From Pain to Design Recommendations for Assistive Robotics

Citation for the original published paper (version of record):
Walczak, N., De Cet, M., Romanowski, A. et al (2023). From Pain to Design Recommendations for Assistive Robotics. ACM International Conference Proceeding Series: 428-430.
http://dx.doi.org/10.1145/3623809.3623950

From Pain to Design Recommendations for Assistive Robotics

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ABSTRACT

Assistive technologies are vital for individuals with physical limitations, and understanding the diverse impact of physical pain is crucial for designing effective assistive robotic solutions. Through an iterative study, we aim to develop comprehensive design recommendations that cover personalization, concealment, compatibility, ease of use, preventive measures, skin-friendliness, affordability, adaptability, and multimodal features. These recommendations prioritize user experience and acceptance, ultimately contributing to innovative and user-centric assistive robotic technologies.

Understanding diverse physical pain and its effects is vital for designing effective assistive machines. Our user-centred iterative approach involves two research iterations with 97 young adults, across diverse urban perspectives, to uncover user needs and identify essential features for assistive robotic devices.

CCS CONCEPTS

• **Human-centered computing → User centered design**.

KEYWORDS

assistive technology, design process, mobility enhancement

ACM Reference Format:
Natalia Walczak, Martina De Cet, Andrzej Romanowski, and Mohammad Obaid. 2023. From Pain to Design Recommendations for Assistive Robotics. In *International Conference on Human-Agent Interaction (HAI '23), December 04–07, 2023, Gothenburg, Sweden.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3623809.3623950

1 INTRODUCTION

Assistive robotic agents have shown their potential in supporting individuals with daily tasks to enhance comfort and convenience [5, 6]. Their applications span from aiding urban daily activities [11] and work-related tasks [12, 24], to assisting individuals with impairments [8, 25]. Developers and designers are motivated to find solutions for challenging daily activities, and physical pain, a universal experience, can significantly impact one's life [15, 22]. Regardless of whether pain is acute or chronic, it can manifest diversely and affect various aspects of well-being.

2 RELATED WORK AND APPROACH

Ringwald et al.'s literature review on assistive robot design [17] reveals that while humanlike features can benefit these robots, only a few appearance patterns gain high acceptance. The scarcity of comparable studies and the multifaceted nature of acceptance highlight the importance of understanding target group needs and involving them in the design process instead of adopting a one-size-fits-all approach.

Additionally, extensive literature covers various applications of assistive technologies [1, 7, 9, 13, 21]. For instance, powered and electrical solutions [10, 23] are increasingly introduced to support individuals facing daily challenges due to various disabilities. In the same time, robotic exoskeletons find numerous applications in the biomedical and surveillance fields [1].

Furthermore, studies on the acceptance of assistive robotic technologies reveal promising outcomes. Carral et al. [2, 18–20] found that lower-limb exoskeletons were perceived as promising solutions for older people with mobility impairments and their caregivers. Chen et al. [3] emphasized considering emotional dimensions during assistive technology design, along with functionality and usefulness. Nertinger et al. [14] categorized daily activities by assistance levels. Examples of user-centred research include Power et al.'s [16] iterative design process for lower body exoskeletons and Golgoueh et al.'s [4] work on creating more flexible, light, and discrete assistive devices.

To our knowledge, limited research has explored general users' struggles in basic daily activities and how assistive technologies can support them. This motivated our user-centred approach, aiming to understand users' challenges in basic activities and address them using assistive robotic technology. We describe two iterative research phases in our approach and subsequently present a set of design recommendations for assistive technologies.

3 FIRST ITERATION - ONLINE SURVEY

An online survey included 77 participants (26M, 48F, 1NB, 2 did not respond) who answered open-ended and Likert scale questions. Participant ages ranged from 20 to 57 years (mean=34, SD 11.1). The

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HAI '23, December 04–07, 2023, Gothenburg, Sweden

ACM ISBN 979-8-4007-0824-4/23/12.
https://doi.org/10.1145/3623809.3623950

survey covered demographics and scenario-based inquiries related to mobility problems, frequency, and solutions. It was distributed in Poland (43 responses), Sweden (33 responses), and the UK (1 response).

3.1 Online Survey Results

Participants' mobility-related issues were collected and categorized into themes. They could share multiple struggles and rate them individually. The key insights were:

Commuting to work: Participants highlighted issues related to commuting to work or school, including road conditions, fuel costs, queues, and overcrowded public transport.

Sedentary lifestyle: Many discussed problems arising from a sedentary lifestyle, such as prolonged computer use leading to movement issues and feelings of laziness.

Physical pain: Affecting over half of the participants, revealed pain in body areas like the back, chest, hips, joints, and knees, along with pregnancy-related, injury-related, and post-operative pain.

Outdoor activities: Some faced difficulties in outdoor activities like sports and weightlifting, often due to physical limitations.

These themes were not evenly distributed between Poland and Sweden. Poland emphasized commute-related issues, while Sweden reported more sedentary lifestyle concerns. These findings influenced the subsequent interviews.

4 SECOND ITERATION - INTERVIEWS

The study employed two interview scenarios derived from the first study's thematic analysis. In these semi-structured interviews, participants discussed their daily mobility challenges and solutions, focusing on commuting decisions and end-of-workday struggles.

Twenty participants (8M, 12F), primarily students (n=13), aged 20 to 30 years (mean=24.4, SD 2.54), were interviewed for an hour. They used various transport modes, received public healthcare, and had limited prior experience with assistive technologies. The first iteration identified two main themes: 'Commuting to work' and 'sedentary lifestyle,' forming the basis for semi-structured interview scenarios. Participants imagined scenarios of preparing for work or school and an end-of-workday desk scenario. The interviews also explored participants' perceptions of potential assistive technologies addressing their identified problems, encouraging them to share visions and preferences for such technologies. They discussed key characteristics, willingness to use it for lower limb support, and thoughts on societal integration within a decade.

4.1 Results and Discussion

Thematic analysis was conducted by two coders on interviews from Sweden and Poland. The focus was on body pain during the day and proposed solutions. Themes included requirements, feedback, dimensions, well-being, visibility, affordability, and design choice. Participants also considered new technologies, often referring to existing solutions, and discussed their acceptance and potential target groups for assistive machines.

Pain: During interviews, participants frequently mentioned pain areas: Back-related pain, Head-related pain, and Limbs-related pain. Other pain points included muscle soreness, fatigue, pain due to obesity, injuries, and surgeries.

Design: Participants stressed the importance of well-designed, skin-friendly products with inconspicuous colours for societal acceptance.

Fit: Participants preferred discreet, comfortable, adaptable, lightweight, body-adhering solutions. Some favoured daily use, while others preferred temporary wear.

Visibility: Participants emphasized the importance of minimal visibility, non-intrusiveness, and imperceptibility.

Requirements and limitations: Users expressed interest in new technology but wanted assurance of safety and harmlessness. They sought information on testing and potential risks.

Feedback: Participants suggested technology reminders for breaks, posture correction, and standing up.

Wellbeing: Solutions related to back issues were prominent, with massage as a common suggestion. Users desired technology to reduce tension, track muscle fatigue, enhance strength, reduce anxiety, and support health monitoring.

Affordable: Participants highlighted the importance of cost accessibility for new technologies.

Technical solution: Various technical solutions were proposed, such as spine devices, vibrating mechanisms, sensors, adjustable speeds, and cable-driven technologies.

Specific existing solutions: Users discussed mobile apps, fitness trackers, stretching exercises, medication, warmers, electrical muscle stimulation, knee bands, robots, and exoskeletons.

Acceptance of new assistive technologies: Participants concerned about rapid advancements and side effects, recognizing its potential for enhancing self-sufficiency, experiencing emotions like shame, curiosity, and relief regarding its use.

Target group of assistive machines solutions: Identified target groups encompassed individuals with disabilities, older adults, those with chronic pain, stroke survivors, people recovering from injuries, industrial workers, healthcare professionals, manual labourers, and even recreational and sports enthusiasts, illustrating the broad potential impact of assistive machines.

5 CONCLUSIONS

Developing design recommendations for assistive technologies is valuable, but universal guidelines are complex due to diverse user needs. A user-centred approach, involving the target group throughout the design process is crucial, tailoring technologies to their requirements. Prioritizing lower limb and back pain issues, which emerged prominently, is essential, as these problems significantly impact daily life. Designers should focus on solutions that address these concerns, aiming to alleviate pain, enhance mobility, and support lower limb and back-related tasks, ultimately improving users' well-being.

This study's limitations include its focus on only two European countries and the younger generations, potentially limiting generalizability. Future research should gather data from a more diverse set of countries and include older adults to account for broader perspectives and age-related differences in needs. Implementing and validating design recommendations in practical projects, involving larger and more diverse participant groups, would enhance the applicability and impact of assistive machines, ensuring they address the needs of a wider user base.

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