A Persuasive mHealth Application for Postoperative Cardiac Procedures: Prototype Design and Usability Study

Renata Savian Colvero de Oliveira[1](✉), Grace T Marcon Dal Sasso[2], Sriram Iyengar[3], and Harri Oinas-Kukkonen[1]

[1] Oulu Advanced Research On Service and Information Systems, University of Oulu, Oulu, Finland
renata.deoliveira@oulu.fi
[2] Federal University of Santa Catarina, Florianópolis, Santa Catarina, Brazil
[3] College of Medicine, University of Arizona, Phoenix, USA

Abstract. The global burden of cardiovascular diseases (CVD) is a worldwide public health problem. In 2019, 18.6 million people died from CVD, representing a 17.1% increase compared to 2010. Also, some individuals who experience a cardiovascular event will require some form of cardiovascular procedure, such as a pacemaker or implantable cardioverter-defibrillator insertion, aneurysm repair, or heart valve replacement. Mobile health (mHealth) is a valuable tool for supporting individuals with CVD in self-management, providing medical recommendations, virtual consultations, reminders, and disease monitoring notifications. The main objective of this research was to enhance postoperative care for cardiac procedures. To achieve this, the research involved the development of a new mHealth application and the subsequent evaluation of its usability. The study constituted technological and usability research by using Design Science Research Methodology (DSRM). The design of the mobile application followed the principles of Persuasive Systems Design (PSD) model, which encompass a clear definition of the main task, user interaction through dialogue, system credibility, and social support, aiming to help change user behavior. The sample was non-probabilistic for convenience, and System Usability Scale (SUS) was applied to physicians and nurses as well as individuals in the information technology field. The sample comprised 18 participants, of whom 55.6% were female. The participants rated the application positively, with a median final SUS score of 95 (IQR 90–97.5). Finally, the mobile application presented high usability and user acceptance.

Keywords: Cardiovascular Diseases · Persuasive Systems Design · Usability Study · Mobile Health Applications

1 Introduction

Cardiovascular disease (CVD) is a major cause of death worldwide, making its burden a global public health concern. According to estimates, 18.6 million people died from CVD in 2019, a 17.1% increase from 2010 [1].

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Low- and middle-income countries bear the greatest brunt of the substantial disease burden attributed to cardiovascular diseases (CVD). In the Americas region, CVD is accountable for 36.4 million years of life lost due to premature deaths, 40.8 million disability-adjusted life years annually, and 4.5 million years lived with disability [2]. Brazil mirrors these global statistics, with 30% of deaths attributed to CVD [3].

Some patients who have undergone a cardiovascular event may require cardiovascular procedures due to the disease's progression. These procedures may include the implantation of a pacemaker or implanted cardioverter defibrillator and the correction of an aneurysm [4]. It is essential to prevent post-operative complications, such as atrial fibrillation, kidney failure, reoperation due to bleeding, stroke, and pneumonia [5].

In the current landscape, a comprehensive meta-analysis of randomized controlled trials (RCT) has provided robust evidence supporting the beneficial impact of digital technology on CVD management. This analysis highlights significant improvements in several key areas, including total cholesterol levels, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, physical activity, dietary habits, and adherence to medication regimens [6]. The integration of mHealth solutions plays a pivotal role in this advancement by facilitating patient self-management of CVD. mHealth achieves this through the provision of direct access to medical consultation and advice, as well as the delivery of personalized reminders and notifications that aid in continuous disease monitoring and management [7].

Making healthier lifestyle choices and changing one's behavior are the most crucial ways to halt the progression of CVD. To modify unhealthy lifestyle choices including smoking cigarettes, eating poorly, and not exercising, younger patients should receive regular counseling [8]. Behavior modification is necessary and helpful even in cases where the patient has previously suffered a cardiovascular event to reduce the risk of further events. Taking prescription drugs as prescribed, scheduling frequent doctor's appointments, and controlling risk factors are a few instances of this [9].

In this scenario, the application of persuasive technology can yield significant benefits. Persuasive technology encompasses a broad range of digital tools and platforms specifically designed to influence attitudes or behaviors. This includes, but is not limited to, computers, websites, smartphones and their applications, tablets, wearable devices, and computer games [10]. Each of these technologies has the potential to engage users and effectively guide their behaviors or attitudes in desired directions. According to Fogg's [11] initial description, computing items are persuasive social agents. Stated differently, these technological products possess the ability to impact and trigger social reactions from their users, through various means such as rewarding individuals who provide positive feedback, modeling a particular behavior or attitude, or providing social support. Oinas-Kukkonen and Harjumaa [12] suggested a method for applying design principles to software requirements and their subsequent implementation as characteristics of a system. To make this more practical, they proposed the Persuasive Systems Design (PSD) model, which has four main categories of software features: primary task support (PRIM), dialogue support (DIAL), system credibility support (CRED) and social support (SOCI).

In a recent RCT, the PSD model was utilized to investigate the efficacy of a mobile health behavior change support system as an obesity control intervention. The intervention group lost weight more successfully than the control group, according to the trial (95%CI –3.8 to –1.6, $p < 0.001$). Thus, the effectiveness of the PSD's use in mHealth in modifying behavior can be observed [13].

This study aimed to improve postoperative care for cardiac procedures. This entailed developing a mHealth application prototype and then evaluating its usability, firstly focusing in professionals on the technology and health domains.

2 Background

2.1 Cardiovascular Diseases

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 [14]. The main diseases are known as ischemic heart disease, or acute myocardial infarction and cerebrovascular accidents. Common reasons for the precipitation of these diseases are fatty deposits on the inner walls of blood vessels and bleeding from blood vessels in the brain, for example [14].

2.2 mHealth Applications for Cardiovascular Procedures

To identify the state of the art regarding this topic, a scoping review was conducted in November of 2022 and search keys were created for all the electronic bibliographic databases consulted, including National Institutes of Health US National Library of Medicine (PubMed) and Medical Literature Analysis and Retrieval System Online (MEDLINE), Web of Science, a Scopus, EMBASE and IEEE Xplore. The main descriptors were "Mobile Applications" AND "Postoperative Care" AND "Cardiac Surgical Procedures". After excluding 231 duplicates, 385 articles remained for inclusion and exclusion by title and abstract. After this first stage, 19 articles were selected for full reading. Of these, four were unrelated to the research topic, five did not have results (reports or protocols), one was due to unavailability of full text and three could not be retrieved even after contacting the corresponding author. Finally, six articles were included.

The studies have explored the detection of atrial fibrillation with the help of an electrocardiogram [15, 16], medication adherence [17] and collection of photoplethysmography data to detect patients' heart rhythms allowing them to report symptoms and send messages to their doctors [18]. In a similar direction regarding communication with the healthcare team, Atilgan et al. [19] used a telemedicine system that allowed patients to monitor their vital signs and report symptoms to their doctors via instant messaging and video conferencing. Aydin et al. [20] reported using two different applications, one for control patients' breathing, including breathing exercises, and training to increase lung capacity. The second application was related to medication adherence, and researchers selected it from those available on the Google Play Store and App Store.

This work focused on designing an application that optimized the patient's clinical experience by eliminating the need for additional portable devices to make it more accessible and cost-effective. By unifying the different functionalities, including reinforcing medication adherence, facilitating contact with the medical team, monitoring signs and symptoms after cardiac procedures, providing relevant educational content, and scheduling teleconsultations, all within a single application, we focused on not only improving the patient's post-operative care but also increase their active participation in their recovery process. This approach reflects not only practical efficiency but also a concern for accessibility and convenience for users, thus aligning with the principles of persuasive technology.

2.3 Persuasive Technology and Persuasive Systems Design

To be successful in changing behavior, Fogg's model stipulates that three elements must converge at the same time for a behavior to occur: motivation, ability, and triggers (e.g., an alarm that sounds, a text message, an advertisement). To achieve a target behavior, a person must have sufficient motivation, sufficient skill, and an effective trigger. Furthermore, these three factors must be present simultaneously [21].

The software features that comprise the PSD are split up into the four main categories. Carrying out the user's primary task, such as enabling users to independently track their progress, is referred to as PRIM. By reminding users of tasks related to the primary task or making the user interface visually appealing, computer-human dialogue, DIAL, makes sure that users receive assistance in maintaining their target behavior. Credibility, CRED, explains how to create a system that is more trustworthy by offering accurate, impartial, and fair information and directing users through reliable sources. Lastly, social support, SOCI, explains how to use social influence to motivate users of the system. Some examples of this include bringing together individuals who share a goal, helping them feel included, and offering opportunities for cooperation [12].

3 Methods

3.1 Study Design

This paper addresses prototyping and usability study. The research followed Design Science Research Methodology (DSRM) [22] and the design of the mobile application prototype followed the principles of PSD [12].

The six phases of the DSRM [22] were applied as follows:

(1) Problem identification: The lack of mobile applications for cardiac procedures utilizing persuasive technology.
(2) Definition of objectives: The main objective was to develop a mobile health application for the post-operative period of cardiac procedures and evaluate its usability.
(3) Solution development: Creation of a mobile application through the Adalo® platform.

(4) Evaluation of the solution: The evaluation was carried out using the usability scale (System Usability Scale, SUS) [23].
(5) Communication of Results: The results of the research process were communicated to third parties through this publication.
(6) Critical evaluation: A critical evaluation of the developed solution and the process used to develop it were made in the "discussion".

For the theoretical construction of the application prototype, the four persuasive software main categories of the PSD [12] model were used (Table 1).

Table 1. PSD categories and the presentation on the app

PSD category	Presentation on the application prototype
PRIM	The application was responsible for making the task of post-operative care for cardiac procedures easier for the patient, through various content and properties; Users had access to content specific to their surgical procedure, as well as podcasts and interviews with experts in the field; Users had access to their statistics and progress regarding application usage; The app allowed users to complete online questionnaires to assess their mood, pain, track depression and quality of life post-heart surgery
DIAL	The application had reminders and warnings regarding the use of medication, date, and time of appointments. It also asked about signs and symptoms, requested photos of the surgical wound, requested test results (e.g., prothrombin activity time). Also, the more the user used the application's functions, it was released extra content such as podcasts with experts. The application was made colorful and pleasant
CRED	The application's content was based on international guidelines and organizations, such as: World Health Organization, American Heart Organization, Enhanced Recovery After Cardiac Surgery Society, Society of Thoracic Surgeons, and the Guidelines of the Brazilian Society of Cardiology. There was a "References" topic, in which users had access to the websites and protocols used to build the application. The application had a section about the research team and their affiliations. Furthermore, the logo of the Federal University of Santa Catarina was inserted on the app home page
SOCI	It had a "Message Board", in which they can exchange ideas with peers and report how they are feeling after the surgery (which can be anonymous, with a fictitious name, if desired); The physicians and nurses could also participate

3.2 User Interface Design

To structure the interface, wireframes, originally in Portuguese, were created with the software Balsamiq®. They represent a visual scheme, blueprint, or model of a screen or web page design in an interaction design. It is the basis for an iterative prototype. Besides that, wireframes focus on the screen content and not the graphic details. Its purpose is to illustrate high-level concepts [24]. Figure 1 shows the idea of building a message board in the first illustration, where the patient can choose a fictitious name, and the healthcare professional can also use it. The second shows the options and types of button ideas for the quality-of-life section, including explanatory videos, podcasts, and depression scales.

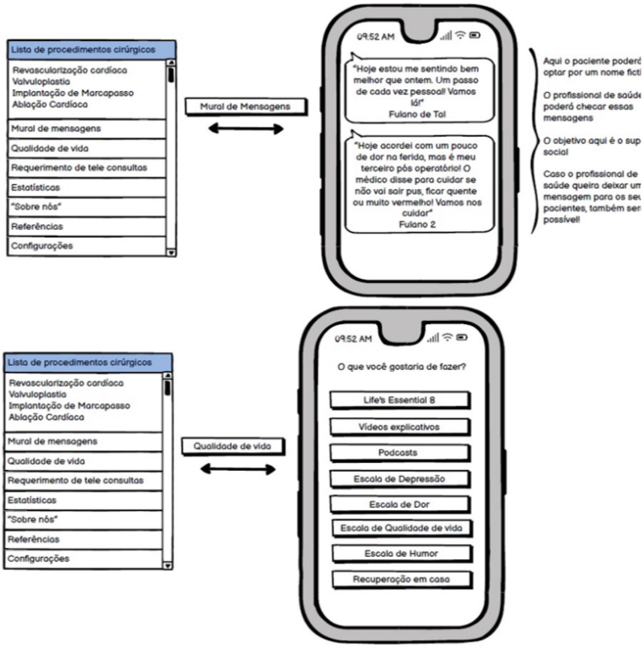

Fig. 1. Application wireframe (message board and quality of life section)

3.3 Population and Sample

The sample was non-probabilistic for convenience, it was chosen due to its practical benefits. This sampling method was accessible, cost-effective, and time-efficient, making it ideal for rapidly gathering feedback in the early stages of development. The survey invitation was emailed to 58 people residing in Southern Brazil, including healthcare professionals (doctors and nurses) and people in the technical field (systems analysis and development, software development, computer science, data science, computer engineering, and experience design of users). These health non-professionals were included to also assess the functional and design aspects of the technology. Of these, 18 responded to the participation email, answering the Informed Consent Form.

As inclusion criteria for health professionals, medical doctors and nurses were included, from any area or specialty, as at this time only the usability and not the content of the application were evaluated. Those who did not belong to the professional category of doctor or nurse were excluded. As inclusion criteria for technology professionals, those from any area or specialty who agreed to participate in the research and who had experience in using and developing applications were included.

3.4 Data Collection and Organization

The prototype of the application was provided to professionals on June 9, 2023, and they were asked to fill out the usability scale through an online form, via GoogleForms®, on June 15, 2023. The collected data was organized in electronic spreadsheets and analyzed on June 20, 2023, to June 24, 2023.

3.5 Data Collection Instruments

Usability was assessed using the System Usability Scale (SUS) [23] after detailed description and guidance provided on GoogleForms®.

The SUS questionnaire [23] has been validated in Portuguese and in Brazil [25, 26], and comprises 10 items, classified by respondents on a 5-point LIKERT scale ranging from completely disagree to completely agree. The SUS items alternate between positive and negative items to avoid response bias, with the aim that participants agree or disagree after reading reflection, and not simply on impulse. To obtain the final score, which varies from 0 to 100, 1 must be subtracted from the user's response for odd-numbered items, as well as subtracting the value of the user's response from 5 for even-numbered items. Then, the score obtained for each item was added, and the result is multiplied by 2.5 [23].

The evaluation of the 10 items that comprise the SUS questionnaire [23] was established by the final score, ranging from 0 to 100. Thus, the classification was established as: 0 to 20.5; 21 to 38.5; 39 to 52.5; 53 to 73.5; 74 to 85.5; and 86 to 100 [27, 28].

Additionally, two optional open-ended questions about user experience were added after the SUS scale was completed by participants: Do you have any suggestions for improvement? What were your biggest difficulties when using the application?

3.6 Statistical Procedures

For the statistical analysis of the variables, the data were organized in electronic spreadsheets in the Microsoft Excel® program and subsequently analyzed using the Stata® 14.0 software (StataCorp, Texas, USA).

To determine the best way to describe the SUS score values, the Shapiro-Wilk test was performed to evaluate the distribution of data in relation to normality. This test is especially indicated for samples smaller than 30 [29]. Only descriptive statistics were applied. The boxplot was analyzed to identify outliers and frequency, median, interquartile range with maximum and minimum values were described.

In the Stata® 14.0 statistical software, the command used to generate the SUS Score for each participant was:

*gen escoretotal = (2.5 * (abs(q1–1) + abs(q2 - 5) + abs(q3–1) + abs(q4 - 5) + abs(q5–1) + abs(q6 - 5) + abs(q7–1) + abs(q8 - 5) + abs(q9–1) + abs(q10 - 5))).*

Where "escoretotal" is a new variable generated, which was assigned to each of the 18 observations and q1 to q10 are questions 1 to 10 of the SUS questionnaire.

3.7 Ethical Considerations

This study was based on ethical principles, based on Resolution No. 466 of December 12, 2012, of the National Health Council [30], which incorporates, from the perspective of the individual and communities, the four basic references of bioethics: autonomy, non-maleficence, beneficence, and justice, among others, aiming to ensure the rights and duties that concern the scientific community, research subjects, and the State. This project was also approved by the Ethics Committee.

All volunteer participants were invited to read and sign the Free and Informed Consent Form, ensuring the confidentiality of their identity and the information provided solely for the purposes of the research, as well as the right to withdraw from the study at any time, without any harm to the participant.

Lastly, this work followed all the foundations of the second article of Law No. 13,709/2018, known as the General Data Protection Law [31].

3.8 Data Security

Due to the sensitive nature of personal health information involved, the application complied with Brazil's strict data protection laws (LGPD), guaranteeing that all patient data is encrypted while it's in use and while it's in transit.

4 Results

4.1 Application Prototype

Fifty-one screens were developed in common with patients and healthcare professionals. Figure 2 represents the "Welcome" screens, where professionals and patients can register and log in. In addition, both have access to the privacy policy. The "Quality of Life" screens has the contents Life's Essential 8 [32] with tips on how to eat better, be more active, quit smoking, have healthy sleep, take care of your weight, control your cholesterol, take care of sugar levels and blood pressure; explanatory videos about cardiac procedures that function as a link to the American Heart Association website; Podcasts with experts; depression, pain, quality of life and mood scales; recovery tips at home and finally, the references used to build the mobile application.

Eleven screens were developed just for patients. The initial screen after patients log in ("Home"), they must choose which cardiac procedure they underwent to carry out: register medications, add a photo of the wound, register signs and symptoms, and record exams. About registering a photo of the wound, patients can download the photo, enter the date it was taken, and indicate what was observed about the wound (pain, local heat, redness and/or secretion, pus) (Fig. 3). Regarding signs and symptoms, the patient can select between some pre-existing options (chest pain, shortness of breath, bleeding, fever, weakness/abnormal tiredness) or write in a space designated for "another" sign/symptom (Fig. 3); they must also record the date. Finally, regarding exam registration, in addition to the registration date, the patient can take a photo and attach it to the application, attach a file download, and/or write the result of an exam (e.g., prothrombin time control).

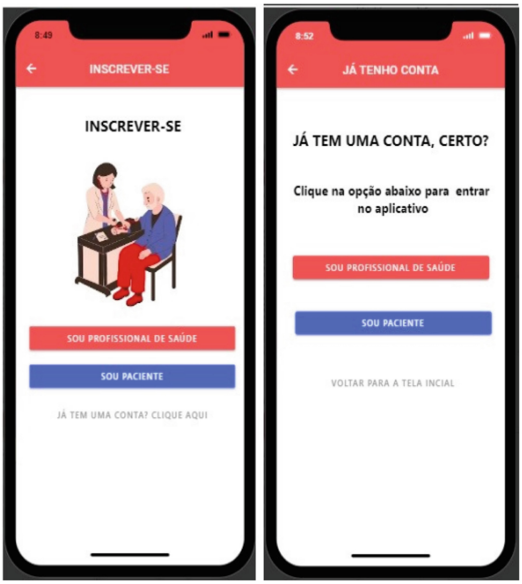

Fig. 2. Patients and healthcare professionals' screens

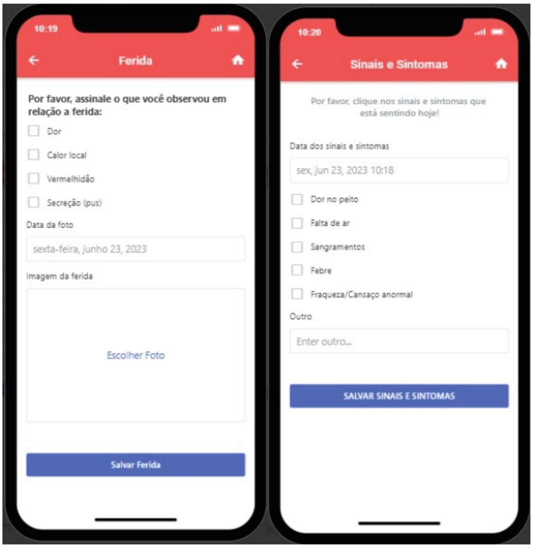

Fig. 3. Patient's screens

Eighteen screens were developed just for professionals. The initial screen after professionals log in ("Home"), they must choose which cardiac procedure to consult to obtain a list of patients. By clicking on the selected patient, they will access medications in use, photos and details of the wound, and signs and symptoms (Fig. 4). In the medicines in use, the professional can quickly see the medications registered by the patient with the name and how many milligrams (e.g., Rosuvastatin 20) (Fig. 4); by clicking on the arrow next to the medication, the professional can view in more detail the number of tablets used and the frequency of use of that medication. Regarding the photo of the wound (on the right of Fig. 4), the professional has access to all the photos added by that patient; when clicking on the arrow, he will have more details, such as how many days ago the photo was attached, and what the patient pointed out about it (local pain, local heat, redness, secretion/pus). Regarding signs and symptoms, the professional has access to a list of records about how many days ago they were recorded (e.g., 24 days ago, 17 days ago); by clicking on the arrow on the right of the screen, professionals have access to the details of the recorded signs and symptoms.

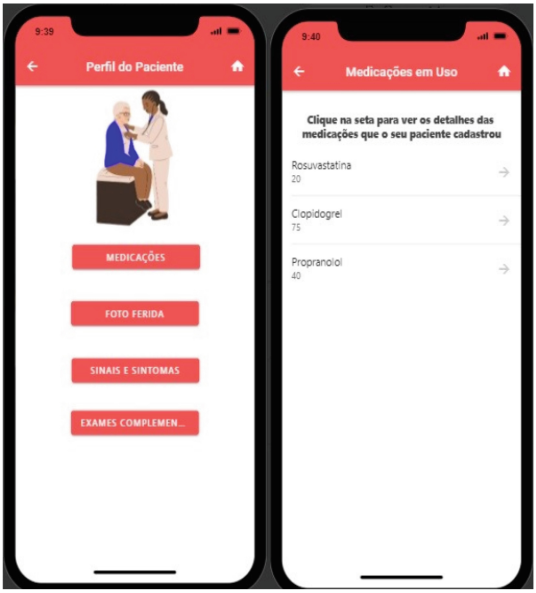

Fig. 4. Healthcare professionals' screens

4.2 SUS Score

According to the sociodemographic data, the population of this research was predominantly female, 55.6% (10); mean age of 38.2 (±9) years; 50% work as health professionals and the rest in the technology area (among them: systems analysis and development, software development, computer science, data science, computer engineering and user experience design), on average they had 12.2 (±9) years of experience; 61.1% usually use mobile applications related to health and 66.7% have never participated in scientific research before.

After participants completed the SUS questionnaire, each participant's final score was calculated, and the SUS classification level was assigned to each value obtained

(Table 2). Evaluation of usability has shown to be crucial for confirming how users and the system interact. After performing the Shapiro-Wilk test, it was found that the final score data did not pass normality. According to the box-plot analysis, this situation is justified since participant P11 was an outlier. However, it was decided to keep the participant due to the small sample size. The median SUS final score was 95 (IQ 90;97.5), ranging from a minimum score value of 62.5 to a maximum of 100. In summary, participants provided an overall application rating that reflects high satisfaction.

Table 2. SUS global classification according to each participant's final score

Participant	Final Score
P1	97,5
P2	90
P3	97,5
P4	92,5
P5	87,5
P6	77,5
P7	100
P8	100
P9	95
P10	95
P11	62,5
P12	100
P13	85
P14	97,5
P15	90
P16	95
P17	100
P18	97,5

4.3 Non-mandatory Open-Ended Questions

Two questions followed the completion of the SUS scale. "Do you have any suggestions for improving the application?" (Table 3) was the first question. This inquiry seeks to ascertain the areas in which the application requires improvement.

It was observed that, except for participant P17 (nursing), no other suggestions for improving the content were offered by the health professionals involved. This may have occurred because they did not belong to the cardiology area.

Participant P8 suggested that urgent alerts be added. This functionality was not tested, as at this stage of the prototype's development, there was no mutual interaction between healthcare professionals and the patient.

Participant P16 suggested several improvements. He also pointed out that the healthcare professional could carry out depression, pain, quality of life, and mood scales. However, we intentionally kept this option open to allow professionals to explore and understand how this feature how this feature works within the patient app.

Table 3. Suggestions obtained to the first non-mandatory question "Do you have any suggestions for improving the application?"

Participant	Suggestions
P5	Suggests starting content after login with the "General" menu and adding a "Cardiac Procedures" menu
P8	Suggests the inclusion of an urgency alert when identified
P9	Suggests the option to view the password on the login screen
P11	Suggests improvements in the visual part and in some fields. However, he/she does not specify which
P13	Mentions that he/she does not remember the system authorizing access only after receiving a confirmation email after registration. Participant also observed that some checkbox-type inputs behaved like radio-type inputs during initial tests, but he/she doesn't remember which screen this occurred on
P15	Suggests reviewing navigability
P16	a) Suggests that the link to accept the terms is clear and visible when starting the application b) Questions the need to request the number of Personal National Identification, suggesting that the email may be sufficient as identification, especially considering the use of Android and iPhone c) Mentions that, when accessing as a professional, it is also possible to take the "test" to measure the scales (depression, pain, quality of life and mood). Furthermore, it suggests that these tests can be carried out on the home screen, inviting the user to carry them out d) Suggests that a list be displayed with patients who had changes, indicating with colors (green for positive changes and red for negative changes) and a score as a metric for professionals e) Proposes improvements in the "Patient Profile" sections, such as adding start and end dates for medication history, including the number of days with reference to the surgical procedure in images for healing analysis, associating information on days after the procedure in Signs and Symptoms and exams, and extract information from exam images using Natural Language Processing to automatically identify abnormal values and alert the medical doctor
P17	Suggests the inclusion of a control table for the International Normalized Ratio result and anticoagulant adjustment
P18	Suggests adjustments to the app's appearance (without specifying which ones)

Finally, it is worth highlighting that of the 14 answers obtained to the question: "What were your biggest difficulties when using the application?" (Table 4), none reported difficulties regarding usage of the application. Two of the fourteen answers to the question that addressed additional topics are shown in Table 4.

Table 4. Additional topics obtained to the non-mandatory question "What were your biggest difficulties when using the application?"

Participant	Answer
P5	The participant mentions that, as he was not from the health area, he/she had difficulty understanding the meaning of cardiac procedures. However, he/she did not mention difficulties using the application
P11	No difficulties were reported, however, the participant reports that the graphic part is not attractive, and the reports could have time-evolution graphs, the scales could be more attractive to choose from. He/she states that the statements mix with the titles, there is a lack of a share button, a lack of FAQ or HELP. Finally, he/she suggests using a conversational agent to capture the user's attention

5 Discussion

Regarding the developed application prototype's usability, the research provided positive results (Median 95; IQ 90; 97.5). The findings show that participants accepted the system well, with the majority of reviews (83.3% gave it high rates).

The implementation of application pilots, as demonstrated in this research, is a widely endorsed approach during the development and testing phases, as supported by literature references [33, 34]. This study conducted a thorough usability assessment of the mobile application designed for healthcare professionals. It employed various strategies to identify and rectify issues in user-system interactions, aiming to enhance the application's functionality. The feedback from participants was indicative of their deep engagement and interest in the ongoing refinement of the application. Their recommendations primarily focused on visual improvements and interface adjustments, including design enhancements and modifications to input fields. Additionally, they proposed functional enhancements such as the inclusion of urgency alerts, password visibility options, testing of scales on the home screen, and the display of metrics for professional use. These suggestions reflect the participants' concern with usability and improving the user experience, highlighting the importance of intuitive and functional interface design. However, it is essential to highlight that the application was not tested in real-life scenarios, particularly during professional-patient interactions. Consequently, professionals couldn't observe alerts and consultation requests in real-time. These aspects were only evaluated through interactions with two "model patients," where fictitious data had been included for simulated tests.

The majority of participants in the survey reported a seamless experience with the application, expressing favorable views on its usability. This outcome is significant, as it suggests that the application was crafted with an emphasis on intuitiveness and user-friendliness, thus enhancing user engagement and ensuring a positive user experience. This ease of use appears to transcend educational backgrounds and prior experience in scientific research, indicating that the application's design elements contributed to its simplicity and accessibility. Moreover, the absence of reported challenges may be seen as an indication of the effectiveness of the application's instructional interfaces, which offer clear directions and suitable guidance to users. This is especially relevant since 50% of the participants were not in the healthcare industry and may not have known much about cardiac procedures in the past. When an application is difficult to use, unclear, or counterintuitive, users may become discouraged and frustrated, which can lead to low adoption and abandonment [35].

Regarding the existence of mobile applications already developed with the same theme as this work, the literature does not present articles, to date, based on the PSD principles of Oinas-Kukkonen & Harjumaa [12]. The applications found after literature review [15–20] presented some features described in the PSD, however, without reference to persuasive technology, indicating that they were not designed with this purpose in mind, different from us. Therefore, the application developed in this study stands out as an innovative contribution in the research context at hand.

While there are existing studies on cardiac rehabilitation programs using Persuasive System Design (PSD), Salvi et al. [36] developed a notable mobile health system aimed at encouraging patients to participate in cardiac rehabilitation post-coronary artery disease. This system features functionalities for exercise tracking, guidance, motivational feedback, and educational materials. They conducted a randomized controlled trial to compare this mobile rehabilitation approach with standard care. The patient interface of the system included sections like "home," "messages," "calendar," "exercise," and "learning," while the professional interface facilitated initial assessments, progress tracking, and alert generation for complications. Despite encountering some technical challenges, the study revealed high user acceptance, perceived usefulness, and enhanced educational outcomes. However, the authors emphasized the need for further research to validate these findings and to affirm the efficacy of the design methodologies employed.

A systematic scoping review carried out by Ramachandran et al. [43] examines the acceptance of technology in cardiac telerehabilitation programs in patients with coronary artery disease. Although the article's objectives differ from ours, there is direct relevance to this research, as both studies address the use of technology in the context of cardiac care. Furthermore, both seek to understand the acceptance and usability of applications by users. The findings highlight the importance of technology acceptance by users, as well as the perception of usefulness and resulting educational benefits. These aspects were also evaluated in the present research, in which the results indicated a favorable acceptance of the application by professionals. Participants also demonstrated a high level of involvement, offering suggestions for improvement and showing a significant interest in the continuous improvement of the tool. Thus, both studies emphasize the relevance of technology acceptance and application usability in cardiac care. Furthermore, they also addressed the usability issue. The authors stress the significance of creating user-friendly interfaces that are easy to use and promote pleasant user interaction. This strategy is consistent with our research, which also assessed the developed application's usability. To improve patient adherence and engagement outcomes, it is crucial to consider technology acceptance and usability when developing and implementing applications in cardiac care, as demonstrated by the results of this study and those of Ramachandran et al. [37].

Notably, not every intended PSD feature could be implemented during the application development process. It was not possible to create a ranking system, send out reminders, or integrate gamification for patients using stars and badges. These limitations arose because the focus of usability tests was aimed at professionals at this stage. Regarding what was intended in the methodology, the principles of supporting the primary task and supporting the system's credibility were thoroughly covered. Nonetheless, it is recommended that the postoperative phase of cardiac procedures be tailored into the categories of young and elderly adults to provide pertinent functionality for these various groups, which have different profiles, to further improve the persuasive components.

The necessity for a more detailed evaluation of adherence to the developed application in future research is crucial. While the current results indicate positive user reception and significant engagement with the application, a thorough examination of its effectiveness in enhancing therapeutic adherence, particularly using patient samples, is needed. In this vein, the study by Al-Arkee et al. [38] underscores the effectiveness of mobile applications in improving medication adherence for cardiovascular diseases. Their review, which included 16 randomized controlled trials, found that nine trials showed a statistically significant increase in medication adherence in the intervention group. Moreover, a meta-analysis of six trials indicated that mobile app-based interventions had a positive and significant impact on medication adherence, though no significant correlation was found between the duration of application use and therapeutic adherence outcomes. This parallels the findings of the current study, both underscoring the critical role of therapeutic adherence in cardiovascular diseases and the potential of mobile applications to enhance it. These studies lay a strong foundation for future research aimed at assessing the effectiveness and adherence to the developed application, as well as exploring additional methods to increase therapeutic adherence and improve cardiovascular treatment outcomes. Additionally, this research contributes to the growing body of scientific evidence supporting the use of persuasive technology and Persuasive System Design (PSD) in facilitating behavior change, underscoring their value and necessity in healthcare interventions.

Regarding the study's limitations, it is stated that the initial pilot application will require future improvements, as the needs of professionals and patients may change over time. Furthermore, this study did not evaluate usability from the patient's point of view, and future work is recommended. Additionally, since this study was developed in Brazil, there might be cultural variations in the application's content and user interface. Finally, the selection technique used to obtain the sample was non-probabilistic for convenience, resulting in a small sample size (n = 18).

6 Conclusion

The noteworthy research findings show that users were highly satisfied with the developed application, which prioritized usability and interface design.

The outcomes of this study show that success in prioritizing usability and user experience can be achieved when developing health-related mobile applications using a user-centered persuasive systems design approach.

Finally, it is desirable to conduct clinical trials to investigate the application's potential benefits in reducing postoperative complications and improving health outcomes. These studies will allow for a more in-depth assessment of the clinical impact of the application, providing robust scientific evidence and contributing to its validation as an effective tool in the context of postoperative cardiac procedures. Based on the results obtained, it will be possible to identify new opportunities for improvement and development of additional resources, consolidating the application as a comprehensive and efficient solution for patients and healthcare professionals

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