Patient- and Caregiver- Centered Systems for Cardiac Tele-Rehabilitation

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Context and Motivation

Over the past few decades, mortality from Coronary Artery Disease (CAD) has decreased. However, about 470,000 recurrent myocardial infractions are reported in the US [1]. Cardiac rehabilitation and secondary prevention programs have been proven effective to minimize recurrence and risk of disease. Traditionally, these programs are delivered to patients in a hospital or community healthcare center. Some constraints such as geographical distance to healthcare center, lack of time and psychological barriers to change behavior lead to decline in motivation to pursue long-term rehabilitation programs [9]. The rapid and deep penetration of mobile technologies (such as smartphones, smartwatches and activity trackers) and its popularity among diverse groups of people (in terms of age, socio-economic status, education backgrounds etc.) provide a great opportunity to leverage these to address the barriers in traditional cardiac rehabilitation systems. My background and interest in mobile technologies motivated me to pursue research in the direction of telemonitoring. While telemonitoring and tele-rehabilitation solutions show immense potential as an effective approach to address such issues, studies show a gradual decline in interest and lack of motivation in patients over a period of time which ultimately results in lack of therapy adherence [2,8]. Adopting persuasive technology in tele-rehabilitation solutions can contribute to solve these issues. The overall objective of my PhD research is to define, design and develop a *comprehensive tele-rehabilitation solution* for cardiac patients. This patient-centered solution will be complemented with a user-centered caregiver dashboard application to facilitate the telemonitoring process.

Related work

In the broad contexts of e-health and mHealth (mobile health), there are many past and ongoing studies that test the effectiveness and the applicability of home-based rehabilitation approaches for various medical applications [2]. These include technology-delivered or technology-mediated approaches to promote healthy lifestyle and minimize behavioral risks. While most available literature evidences cater to generic health behavior and lifestyle issues, far less has been achieved in building solutions that are tailored to a specific target group and do not help in resolving context-specific issues that arise.

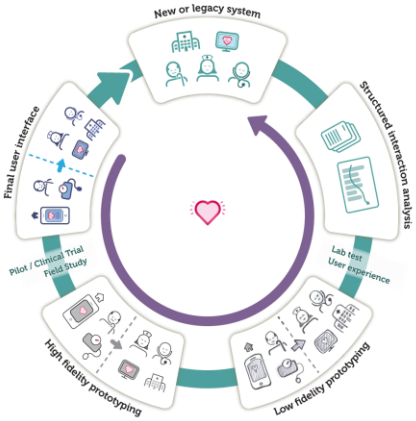


Figure 1: Different phases of the iterative multi-disciplinary user-centered design approach used in designing and developing the HeartHab prototype

To guide a rigorous Human-Computer Interaction (HCI) research and to effectively apply behavior change and persuasive technology in tele-rehabilitation, previously developed theories are insufficient. Most behavior change research in HCI target users either on a personal level (such as self-determination and goal setting) or on a social level (such as peer-group and social networks). They lack addressing the need to have a comprehensive solution. It is therefore essential to develop more pragmatic and qualitative approaches that can generate the knowledge required to form the foundations of building such systems [3].

Research Goals

Figure 2 depicts the envisioned conceptual architecture of the comprehensive tele-rehabilitation system I aim to develop for Coronary Artery Disease (CAD) patients. To achieve this objective, my research aims to realize the following goals:

1. Construct a secondary prevention tool for cardiac patients to manage their own cardiac recovery and prevent recurrence of cardiac disease.
2. Address existing challenges in current telemonitoring solutions by exploring and exploiting persuasive technology and behavior change theories.
3. Make a substantial contribution to the domain of Human-Computer Interaction, by making the system intuitive, customizable and connect with the user instantly.

Research Method

Since a cardiac tele-rehabilitation system involves different users such as patients, care-givers and

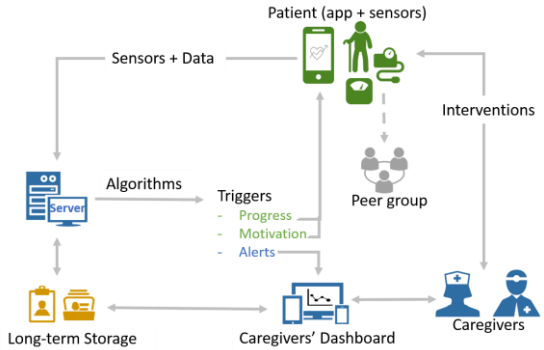
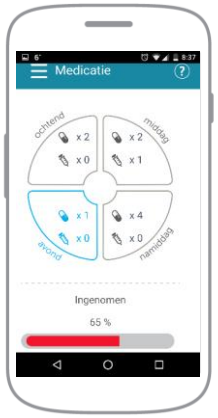


Figure 2: Conceptual architecture of the comprehensive tele-rehabilitation solution

doctors, I chose to adopt an iterative multi-disciplinary user-centered design approach (Figure 1) [4]. To better understand the current approaches in telemonitoring and identify user needs and resources, I collaborated with medical practitioners involved in rehabilitation at the local rehabilitation center. We conducted a workshop to better understand needs of the caregivers. I also had multiple brainstorming and discussion sessions with the medical team to gain deeper insight into their expectations from the tele-rehabilitation system. Based on these discussions, I developed a script to generate various risk-factor combinations that a patient can have. These combinations facilitated in categorizing patients using Behavior Wizard [10]. This wizard can assist in tailoring the system to suit patient-centric needs.

King et al. [5] suggest that the integration of behavioral science theory with an iterative user-oriented design process may enhance the potential of mobile applications aimed at promoting behavior



(a) Medication Overview

(b) Exercise Target

Figure 3: Screenshots of the medication and exercise target modules of the HeartHab prototype

change in key health areas such as promoting physical activity. I collated different persuasive design patterns that are relevant to cardiac tele-rehabilitation and thoroughly evaluated various theories pertaining to behavior change and persuasive technology. I also conceptualized 8 principles to efficiently leverage various existing behavior change theories and frameworks to guide the design of persuasive behavior change systems for rehabilitation [7]. Furthermore, these conceptualized principles can also form a foundation to guide the design process of future applications aimed specifically at remote rehabilitation for critical health domains.

To tailor the visual interface and adapt it to the specific target group more accurately, I applied the conceptualized principles and understanding gained from discussions with the medical team while creating the mock-ups for the low fidelity prototype. The low-fidelity prototypes were fine-tuned to create high-fidelity prototypes with the assistance of my research team's graphical designer. To optimally realize the design patterns and to make the user interface more usable, some basic interactions were added to the high-fidelity prototype. They were then organized into logical navigational structures and a lab-based usability test was conducted with a group of 6 patients at the rehabilitation center to get some preliminary feedback.

Based on the outcomes of the usability test, the interactions and features were further enhanced. A basic feedback and reminder mechanism was integrated to promote better adherence to therapy. This is not the final user interface that will be deployed in clinical trials, but the output of the first iteration of the multi-disciplinary user-centered design approach.

Some features of the prototype (named HeartHab) at this phase, are being tested in a longitudinal field study with a different groups of patients [7].

Outcomes

Usability tests [lab tests]

To evaluate initial user experience of the HeartHab prototype, a preliminary lab test was conducted with a group of 6 cardiac patients who were then undergoing in-hospital rehabilitation. The goal of this study was to observe how participants interacted with HeartHab while performing different tasks and gain insight on some fundamental usability aspects such as patients' comfort with using mobile technology, ease of navigation through different screens of HeartHab and understandability and relevance of various features. The overall response of participants during and after the test was encouraging. All participants said that if given, they would like to use this application on a daily basis. Apart from one participant who had no interest in using technology in general, all other participants gave a positive feedback with respect to their interest in using such a system for tele-rehabilitation.

Pilot tests [on-going field tests]

After getting appropriate approvals from the ethical committee, the prototype was tested with an initial group of 4 patients. It is scheduled to be rolled out to the next group of patients with additional features in the upcoming weeks. The aim is to test the prototype for a longer duration (4-6 weeks) to assess the robustness of the system, collect usage logs to identify patient usage or behavioral patterns and to test various modules that are relevant to different groups of patients. These observations can help gain insight on

tailoring the prototype better in the subsequent iterations.

Discussion and Next steps

Achieving an ideal change in health behavior through the process of tele-rehabilitation is sensitive and demanding for a cardiac patient. Evaluating this change is challenging and adds complexity to the overall research process. In initial prototypes, it is not feasible to demonstrate substantial influence of novel methodologies on health behavior change. A detailed analysis by Klasnja et al. [6] states that a thorough understanding of system use, and the resultant design knowledge, is arguably the biggest contribution that HCI can make to the development of effective systems in the domain of behavior change. I aim to contribute in that aspect by using different methods of bridging theories and formulating conceptual principles and adopting an overall iterative multi-disciplinary user-centered design approach to guide the design of systems for rehabilitation of CAD patients.

Although using this approach has yielded some positive initial outcomes, I do not have a detailed insight into the persuasiveness of the application which can only be evaluated in a longer study. In the next steps, I plan to use the outcomes of the ongoing studies to further strengthen and improve the current user experience and contribute to the development of effective persuasive systems for tele-rehabilitation.

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