Mobile health App for patients in the postoperative period of cardiac surgery

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Abstract

There is evidence that digital technology can positively contribute to cardiovascular disease (CVD), such as total cholesterol, physical activity, healthy diet, and medication adherence. For this, mHealth is an ally that can provide self-management of CVD, such as medical recommendations, medical consultations, reminders, and notifications for disease monitoring. The main objective of this master's thesis project is to develop a digital health support application for the postoperative period of cardiac surgery and to evaluate its usability criteria based on the user's experience. It will be technological, innovative research of a quantitative nature. The design of the mobile application prototype will follow the principles of The Design Science Research Methodology. It will also consider the Persuasive Systems Design, motivating users by leveraging social support and encouraging people to continue using it. We will apply a usability test with physicians, nurses, programmers, and patients in the postoperative period of cardiac surgery in a hospital in southern Brazil.

Keywords

Mobile Applications, Postoperative Care, Cardiac Surgical Procedures, Persuasive Systems Design.

1. Introduction

The global burden of CVD is a worldwide public health problem as it is one of the leading causes of death globally. In 2019, an estimated 18.6 million people died from CVD, equivalent to an increase of 17.1% compared to 2010 [1]. A proportion of individuals who suffer a cardiovascular event will require some cardiovascular procedure, whether it be the insertion of a pacemaker or implantable cardioverter-defibrillator, aneurysm repair, or heart valve replacement [2]. In this case, it is necessary to avoid patients' postoperative complications such as atrial fibrillation, renal failure, and reoperation due to bleeding, stroke, and pneumonia [3].

Coronary artery disease (CAD) is a type of CVD caused by plaque buildup on the walls of the arteries that supply blood to the heart muscle and other body parts. This plaque is mainly composed of cholesterol deposits, which hinder blood flow over time due to the narrowing, and there may be a partial or total blockage [4]. In Brazil, the number of people with CAD increased from 1.48 million in 1990 to more than 4 million in 2019, and the crude prevalence of CAD rose from 0.99% to 1.85% in the period. However, the prevalence rate standardized by age has remained stable [5].

The project's objective is essential for the high global burden of mortality caused by CVD, the increase in the number of patients with CAD in Brazil, and the necessity of user empowerment to be protagonists of their health. Furthermore, it aims to help people in the postoperative period of cardiac surgery, improve their medication adherence through social support, provide a direct communication channel with doctors, and improve user monitoring.

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Most applications offered today provide support primarily in patient care. So far, minimal effort is being made specifically for social support. This way, an attempt will be made to fill this knowledge gap.

Finally, this work intends to answer the following research question: What results from a mobile health application for digital support to cardiac surgery postoperative patients?

1.1. Objectives

General objectives: To develop a digital health support application for the postoperative period of cardiac surgery and to evaluate its usability criteria based on the user's experience.

Specific objectives: Specific objectives are in below such as

1) Design the application according to the interface and user experience (UI/UX) design criteria.

2) Design the application considering the Design Science Research Methodology (DSRM) and the fundamentals of Persuasive Systems Design (PSD).

3) Structure the application's content and interactive tools on the Adalo® platform.

4) Apply the usability scale (System Usability Scale - SUS) and analyze the user experience.

2. Theoretical framework

2.1. Cardiovascular diseases: definition and epidemiology

According to the World Health Organization (WHO), CVD is a group of disorders of the heart and blood vessels that include coronary heart disease, cerebrovascular disease, peripheral arterial disease, rheumatic heart disease, congenital heart disease and deep vein thrombosis and pulmonary embolism [6]. The primary conditions are acute myocardial infarction (AMI) and stroke. Common reasons for the precipitation of these diseases are fatty deposits on the inner walls of blood vessels and bleeding from a blood vessel in the brain, for example [6].

In the Region of the Americas, CVD accounts for 36.4 million years of life lost (YLLs) to premature death, 40.8 million disability-adjusted life years (DALYs) each year, and 4.5 million years living with disabilities (YLDs) [7].

Following global statistics, CVD was the leading cause of death in Brazil in 2019, except for the North region's Amazonas state, where AMI was the leading cause. For YLLs, 8,130,233 years of life were lost due to CVD mortality in the same year. This number was higher among people aged 50 to 60 compared to other age groups. In addition, from 2008 to 2019, the main groups of clinical and surgical cardiovascular procedures totaled 8,743,403 paid by the Unified Health System (SUS). Of these, more than 7 billion were clinical, mainly due to heart failure, which accounted for 41.3% (3,085,359) of hospitalizations [5].

The consequence of cardiovascular events can be evidenced in the 2023 American Heart Association report update. American statistics showed that 481,780 percutaneous coronary interventions were performed in 2018 and 161,816 coronary artery bypass graft surgeries in 2019 [8].

In Brazil, research that evaluated the evolution of the incidence and mortality of cardiovascular surgeries performed at the Heart Institute of the Faculty of Medicine of the University of São Paulo between January 1984 and June 2019 showed that in total, 105,599 surgeries were performed, with an annual average of 2,964 procedures and a mortality rate of 5.63% [9].

2.2. Mobile applications (mHealth) and CVD

So far, there is evidence that digital technology can positively contribute to CVD. For example, a meta-analysis of nine studies found that digital health interventions (telemedicine, web-based strategies, email, cell phones, mobile apps, text messages, and monitoring sensors) significantly reduced CVD (RR=0.61, 95%CI 0.45;0.83). In addition, five studies that incorporated data monitoring also showed benefits in reducing diastolic blood pressure ($p<0.001$). [10]

More recently, a meta-analysis with randomized controlled trials (RCTs) with at least four weeks of intervention aimed to identify and measure the effectiveness of digital technology, including cell phones

and software applications, in patients with CVD. The study demonstrated that digital technology intervention in cardiac patients was associated with improvements in total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), physical activity, physical inactivity, healthy diet, and medication adherence (all $p \leq 0.05$) [11].

Another evidence that its use can be very effective for people is described in another meta-analysis of 12 RCTs with data on ischemic heart disease, heart failure, or hypertension in adult patients. It concluded that mobile phone technologies were associated with a significantly lower rate of hospitalizations (OR 0.77, 95%CI 0.62; 0.97) in patients with heart failure. In addition, patients with high blood pressure, when exposed to mHealth, had significantly lower systolic blood pressure ($p=0.02$) [12]. Similar results were also found by [13]. They analyzed 9 RCTs to identify the effectiveness of mHealth interventions (cell phones, computers, laptops, and tablets) in reducing men's CVD risk. The authors found improvements in body weight, body mass index (BMI), waist circumference, and blood pressure among men who received these interventions ($p<0.01$; $p=0.01$; $p=0.02$; $p< 0.01$, respectively).

2.3. Mobile applications (mHealth) related to cardiovascular surgery

A systematic search was carried out in the scientific literature of studies on the subject of interest, counting on the technical support of a librarian from the University Library of the Federal University of Santa Catarina (UFSC). The search syntaxes were directed to the following electronic databases: National Institutes of Health US National Library of Medicine (PubMed) and Medical Literature Analysis and Retrieval System Online (MEDLINE), Web of Science, Scopus, EMBASE and "IEEE Xplore."

After the searches, the files were organized on the Rayyan® selection platform [14], where 231 duplicates were excluded, leaving 385 articles to be included and excluded by title and abstract. After this first stage, 19 articles were selected for a full reading.

3. Method

3.1. Nature and type of study

This will be technological, innovative research of a quantitative nature. The design of the mobile application prototype will follow the principles of The Design Science Research Methodology (DSRM). In addition, the Persuasive Systems Design (PSD) will also be considered.

3.2. The design science research methodology (DSRM) and persuasive systems design (PSD)

The DSRM originates in the differentiation between natural and artificial environments proposed by [18]. For the author, natural science describes and teaches how natural phenomena work and interact with the world. According to [16] identified six phases of DSRM, namely problem identification, objectives definition, design and development, demonstration, evaluation, and communication. In this study, we will apply these phases in the following manner:

1) Problem Identification: The lack of PSD-focused heart surgery mobile apps; 2) Definition of objectives: The main objective is to develop a digital health support application for the postoperative period of cardiac surgery and to evaluate its usability criteria based on the user's experience; 3) Solution development: Creation of a mobile application through the Adalo® platform; 4) Solution evaluation: The evaluation will be made with the usability scale (System Usability Scale - SUS); 5) Communicating Results: The results of the research process will be communicated to others through the publication of at least two scientific papers; 6) Critical evaluation: A critical evaluation of the developed solution and the process used to develop it will be made in the "discussion" of the project and it will include a reflection on the assumptions and limitations of the DSRM in relation to the issue at hand and suggestions for future improvements. Finally, DSRM is an iterative process. The steps can be repeated until a satisfactory solution is reached.

PSD [17] comprises a holistic framework for developing persuasive technology. Fogg [18] introduced the concept of persuasive technology, describing computing products as persuasive social actors. These technology products can influence and provoke social responses in users by rewarding people with positive feedback, modeling behavior or attitude, or providing social support. The design of this application intends to fulfill the four fundamentals of PSD as follows:

1) Primary task support: The application will be responsible for making the task of postoperative cardiac surgery care more accessible for the patient through different contents and properties; Users will have access to content specific to their surgical procedure, as well as podcasts and interviews with experts in the field; Users will have access to their stats and progress regarding app usage. The application will allow users to respond to online questionnaires to assess their mood (Brunel-Brums Mood Scale) [19]; pain (Visual Analog Scale) [20]; track depression (self-administered Montgomery-Asberg Depression Scale) [21] and quality of life after cardiac surgery (Medical Outcome Study Short Form-36: MOS SF-36) [22].

2) Dialogue support: It intends to provide users with flyers and stickers to present and promote participation; The application will have reminders and notices regarding medication use, date and time of consultations, ask about signs and symptoms, request photos of the surgical wound, and request test results (prothrombin activity time, for example). The more the patient uses the application's functions, the more scores he will acquire, placing him in a ranking (which can be anonymous, with a fictitious name) and releasing extra content such as podcasts with specialists; The application will be colorful and have large letters to please users.

3) System Credibility Support: The content will be based on guidelines and international organizations, such as the World Health Organization, the American Heart Organization, the Enhanced Recovery After Cardiac Surgery Society, the Society of Thoracic Surgeons, and the Guidelines of the Brazilian Society of Cardiology. There will be a "References" topic, where users can access the sites and protocols for building the application. In addition, the app will feature a section about the research team and its affiliations.

4) Social support: It will unite patients with the same goals who have recently undergone heart surgery with the same health professionals; It will have a Wall in which they can exchange ideas and report how they are feeling after the surgery (which can be anonymous, with a fictitious name); Users will be able to access the application's statistics, where they will have information on the percentage of people who are performing tasks (taking medication at the correct time, filling in signs and symptoms, photos of the postoperative wound, participating in the Wall); The app will reward stars and badges (unlocking extra content) and will have a ranking showing the most engaged patients.

Aiming to fulfill the PSD criteria to guarantee the system's success, the mock-ups of the mobile application are represented in Figure 1 and application flow model is represented in Figure 2.

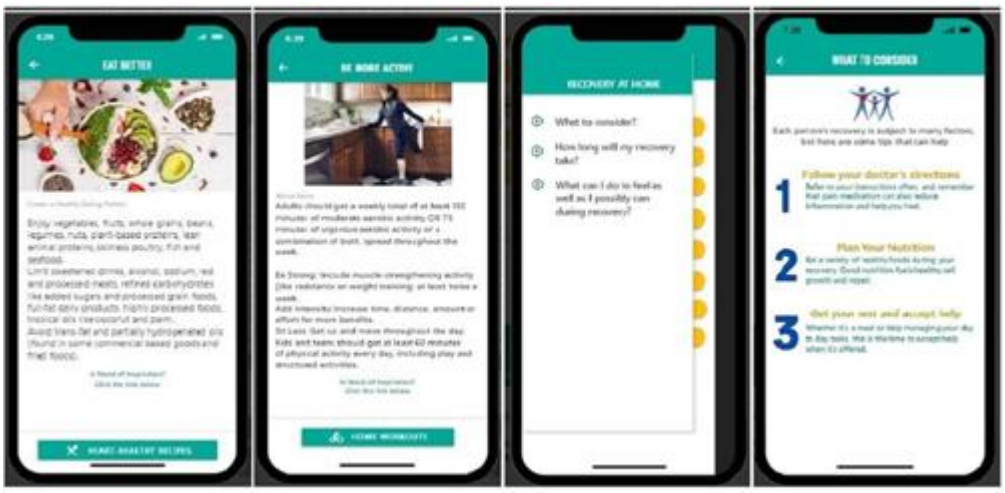

Figure 1. Application mock-ups. Source: Prepared by the author with the Adalo® Sofware (2023)

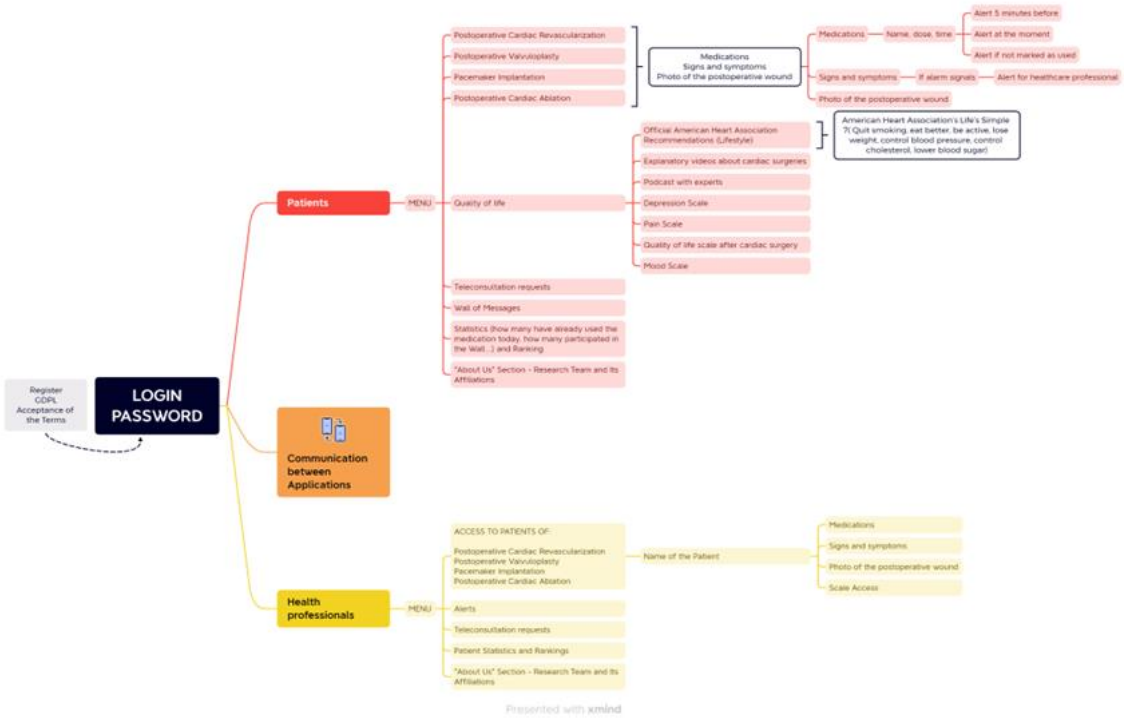

Figure 2. Application flow model. Source: Prepared by the author with the Xmind® Software (2023)

3.3. Population and sample

The Usability test (SUS) [22] will be applied to health professionals (physicians and nurses), programmers, and patients with postoperative heart surgery in a Hospital in Florianópolis. The sample will be non-probabilistic for convenience.

4. Expected results

- The usability of the system be rated at least as "excellent".
- The user experience generates a positive perception of the application.
- Reduce the global burden of years lived with disability and mortality.

- Contribute to the rapid recovery and commitment to the treatment of patients in the postoperative period of heart surgery and make the user the protagonist of their health.
- By implementing persuasive strategies, users are expected to adhere more to the mobile application, mainly through social support, allowing patients to connect with others who share similar problems. Users will also have more autonomy in adopting healthy behaviors, including self-monitoring through scales for depression, pain, quality of life, and mood, and tracking their health conditions through graphs. Tracking signs and symptoms and evaluating postoperative wounds, for example, is expected to lead to better adherence to treatment and a reduction in postoperative complications.

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