-the-shelf technologies via co-design workshop methods. Testing the α prototype within the first year of the project accelerated understanding of users relative to the potential technologies to be explored and assisted the design team in developing a common vision and shared understanding of the concept.

Integration of novel technologies and refinement of the concept in line with user requirements was the focus of the β prototype cycles, leading to the final cycle – γ prototype development. Periodic user-centered design reviews were carried out in each cycle, focusing on primary users for the α prototype, and expanding to include secondary and tertiary users as the concept progressed to the β and γ prototypes.

3 Practical Benefits and Challenges Encountered

3.1 Benefits of Implementing UCD to XoSoft

The main benefits of adopting a UCD approach in the XoSoft project were:

1. Clear and early definition of target users and their needs facilitated early design work and prototyping;
2. Creation of user personas and a concise design brief enhanced understanding of users among non-clinical partners and gave focus to multidisciplinary design activities;
3. Early and frequent user feedback aided regular refinement of the concept and timely user input on new/altered components e.g. garment redesign.

3.2 Challenges of Implementing UCD to XoSoft

Challenges associated the UCD of XoSoft have included:

1. Ethical considerations associated with involving users in research, particularly potentially vulnerable populations like target users of XoSoft.
2. Technological challenges associated with the integration of components with varying Technology Readiness Levels (TRLs) into a single system e.g. high TRL components like garment materials and inertial measurement units, together with low TRL technologies like soft sensors.
3. Time constraints, since ideally in iterative design, the cyclical design process should be repeated for as long as required to achieve the optimal system. With a finite timeframe for the project, rapid progress within and between cycles was required.

4 Conclusion

A user-centered approach offers many benefits in terms of structuring and implementing the design process for a soft lower body exoskeleton, as seen in the XoSoft project.

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