A Persuasive approach in using Visual Cues to Facilitate Mobility Using Forearm Crutches

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Abstract. Patients suffering from neurological, orthopaedic diseases or injuries usually have lower body mobility impairment. Therefore, they require special assistance during rehabilitation process. Such assistance is normally provided by therapists and through the use of tools such as crutches or canes. However, patients prefer to experience independence and not having to rely on therapists. This is meanwhile they normally experience a challenging process to use the tools correctly which as a result can place them in a position to suffer from negative consequences such as falls or injuries.

Recent studies have shown that through augmentation, technologies can provide an engaging and motivating experience for physical rehabilitation. In this paper we review examples of currently existing practices and propose a new persuasive system, called *Augmented Crutches* which aims at helping people with mobility impairment to enhance their independence and reduce their need for receiving intervention from therapists. To develop the tool, we performed expert consultation with therapists identified patients pain points during the process. We found out the most common and hardest challenges are the positioning and coordination of the crutches. In this research, through consideration of pace setting, controllability and awareness as key design principles, we developed a tool that improves patient's confidence, motivations and perseverance in getting engaged in physical rehabilitation.

Keywords: Persuasive Technologies, Rehabilitation, Behaviour Change, Augmented Experiences, User Experience, Interaction Design.

1 Introduction

Mobility is an important prerequisite for equal participation in social life and satisfaction of basic human needs. Mobility impairments can restrict the participation in social life of those affected such that people lack fair opportunities for fulfilling their needs **[1].** Loss of physical mobility makes maximal participation in desired activities more difficult and in the worst case fully prevents participation **[2]** Among those with mobility impairment, the number of people with the need for learning to walk using assistive technology is increasingly rising **[3]**. Restoration of walking is a primary goal for people with stroke and their therapists. In many cases although the patient can resume

walking, he/she has to face restrictions. few people with stroke are able to mobilize outside the house as they wish, and approximately 20% are unable to get out of the house unaided at all **[4]**. Another example of physical impairment is Cerebral palsy (CP) which the most common childhood motor disability and often results in debilitating walking abnormalities, such as flexed- knee and stiff- knee gait. Current medical and surgical treatments are only partially effective and may cause significant muscle weakness. However, emerging walking technologies can substantially improve gait patterns and promote muscle strength in patients **[5]**. People with Multiple sclerosis (MS) also experience gait impairments as the most common symptoms of the disease **[6]** and the require training in using walking aids like canes, crutches. As they explain further, the idea is to keep patients safe while restoring confidence in their legs and balance.
Many assistive technology can help in facilitating gait disturbance and among them the most commonly used technology is crutches **[8,9]**. However, many patients experience a new discomfort and anxiety to their lives especially when using crutches especially if their disability is a result of accident or injury. Walking with crutches requires instruction, coordination and constant practice which requires a physical therapist to constantly assist the patient during the learning process mostly to avoid suffering negative consequences, such as falls or other injuries. However, in many cases patients can not have access to constant intervention and support from therapists or would rather to be independent when using crutches. *Augmented Crutches*, introduces a novice practice in helping patients using crutches without the need of constant supervision by therapists. In this research we worked closely with therapists to identify main pain points of using crutches and among all the hardest challenges are the position and coordination of the crutches. *Augmented Crutches* studies human behaviour aspects in these situations and augments the space around the user with time sensitive digital elements embedded in the design. This is performed through a mini-projector connected to a smartphone, worn by the user in a portable, lightweight manner. This paper discusses the initial stage of the design and evaluation of the persuasive aspects of the system and identifies *pace setting*, *controllability* and *awareness* as the key design dimensions for the successful creation of persuasive experiences as key motivating elements to help patients using crutches.

2 Background

Technologies focusing on augmentation have the capability of creating an interactive, motivating environment for patients with mobility impairment in which practice, learning and feedback can be manipulated to create individualized treatments to retrain movement **[17]**. Many of technologies focusing on augmentation of the user experience are persuasive in nature. Persuasive technologies for physical rehabilitation have been proposed in a number of different health interventions such as post-stroke gait rehabilitation **[10,11]**. For example, Luo et al. **[12]** developed a training environment that integrates augmented reality (AR) with assistive devices for post-stroke rehabilitation and training. Tsuda et al. **[13]** created a robot that provides textual cues based on information such as body acceleration. The textual cues are about the walking stride: whether it is short, long or correct. This improves the walking performance because it acts like a memory recall about the task.

In order to design the interactive augmented crutches, we used textual cues as well as visual cues. Through the application of textual cues within the design of the crutches, users experience memory retrieval which improves their walking performance **[13]**. Visual cues as well play an important role to help patients as they are self explanatory and facilitate users remember interactions through the use of visual working memory (VWM) **[18]** Rehawalk **[15]** is a rehabilitation system that projects the visual cues (footprints) on a treadmill during the gait training of the patient. Slekhavat et al. **[16]** developed a projection-based approach AR feedback system that improves movement kinematics in rehabilitation exercises. Another example is LightGuide **[14].**

In contrast to the named solutions above, our approach is suited for gait training with crutches and projects visual cues directly on the floor. This approach provides a closer to reality experience and facilitates portability of the tool. Moreover, despite other persuasive systems for rehabilitation **[20,21]** our solution focus on adaptability of the tool as well. Finally, focusing on the concept of Ambient Intelligence for Persuasion **[8]** our approach provides persuasive and motivational feedback in two different ways: (i) through persuasive comments and communication as well as information about gait training, and (ii) through carefully-timed visual cues, including the remaining time the patient has to complete each phase of the gait training.

3 Augmented Crutches

The two most common models of crutches are: axillary crutches and forearm crutches, or Lofstrand. Forearm crutches are the dominant type used in Europe which we use for the purpose of this research. In collaboration with therapists we learned that the more common types of crutch gait used are: three-point gait, four-point gait; and single crutch gait. These approaches are different mainly depending on how the user would put weight bearing on the injured side. Many studies of crutch walking have been made by researchers. For example, studies about the amount of weight bearing during crutch walking and studies to improve the user's walking with crutches **[9, 11]**. However, we could not find any study related to crutch gait, i.e. the coordination between the foot step and the crutch, which exhibits changes throughout the rehabilitation process.

Fig. 1. Augmented Crutches.

Augmented Crutches was designed and developed as a projection-based system that provides bio feedback to the user in a comprehensive and persuasive manner. The physical space surrounding the crutches is augmented and provides user with digital feedback, precisely-timed cues and motivating elements like textual quotes. It is worn as a belt that contains a front pocket where a Philips PicoPix mini-projector is connected to an Android phone running the system. This setup allows for portability and avoids the complicated task of VR treadmills, which would require additional training and would confuse learners with significant crutch-walking experience. To provide guidance when walking with crutches, the visual cues indicate the start of the process. Users are motivated by the combination of what is projected on the floor (visual cues), the timed challenge of moving along the path and motivating comments displayed to them. The design considerations that were addressed included:

a) **Adaptivity.** System adaptivity aims to satisfy the users needs and is addressed by the enhancement of user's affordances through development of a digital dashboard accessed using the mobile phone application. Using the information received from the questionnaire implemented within the dashboard, the system performs a triage and generates the adequate gait training (three-point, four-point or single gait).
b) **Visual Cues.** Visual cues provide information about the position of the foot and the crutch, and the sequence of movements which improve user's performance.
c) **Pace setting.** The element of pace setting is integrated in the design of the tool through generation of visual and textual cues. Users follow the cues within the intervals that they appear when using crutches. Through visual implementations, the user can see time needed to complete the sequence of the gait training also be informed about the sequence change.
d) **Feedback.** User receives feedback through the system once a sequence is completed. At this point motivational message is displayed to the user which improves their willingness to continue the process. Using feedback, users can monitor the progress of the gait training and react accordingly.

4 Evaluation

We aimed to get better understanding about users' behaviour during the evaluation session. We recruited 21 participants (7 who used crutches before and 14 who never walked with crutches). Ages ranged from 18 to 56 years old. All participants filled in a consent form before the start of the session. Once participants started interacting with the tool, they were shown the visual cues for 15 seconds before changing to the next one. Participants could understand and follow the visual cues. They were interviewed after each session, and filled-in a questionnaire in relation to criteria such as flexibility, easy to use, portability, usability, adaptability, constraints, drive and support.

Most users involved in this qualitative study were quite interested in the walking process and noted the importance that our system brings in terms of awareness, e.g. one user mentioned "*This is useful for understanding the crutch walking process*".

Users received feedback through the display of footprint and crutches icons. All users were able to understand the visual cues and the position of them. Few number of users expressed some frustration with the pace setting and coordination. Users reported high levels of motivation, which we assume could partially be due to the novelty of the tool provided to them. Although we did not measure motivation in detail, but we could confirm user engagement and motivation through behaviour observation. To motivate users, system showed motivational messages at specific points of the use of the crutches. We clustered the collected data and identified three main elements that formulate the design of the behaviour change support systems for gait training sessions.

Pace setting: Pace setting is the core design consideration in this project. Textual or visual cues implemented in the design of the tool can only be effective if they are displayed at the proper timing. Pace setting set up can be modified by the user to provide faster or slower experience when using crutches. Some messages (e.g. U9[1]) such as: "*timer also aims to encourage the person to learn to walk better with crutches*" confirms motivating aspects of design through implementation of pace setting. Also pace setting helps to make process less monotonous therefore more motivating as argued by a participant: "*Without the timer, it would be monotonous*" (U9)
Controllability: Most users feel confident and in control of the process. Predictability of design also makes positive contribution into controllability as users report experiencing the progress as expected and therefore more confident and in control. Users reported the ease of use of positioning and coordination of the system (U1, U2, U3, U4, U6, U7, U9), or articulated that "*numbers helped*" (U4, U6, U7, U9) or said "*the projection helps you see the sequence and what goes first (...) thanks to the [visual cues] that were being displayed*". However, one user was confused with the projection moving forward with him.
Awareness: Being aware of their progress was also highlighted by the users in this experiment. The notion of progress is particularly important in behavior change support systems, as it motivates the user towards achieving a desired goal. This is true also when progress is slow. In our case, the system was regarded close to a game. In fact, some suggestions were given to "*This is almost a game*", e.g. "*Maybe instead of showing different timings, [the system] could present different challenges: stairs, ramps*"

5 Conclusions and Future Work

Walking with crutches is a challenging process. Augmented Crutches provides a portable and adaptable solution that address the challenge while motivating users and reducing their need for receiving intervention from expert therapists. By digitally augmenting the physical space around the user, our system helps people to learn how to walk using crutches while developing self-confidence through increased level of controllability and predictability. Future work, would focus on improvements to the technical design of the system to allow more detailed real-time adaptation to users' gait speed and consideration regarding predictable achievement of users desired proficiency in using crutches. Another future direction would be to develop an audio-enhanced persuasive solution for the blind to learn using crutches independently.

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[1] [1] *Ui refers to the participant's anonymous ID used during the evaluation session.*

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