FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Developing a game to promote patient participation in the rehabilitation process: the case of hip replacement surgeries

Helena Isabel Teixeira Gonçalves

Mestrado em Engenharia Eletrotécnica e de Computadores

Supervisor: Marta Campos Ferreira

Second Supervisor: Carla Sílvia Fernandes

July 31, 2023

Resumo

Ao discutir novos métodos e abordagens aplicadas no contexto da saúde, o termo eHealth é sempre destacado. *eHealth* é uma área em desenvolvimento que liga a saúde pública e a informática médica aos serviços de saúde através da Internet ou outras tecnologias relacionadas. Quando este conceito é aplicado, o principal objetivo é melhorar os cuidados de saúde através das tecnologias de informação e comunicação.

Outro termo essencial a ser explorado é a gamificação. A gamificação é a aplicação de mecanismos e dinâmicas de jogos em contextos alternativos de forma divertida. Este método pode motivar seus usuários e trazer diversos benefícios cognitivos. A área da saúde digital (*eHealth*) também começou a explorar essas abordagens, e atualmente, existem várias gamificações existentes, como será possível verificar neste estudo.

Na área da saúde, a aplicação da gamificação no contexto da reabilitação tem se mostrado relevante. Ao recorrer a uma tecnologia gamificada, o paciente demonstra ganhar mais coragem para continuar nos processos de reabilitação que podem tornar-se desgastantes.

Esta dissertação apresenta uma abordagem interativa para promover a participação do paciente no processo de reabilitação no caso de cirurgia de quadril. O principal objetivo é dotar o utente de todos os conhecimentos necessários que lhe permitam uma reabilitação mais tranquila e segura.

De forma a garantir uma interação efetiva entre o sistema e o utilizador final, foi seguida uma metodologia de Design Centrado no Utilizador, que envolveu três fases:1. Levantamento de requisitos, 2. Prototipagem e 3. Avaliação. O estudo teórico dos conceitos essenciais para este projeto e a análise aprofundada dos trabalhos realizados nesta área, presentes no estado da arte deste documento, permitiram definir e clarificar o conceito desta dissertação. Para aprofundar o conhecimento adquirido e entender as necessidades dos usuários finais e pacientes submetidos à artroplastia de quadril, foram realizadas entrevistas individuais. Isso levou à definição de pontos cruciais para esta dissertação.

Para medir a usabilidade do sistema desenvolvido, foram aplicados testes de usabilidade. Foi desenvolvido um protótipo para dispositivos móveis e os resultados dos testes foram positivos; os usuários ficaram satisfeitos com o resultado, considerando-o um produto valioso para sua recuperação. Este resultado comprova a excelente receptividade destas tecnologias na área da saúde, sendo um projeto que pode ser facilmente alargado a outras áreas da reabilitação.

Palavras-Chave: *Gamification, eHealth, Hip Arthroplasty, Rehabilitation*

Abstract

When discussing new methods and approaches applied in the health context, the term eHealth is always highlighted. eHealth is a developing area that links public health and medical informatics to health services through the Internet or other related technologies. When this concept is applied, the main objective is to improve health care through information and communication technologies.

Another essential term to explore is gamification. Gamification is the application of game mechanisms and dynamics in alternative contexts in a fun way. This method can motivate its users and bring several cognitive benefits. The area of digital health (eHealth) has also started to explore these approaches, and currently, there are several existing gamification, as will be possible to verify in this study.

In the health area, the application of gamification in the context of rehabilitation has been shown to be relevant. By resorting to a gamified technology, the patient demonstrates to gain more courage to continue in the rehabilitation processes that can become exhausting.

This dissertation presents an interactive approach to promote patient participation in the rehabilitation process in the case of hip surgery. The main purpose is to provide the user with all the necessary knowledge that will allow him to have a more peaceful and safe rehabilitation.

In order to guarantee an effective interaction between the system and the end user, a User-Centered Design methodology was followed, which involved three phases:1. Requirements gathering, 2. Prototyping, and 3. Evaluation. The theoretical study of the essential concepts for this project and the in-depth analysis of the works carried out in this area, present in the state of the art of this document, allowed us to define and clarify the concept of this dissertation. In order to deepen this acquired knowledge and to understand the needs of end users, and patients undergoing hip replacement, individual interviews were carried out. These led to the definition of crucial points for this dissertation.

In order to measure the usability of the developed system, usability tests were applied. A prototype for mobile devices was developed and the testing results were positive; users were satisfied with the result, considering it a valuable product for their recovery. This result proves the excellent receptivity of these technologies in the health area, being a project that can easily be extended to other areas of rehabilitation.

Keywords: *Gamification, eHealth, Hip Arthroplasty, Rehabilitation*

Acknowledgments

Expresso, em primeiro lugar, os meus agradecimentos à Professora Marta Campos Ferreira, à Professora Carla Sílvia Fernandes e à Professora Joana Campos, orientadora e supervisores, respetivamente, por toda a disponibilidade e ajuda durante todo o desenvolvimento deste projeto. Igualmente agradecer a todos os que, com os seus conhecimentos, apoiaram este projeto.

Um agradecimento especial à Fisioterapeuta Diana, da WeCare Saúde, por todo o tempo disponibilizado e todo o auxílio que prestou durante todo o trabalho.

Um agradecimento muito especial aos meus pais, que sempre me apoiaram e ajudaram durante todo o meu percurso académico.

Por último, um agradecimento a todos os meus amigos que sempre me acompanharam e com quem partilhei muitos bons momentos.

Helena Gonçalves

"Persistence is the shortest path to success."

Charles Chaplin

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AR	Augmented Reality
THA	Total hip arthroplasty
DGS	Direção Geral de Saúde
ICT	Information and Communications Technology
OTP	One-Time Password
SYS	System Usability Scale
THR	Total Hip Replacement
UCD	User-Centered Design
UI	User Interface
UX	User Experience
VR	Virtual Reality

Chapter 1

Introduction

This dissertation is dedicated to promoting patient participation in hip surgery rehabilitation by proposing a gamified approach focused on the needs transmitted by users. By taking advantage of easy access to mobile devices, this project promotes safe and accessible rehabilitation for the entire population in a mobile application format.

In this chapter, the framing and contextualization of the work, the motivation, and objectives, which fostered the development of the entire project, and the document's structure are exposed.

1.1 Framing/Contextualization

Nowadays, around one million people worldwide undergo total hip arthroplasty, and according to the Direção Geral de Saúde (DGS), this intervention is the surgery with "the highest success rate among all joint replacement surgeries and aims to promote the quality of life through pain relief and improvement of function in patients with hip arthropathy." [3]

Hip arthroplasty, or total hip replacement (THR) or total hip arthroplasty (THA), aims to restore the patient's mobility. It is necessary to perform hip surgery when it is no longer possible to sleep comfortably due to pain, if simple tasks are difficult, such as climbing stairs, and when the quality of life is altered due to hip pain.[4] Carrying out rehabilitation and appropriate transfer of knowledge to the user is considered key to having good results [5]. The rehabilitation of a hip arthroplasty lasts from four to six months[5], and patients use to be around 60 to 80 years. The increase in life expectancy of the population has grown in recent years, leading to a boost in the number of surgeries [5]. In turn, at the speed at which life goes by, users demand more and more rehabilitation to return to their activities quickly.[5]

For the user to have a serene recovery, there needs to be an effective knowledge transfer from health professionals to users. However, to achieve better results, users require high-quality information; although much information is available in various media, this is only sometimes transmitted and understood in the best way [5].

Although an effective intervention, hip surgery patients may experience post-surgical complications, including age.

Recovery from hip surgery begins shortly after the procedure, and, as already said, it is important for patients to move around during this time. Movements such as climbing stairs, walking, or getting into a car are evidence of a good recovery. Physical therapy is part of every patient's recovery process and is crucial to gaining mobility and strength. Patient collaboration throughout the rehabilitation process is essential to obtain good results.[4]

The combination of technology-Internet-health has been increasingly sought after, resulting in the creation of several e-terms such as eHealth. [6]

eHealth is the broadest term for information and communication technologies (ICT), which are tools used in the health sector to prevent, diagnose, treat, follow up, and manage health, thereby lowering costs and increasing the efficiency of the health system.[6]

This term can include health products and other services, such as mobile applications, websites, wearable devices, decision support systems, or even health-related games.

New tools were created to help prevent disease and help in the process of treating it. Below, we can see some of the possible implementations: [6]

- Mobile health (m-health) involves mobile devices or electronic devices that help in health care, such as rehabilitation and treatments.

- Discussion forums and support groups online where people with the same problems can help each other and share their experiences.

- The Internet offers a wide range of specialized websites with useful patient information.

- Several item tools allow remote health control, such as telemedicine, remote medical conferences, and teleconsultations

The term "gamification" became increasingly popular and was very controversial in the video game industry. [7] Instead of creating complex games, gamification aims to simplify and motivate users. This definition is in line with serious games, where both game-based technologies and stimulating interaction with users are present.[8] Serious games allow for an authentic gaming experience; gamification aims to create, above all, a playful experience for the user.[9] As shown in Figure1.1, gamification always has a well-defined objective, accompanies users regardless of their level, and has social, emotional, and intellectual benefits.

When introducing a gamification approach, it is important to focus on the ability of each user to develop the proposed tasks. In healthcare applications, there are two types of motivations: reflective and automatic.[1] The reflective motivations correspond to the definitions of objectives, which help the user to remain faithful to the accomplishment of the tasks; cognitive strategies, to help on the intellectual/mental side of the user and strategies to help improve user confidence. The automatic motivations involve social support and encouragement in each task, in the form of rewards, for example.[1]

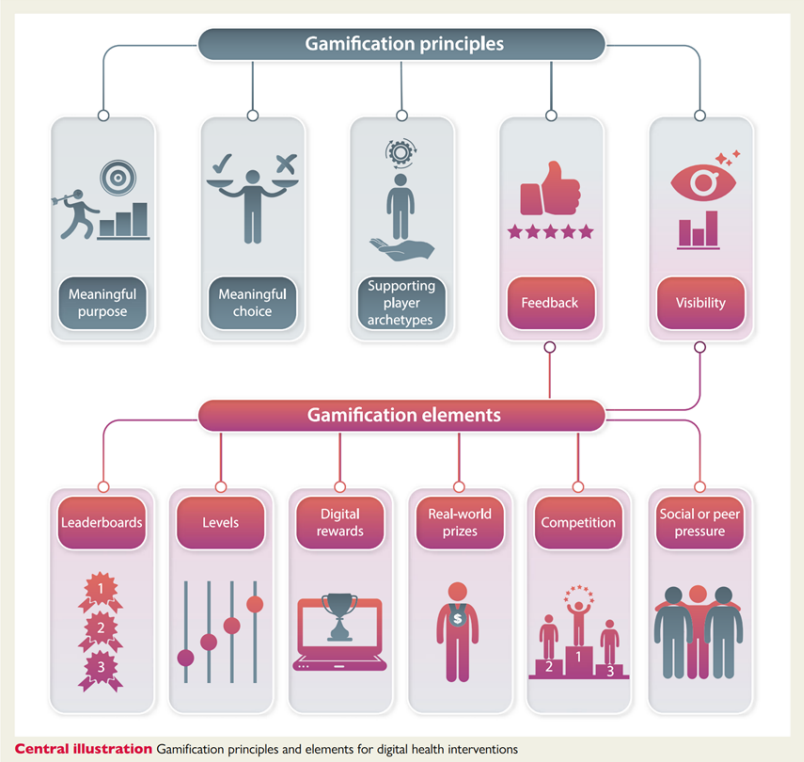

Figure 1.1: Understanding and assessing gamification in digital healthcare interventions [1]

1.2 Motivation

After the surgery, regular physiotherapy and significant commitment from the patient are required, always with the help and monitoring of a physiotherapist. The patient must have his house prepared after being discharged from the hospital, have help with the housework since his/hers autonomy is limited, and he/she must do exercises several times a day, which will speed up his/hers recovery and healing, strengthen the muscles that will support patient new joint, reduce muscle fatigue and soreness, improve circulation and help reduce the level of post-operative swelling and the risk of blood clots. In order to promote self-management of this whole situation, it is essential to create new methods that encourage the patient's active participation throughout the process[10]. Applying new gamified technologies is a mechanism increasingly used in the health area.

In the case of hip surgery, few research studies develop gamified technologies to promote the self-help of the recovering user. However, those that exist, and that will be shown in the next chapter, show strong results.

The creation of these technologies will significantly impact the patient, as it will teach and encourage them to work daily and autonomously on their recovery with motivation in a calm way and avoid injuries.

This is a crucial step to open up future avenues to explore the use of gamified technologies in hip surgery patient recovery. This dissertation aims to fill this gap, developing a game that promotes the participation of the person who underwent hip arthroplasty in the rehabilitation process.

1.3 Objectives

Accordingly, this problem has been segmented into five distinct phases:

- Literature review on gamification for the person undergoing hip replacement;
- Understanding user needs and preferences regarding the introduction of game elements;
- Design and develop a prototype of a teaching solution with gamification elements;
- To test the prototype with (potential) users.

The first segment of this problem is the need to know the solutions developed so far that simultaneously involve gamification and hip replacement surgery. This literature review will allow an understanding of the approaches that still need to be developed and could benefit the end user.

Then, an essential step for the success of this project is carried out, understanding users' needs. This project follows the User-Centered Design methodology, which means that in all stages of development of this work, the end user and the fulfillment of their needs are the main focus.

The next phase defines the elaboration of a game concept that promotes the patient's participation in the rehabilitation of the hip operation. The final prototype is expected to transmit all the necessary knowledge for a more relaxed and motivating rehabilitation for the patient.

Finally, the objective is to test the usability of the developed system with potential patients.

1.4 Document Structure

The current chapter, Chapter 1, incorporated the framework/contextualization, motivation, and objectives of the proposed work to be developed. In the rest of the document, six additional chapters are presented.

In Chapter 2, State of the Art, there is an analysis of the studies carried out on the theme of this dissertation, contributing to the theoretical framework of the elaborated system. It begins by exposing in detail the research methodology and analysis carried out. The result of the study carried out included the analysis of the type of technologies used (mobile applications, websites, other platforms), the receptiveness of users to the use of new technologies during rehabilitation, the effect that the use of these technologies has on recovery, the analysis of various and different approaches to the respective gamification and the identification of approaches that have not yet been developed.

Chapter 3, Methodology, presents a set of methods, strategies, and processes used to explain problems. Additionally, a detailed description of the entire methodological process is present.

Chapter 4, Definition of Requirements, describes the entire procedure for surveying and identifying the needs, difficulties, and expectations of future users of the developed product. This analysis led to the definition of the first system requirements for promoting patient participation in rehabilitation after hip surgery.

Chapter 5, Application *RehabApp*, exposes the platform that solves the pictured problem. It starts with explaining the platform concept, passing through the representation of the system architecture and the mobile application. Next, the interfaces of the *RehabApp* application are explained, as well as its entire operation.

Chapter 6, Testing, represents all the methodologies and steps adopted to evaluate the system's functionality. This chapter presents an in-depth analysis of the usability of the entire application.

Chapter 7, Conclusions and future work, exposes all the conclusions regarding the various objectives of this dissertation, as well as its literary contribution. This chapter also presents the limitations and possible changes associated with this project.

Chapter 2

State of the Art

2.1 Literature Search

A literary review was carried out during October and November 2022, which followed the guidelines of the PRISMA declaration. This review was divided into two distinct parts: 1. Definition of the Research Query 2. Selection of Studies.

2.2 Definition of the Research query

It started by developing a query that was applied to the different databases used. It was made a query involving the various related keywords, particularly related to gamification and hip arthroplasty. For this, different synonyms of these terms were used and combined with the Boolean operators "OR" and "AND." The developed query can be found in Table 2.1.

Table 2.1: Search strategy

Query
(Game OR "Video Games" OR "Virtual Games" OR "Games Recreational" OR Gamification OR "Mobile Game" OR "Mobile App" OR "Mobile Application" OR "Mobile game" OR "Website" OR gamified OR app OR mobile OR "game-based") AND ("hip rehabilitation" OR "hip replacement")

The search for articles was performed in three databases CINAHL (Cumulative Index to Nursing and Allied Health Literature), SCOPUS, and PubMed. No time limits were applied in this process.

Before beginning the survey, the following questions were developed to conduct this study:

- Are people undergoing total hip replacement (THR) receptive to using information and communications technology (ICTs) during their rehabilitation?
- What types of ICTs have been developed in recent years?

- How is post-THR rehabilitation approached?

2.3 Material Selection

The exclusion and inclusion phase was carried out with the articles for review defined. It was necessary to develop some criteria in order to facilitate this process.

- Inclusion Criteria:

  1. Articles dealing with the development of gamification via ICTs (via mobile app, Website) for hip arthroplasty;
  2. Articles dealing with the benefits of gamification for hip arthroplasty;
  3. Users' perception regarding the use of gamified technologies during the hip surgery rehabilitation process;
  4. Patients' habits during the hip surgery rehabilitation process.

- Exclusion criteria:

  1. Articles that do not focus on hip arthroplasty;
  2. Articles that involve only the process before and during the operation.
  3. Articles that do not involve any presentation or exposition on the gamification theme.

This literature review phase was divided into three parts: the analysis of the titles, the analysis of the abstracts, and, finally, the analysis of the full articles. For this, all articles were individually studied to track those that best fit this study. After implementing the query in all databases, 784 articles were added to the study. First, duplicate articles were eliminated; here, 343 articles were removed, leaving 441 for analysis. After reading the title and always trying to answer the developed questions and the stipulated criteria, 264 articles were eliminated. The remaining 177 studies were subject to an analysis of the respective abstract; here, 120 were eliminated. Finally, a first analysis of the articles in their entirety was carried out, and of the 57 selected, 23 were eliminated, leaving 34 to be included in the article. After this process, it was possible to develop the diagram of Figure 2.1 . Then, a more in-depth analysis of each article was carried out, where 11 were removed, making a total of 24 articles included in the study.

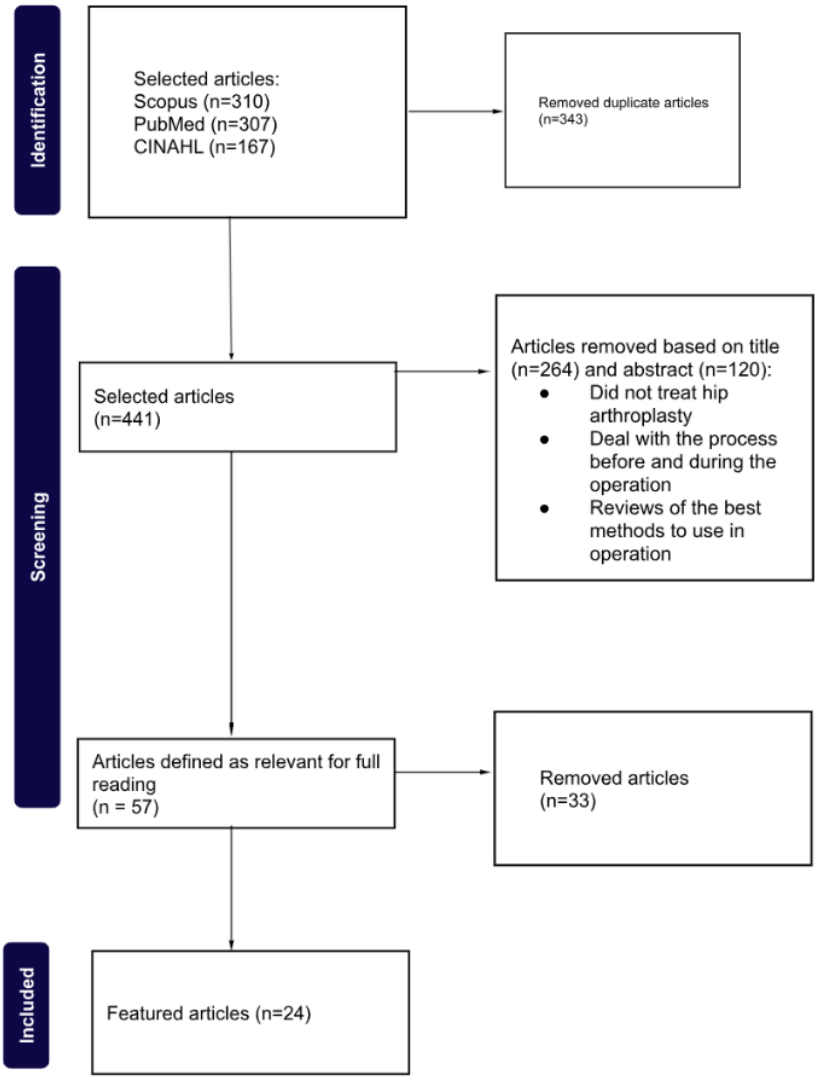

Figure 2.1: PRISMA Flow Diagram of the process of identifying and selecting studies from the systematic review of literature

After the final selection of articles, it is possible to perform a descriptive analysis of the selected sample. In order to better understand where the articles come from and what time they fit, the graphs shown in Figure 2.2 were developed.

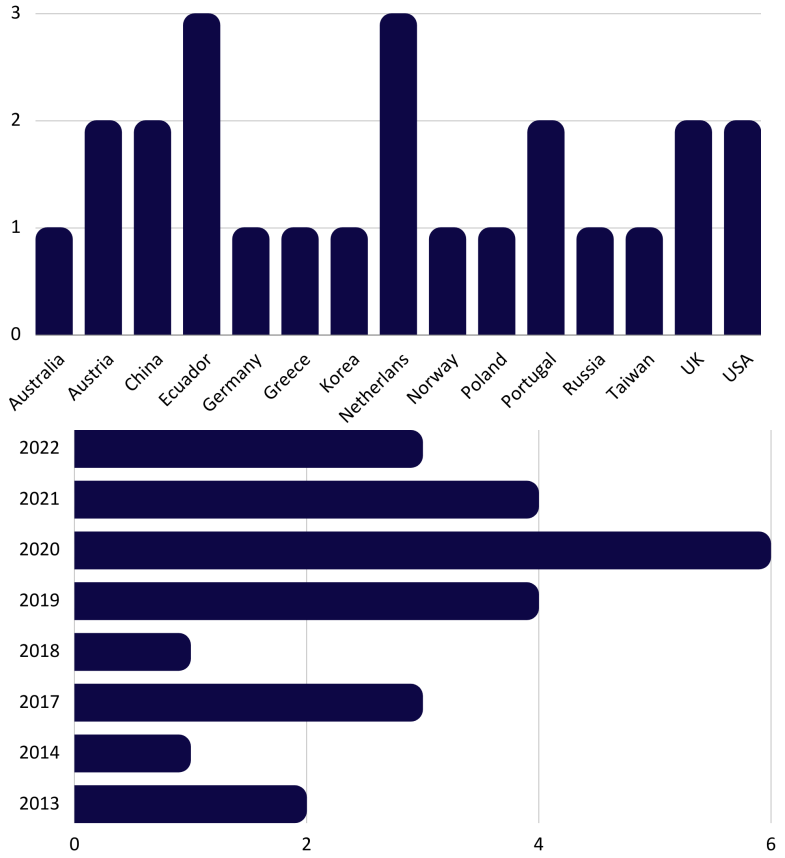

Figure 2.2: Statistical Graphics

In Figure 2.2, it is possible to observe that the articles are from several countries, not focusing on just one. Ecuador and the Netherlands were the most developed studies in this area, each with a total of 3 articles selected for this study. Portugal only contributes with two articles in this area. Regarding the year of publication, these articles were developed between 2013 and 2020. As no temporal filter was placed in the database search phase, it was possible to conclude that the use of ICTs is something little discussed, with aspects to be developed.

2.4 Data analyses

A data extraction table, which can be found below, was used to organize the relevant studies. The registered information included: Authors, Year, Country, Purpose, Study design, Participants,ICT*Technology, andICT* Solution.

Table 2.2: Studies included in this review

ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E1 [11]	Pulik Ł, Romaniuk K, Dyrek N, Grabowska N, Łęgosz P/ 2022/ Poland	Develop the first Polish mobile Application for total hip arthroplasty (THA) patients.	Development design	No Participants.	Mobile Application	Aids the patient in fully comprehending the procedure and reduces anxiety associated with surgery in an environment where reliable information may be scarce.
E2 [12]	Wang Q, Hunter S, Lee RL, Wang X, Chan SW./ 2022/ China	Utilize self-efficacy and learning theories as a framework to direct the creation of an arthroplasty-related mobile application rehabilitation program.	Experimental design	84 patients undergoing primary total hip or knee arthroplasty, with 42 receiving standard care and 42 receiving a 6-week mobile application rehabilitation program.	Mobile App (WeChat)	Boosting the self-efficacy of participants for rehabilitation

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ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E3 [13]	Christensen, Jesse C.; Stanley, Ethan C.; Oro, Evan G.;Carlson, Hunter B.; Naveh, Yuval Y.; Shalita, Rotem; Teitz, Levi S. / 2022 /USA	Establish the validity and reliability of the OnStep application in adults.	Research Article	Gait analysis was performed on 20 healthy adults for the validity of the smartphone.	Mobile application (OneStep)	Uses the information from the smartphone's built-in sensors to measure a person's gait parameters. The smartphone's sensors collect acceleration and angular data at a sampling rate of 100 Hz. Proprietary algorithms then analyze these data to determine the spatiotemporal variables for each stride.
E4 [14]	Fernandes CS, Magalhães B, Goncalves F, Nogueira PC, Santos C./2021/Portugal	Establish an overview of the use of games in patients submitted to hip arthroplasty.	Scoping Review	No participants	Computer software, Video games, and Mobile games are used with an objective that essentially focuses on physical functions.	The games under analysis include rehabilitation or relational aspects, and mostly exergames.
E5 [15]	Wang Q, Hunter S, Lee RL, Wang X, Chan SW./2021/China	Understanding patients' needs for rehabilitation services. Delivered through mobile apps after total hip or knee replacement	Qualitative study.	20 patients were discharged from the hospital after a total hip or knee injury.	Mobile Application (WeChat)	WeChat facilitates multiple functions such as instant communication, patient grouping, and data transmission.

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ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E6 [16]	Guggenberger B, Jocham AJ, Jocham B, Nischelwitzer A, Ritschl H./2021/Austria	After a total hip replacement and after completing inpatient rehabilitation, support patients' home exercise programs.	Case Series	30 healthy participants	Smartphone-based training game (TG)	After THA and inpatient rehabilitation, the TG was intended for patients in their home training program. The project's goal was to create a TG that used bodyweight exercises in an augmented reality environment to improve lower limb strength, mobility, and coordination.
E7 [17]	Saunders, R., Seaman, K., Emery, L., Crompton, D., Lynch, C., Penjor, D., Sagar, S./2021/Australia	To investigate the experiences, benefits, and suggestions of an eHealth program for THA pre- and postoperative education among patients.	Qualitative Descriptive Study	9 patients who used the My Hip Journey eHealth after total hip arthroplasty.	Weblink (eHealth program)	Educate patients via fact sheets, instructional videos, and exercise videos about the necessary pre-and postoperative care for their procedure.
E8 [18]	Bahadori, Shayan; Collard, Sarah; Williams, Jonathan Mark; Swain, Ian/2020/Norway	Evaluate the evidence for the efficacy of commercial wearable technology and smartphone apps in supporting patient monitoring and rehabilitation following THR.	Systematic Review	No Participants	Wearable Technology and Smartphone Apps	———

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ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E9 [19]	Stauber, Anja; Schüßler, Nadine; Palmdorf, Sarah; Schürholz, Nina; Bruns, David/2020/ Austria	Determine the effectiveness of RECOVER-E on patients' surgical outcomes.	Study Protocol	160 patients undergoing primary TKR or THR	Mobile app for iOS and Android smartphones (RECOVER-E)	Gives important information on the preoperative phase, surgery, and recovery; it also incorporates 8 videos with short and simple exercises to train muscles and increase flexibility.
E10 [20]	O.A. Kaplunov1, Yu.A. Orlova2, A.V. Zubkov2, E.Yu. Nekrasov1, R.I. Gabidullin1, V.M.Konstantinov2,V.L. Rosaliev2, K.O. Kaplunov/ 2020/Russia	Utilize a universal software platform consisting of an application and a chatbot on a PC and mobile device to develop and implement a technology for the prevention, control, and management of patient actions during the outpatient medical rehabilitation phase.	Pilot Study	No participants	Universal software platform on a mobile device and a PC.	Based on existing clinical recommendations, the doctor provides customized indications that enable the expert-based vector of preventive measures to target the patient's behavior.

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ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E11 [21]	van Dijk-Huisman, H.C., Weemaes, A.T.R., Boymans, T.A.E.J., Lenssen, A.F., de Bie, R.A./2020/ Netherlands	Investigate the Application of Hospital Fit's potential to boost levels of physical activity and functional recovery after orthopedic surgery.	Pilot Study	97 patients undergoing total knee or hip arthroplasty.	Smartphone app combined with an accelerometer.	Provides real-time feedback on daily standing and walking minutes for patients and their physiotherapists. It also has 25 videos proposed to improve physical fitness, upper and lower leg strength, and functional recovery.
E12 [22]	Pérez-Medina, J.-L., Espinosa-Alvarez, P.-D., Jimenes-Vargas, K., Acosta-Vargas, P./2020/Ecuador	Usability study between a simple and a gamified serious game environment is presented to support therapeutic exercises for patients with hip replacement.	Pilot Study	30 participants	Two gamification developed in JavaScript and in Unity 3D.	The serious games capture the patient's movements and emulating them by an avatar in a game environment, while data is transmitted by the UDP protocol and the artificial intelligence algorithms are consumed by the API Rest.

Continues on the next page

ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E13 [23]	Chung, C.-J., Tuan, H.-W./2020/Taiwan	This study aims to introduce the idea of serious games in medical rehabilitation, create a game-based virtual rehabilitation system and platform, increase the patient's willingness to recover, and finally make training less boring.	Literature review	No participants	Application involving virtual reality.	Increase home rehabilitation convenience. The virtual reality device allows a fun interactive mode so that patients have a better rehabilitation process.
E14 [24]	Bahadori S, Wainwright TW, Ahmed OH./2019/UK	To evaluate the comprehensibility of the data given inside total hip replacement and total knee replacement applications to see more about the effect this could have on patients	Systematic search	No participants	15 Smartphone applications	Help rehabilitation of patients undergoing THR and TKR
E15 [25]	Dayucos A, French LA, Kelemen A, Liang Y, Sik Lanyi C./2019/USA	Determine the feasibility, usability, and utility of a website designed to improve the quality of preoperative education for hip and knee arthroplasty patients and increase engagement.	Pilot Study	80 patients between the ages of 40 to 65 years old scheduled for hip and knee	Website	Educational Website that provides videos and PDFs of educational material, helping patients with the preoperative process.

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ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E16 [26]	Perez-Medina, J.-L., Jimenes-Vargas, K.B., Leconte, L., Villarreal, S., Rybarczyk, Y., Vanderdonckt, J./2019/Ecuador	Determine the advantages and disadvantages of supporting the telerehabilitation process with ePHoRt architecture	Pilot Study	No participants	Web-Based Platform (ePHoRt)	Remote home monitoring rehabilitation exercises in patients after hip replacement surgery
E17 [27]	Bahadori, Shayan; Wainwright, Thomas W.; Ahmed, Osman H./2018/UK	Examine the content of smartphone apps produced for patients undergoing total hip replacement and total knee replacement surgery.	Study review	No participants	15 Smartphone applications	Help rehabilitation of patients undergoing THR and TKR
E18 [28]	KRUMSVIK, Ole Andreas; BABIC, Ankica/2017/Greece	Offers a smartphone safety reporting Application that is intended to cut down the occurrence of adverse events after THA.	Pilot Study	An expert in Human-Computer Interaction was brought in to evaluate the app's design and interaction flow. A physician was brought in to discuss the content and suitability of the prototype, a physiotherapist evaluated the statements, and a nurse who had recently undergone THA tested the app.	Mobile application (SafeTHA)	Helps patients self-report important factors, aids in the progress and quality of recovery, and helps to prevent postoperative adverse events like pain, anxiety, and loss of mobility. It provides patients with information regarding the recommended levels of activity following surgery, risk factors and methods for reducing them, managing the surgical area, and pain aspects.

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ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E19 [29]	Ling, Y., Meer, L.P.T., Yumak, Z., Veltkamp, R.C./2017/ Netherlands	Evaluate the Fietsgame's usability.	Pilot Study	9 participants (2 physiotherapists and 7 patients, all the patients were in the recovery process after hip surgery).	Fietsgame	Transforms routine rehabilitation activities into engaging exercise games. An Internet of Things server links exercise games to a patient's personal record and a therapist interface. As a result, the patient and the physiotherapist can keep monitoring the patient's health. A 3D depth camera was used to automatically monitor the users' performance.
E20 [30]	Rybarczyk, Y., Deters, J.K., Gonzalvo, A.A., Gonzalez, M., Villarreal, S., Esparza, D./ 2017/ Ecuador	Focuses on the identification and validation of a reliable, low-cost motion capture technology (Kinect).	Pilot Study	No participants	Web application	Platform for at-home rehabilitation. It is made for patients who have had hip arthroplasty surgery. It includes exercise demonstration videos and a 3D avatar that imitates the patient's movements captured by the Kinect (a device) in real-time.

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ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E21 [31]	Jeong YW, Kim JA./2014/Korea	Create a computer-tailored online education program to encourage self-care for total hip replacement patients.	Pilot Study	No participants	Web-based teaching-learning system	Taking into account each individual's health status, the developed program used flash, animation, and video to present individualized messages.
E22 [32]	Garcia, J.J., Romero, N.A., Boerema, S.T., Keyson, D., Havinga, P./2013/ Netherlands	In the context of THR patients, verify the established critical moment thresholds and sampling strategy. Explores potential technology-based design opportunities and presents the design trajectory of ESTHER as a tool for investigating in-depth THR patients' experiences with home surgery recovery.	Pilot Study	5 THR/TKR patients (3 male, 2 female)	Mobile Application (ESTHER)	ESTHER (Experience Sampling for Total Hip Replacement) is a research and design toolkit that was made to study the experiences of Total Hip Replacement (THR) patients after surgery and to evaluate the design of interventions to help patients through the complicated process of home recovery. It enables patients to determine their mood and IMA value through the use of a sensor platform.

Continues on the next page

ID	Authors/ Year/ Country	Purpose	Study design	Participants	ICT* Technology	ICT* Solution
E23 [33]	Lehrl, S.; Gusinde, J.; Schulz-Drost, S.; Rein, A.; Schlechtweg, P. M.; Jacob, H.; Krinner, S.; Gelse, K.; Pauser, J.; Brem, Matthias H./2013/Germany	Using mental stimulation to improve rehabilitation	A prospective controlled study	32 patients- 16 patients who played the video game Dr. Kawashima's Brain Training: How Old Is Your Brain? were compared in terms of rehabilitation progress to 16 individuals who did not play.	Nintendo (Dr. Kawashima's Brain Training: How Old Is Your Brain?)	There are a variety of tasks in this game that must be completed as quickly and accurately as possible.
E24 [34]	Fernando Dias Correia; André Nogueira; Ivo Magalhães; Joana Guimarães; Maria Moreira; Isabel Barradas; Maria Molinos; Laetitia Teixeira; Joaquim Pires; Rosmaninho Seabra; Jorge Lains; Virgílio Bento/2019/Portugal	The purpose of this study was to compare the clinical outcomes of supervised conventional rehabilitation with digital physiotherapy with an artificial intelligence system following THA.	Pilot Study	66 patients	Mobile app (for patients) + Web-based Portal (for clinical teams)	The mobile Application provides video and audio instruction about each exercise as well as biofeedback during the exercises. The web-based portal allows the clinical teams to monitor results remotely and prescribe/edit exercises.

After analyzing the 34 initially selected articles, 1 article was included, and 11 were excluded for the following reasons: it only involves prediction, does not have adequate evidence that interventions in virtual reality are effective, and does not have any additional information necessary for this project. In the end, there were 24 articles in this study.

2.5 Outcomes

After analyzing all articles, the use of different types of ICT in THR is evident. It was found that ICTs using mobile applications, websites, and sensors, were all developed to assist in rehabilitating total hip arthroplasty (THA). The use of mobile applications is the most common form to bring gamification to this area[11, 12, 13, 15, 16, 18, 19, 25, 27, 28, 34]. All of these articles were made to help patients before or after THR. The way these apps approach rehabilitation differs from each

other; including instructional videos[11, 12, 19, 34] is an exciting way to demonstrate the exercises that need to be done. Ensuring that the patient maintains sound mental health is another aspect addressed by some applications; reducing anxiety and helping the patient understand the whole process are the main objectives of these apps[11, 28]. The use of sensors and accelerometers to help better perceive the movement is also an interesting addition to this Application; this use demonstrates the potential to enhance patients' physical activity levels [21, 32].

Another way ICTs are applied is by using websites[17, 27, 26, 31, 34]; this content is similar to the ones on mobile apps.

Only one article involving virtual reality(VR) was added [23]; the VR device allows a fun interactive mode to rehabilitate patients better. Study [16] involves a system similar to virtual reality, called augmented reality (AR), where the real environment is augmented with virtual objects; this study is only applied in healthy patients, which makes the results unrelated to the true situation. The study's implementation of gamification is challenging for patients to use at home.

Three studies do not involve gamification [15, 18, 28, 33]. However, they address topics that can be included in ICT, making them even more helpful and appealing. All of them allow the patient to self-report their current state post-surgery, such as pain level, anxiety, and mobility.

Most of the participants included in these studies were essentially people who underwent THA; some studies also include professionals, like physicians and physiotherapists to evaluate the ICT developed.

The following studies stood out among the 23 analyzed:

- In study E2 [12], the mobile Application developed includes a six-week program, where the exercises, similar to the usual rehabilitation care, were demonstrated by videos and photos to evaluate the effectiveness of the app, the participants were divided, and one group received the usual care and the other received the usual care and program provided by the app.

- In the E5[15] study, the mobile Application WeChat allows instant communication, patient group, and data transmission; this qualitative study does not involve gamification. However, it has an exciting approach to contact between the patient and the healthcare provider.

- In study E7[17], a web link with an eHealth program was created; in these fact sheets, instructional and exercise videos were provided to patients; this qualities descriptive study gives a direct perspective of the patient.

- In the E10[20] study, the mobile app RECOVER-E was evaluated; this IOS and Android application includes eight videos with simple exercises to train muscles and increase flexibility; this study explains every essential part of the app, like the content, information, and motivation.

- In E12[22], a usability study is made of a serious game; this game is developed in two different environments, JavaScript and Unity 3D, with different levels of realism; both use a motion detection device to capture the flexion points of each body articulation. This study

explains the architecture for the developed serious games, which is helpful for a better in-depth understanding.

- In study E18[28], an application is presented in which the main focus is the patient's mental health. This article does not involve any gamification. However, how an application is developed to approach this subject is very interesting, as it demonstrates that psychological support is essential.

- Study E22[32] presents the link between physical and emotional aspects of recovery; ESTHER application allows the patient to identify their mood and their IMA value given by a sensor platform. This study presents the design trajectory of the app.

- In study E23 [33] aims to improve rehabilitation using mental activation, with the help of Dr. Kawashima's Brain Training: How Old Is Your Brain? (Nintendo; Kyoto, Japan) game. It includes tasks that must be completed quickly and proves that mental activation improves postoperative results.

- Study E24 [34], is one of the most completed articles, and it was added after the literature review using the databases. Although, in the end, it did not show great differences between the group in which digital physiotherapy and conventional physiotherapy were applied, it demonstrates that home physiotherapy rehabilitation with this new digital biofeedback system is feasible and safe after THA and is associated with high patient satisfaction.

All these games have positive results in acceptance by patients. In studies that carried out an analysis between patients who opted for traditional rehabilitation and those who opted for rehabilitation at home using someICT, they demonstrated that the latter presented better physical results.

When article E24[34] was analyzed, the Portuguese company SWORD Health was found, which provides health care that offers virtual and digital physiotherapy. This company provides its users with personalized exercise plans, and individual monitoring by the physiotherapist chosen by the patient. All exercises are performed using a SWORD kit, which allows verification of their execution. This Portuguese company has high quality and good results. However, its services are only available to those with benefits from an employer or health plan. This project aims to provide all patients with the necessary follow-up to obtain the best results. [35]

After all this analysis, we can now answer the questions initially asked.

- Are people undergoing THR receptive to usingICTs during their rehabilitation?
  Yes, people are receptive to the use ofICTs in the rehabilitation process. Patients are interested in rehabilitation at home and have better results.

- What types ofICTs have been developed in recent years?
  Several types ofICTs developed for this area, such as mobile applications, websites, or interactive platforms. Some are combined with sensors or accelerometers to get a deeper

look at user evolution. Virtual reality and machine learning are areas that, despite being underdeveloped, have proven to be interesting approaches for the rehabilitation of THR.

- How is post-THR rehabilitation approached?
  TheICTs developed address the THR rehabilitation process in an interactive and fun way for patients. Many present videos explaining the exercise to be carried out; others combine virtual reality and, based on a game, adopt techniques that make the patient exercise. SeveralICTs even apply a more educational perspective; here, they prepare the patient for rehabilitation.

After all this analysis, it was possible to verify that, in most of the studies, one of the limitations presented was the small number of samples. That said, it is necessary for future studies to apply a larger sample from different locations; in the cases studied, this aspect was not applied, which could compromise the final results. Including patients who have already gone through the rehabilitation process to provide information about what was missing and what they would have liked to see in their rehabilitation process is also an approach that is rarely sought after and interesting to apply.

Another aspect that should have been applied in more studies is the existence of rewards at the end of each activity/task. As will be seen in the following chapter, gamification has a fun and stimulating side; the presence of rewards at the end of each action the participant performs is a stimulating aspect to add. Also, most studies only reach some of the population; only some purchase the developed product. Therefore, covering all patients who have undergone hip replacement surgery is essential.

Chapter 3

Methodology

3.1 User-Centered design

In 1990, Bill Moggride, director of the design firm IDEO, discovered that he and his colleagues were designing different types of work, concluded that the differences between the designs had to do with the connection created between the person and the product they were using, he called it interaction design. [2] Since then, interaction design has grown exponentially, starting to be used by thousands of people. Most interaction design is not easily visible, but this concept interconnects various aspects of design, such as industrial and communication design, human factors, human-computer interaction. [2]. Interaction design is what makes many interfaces used by humans practical and easy to use, [36] it's about behavior. Interaction design is what makes the user incorporate the product into their [36] routine. As Saffer classifies [2], Interaction Design solves specific problems in specific circumstances. This author has developed four different approaches to deal with [2] interaction design problems, this approaches are represented in Table 3.1.

Each developer selects the approach that best fits the project. The more approaches used, the better the project.[36]

User Centered-Design is the most popular approach among the four developed by Saffer. This approach states that the user is the one who knows best [2]; it believes that users know what they want, their goals, and their needs, and the design has to meet these aspects. Designers must develop products that fit into people's lives, not the other way around. [2]

The roots of this concept are in ergonomics and industrial design [2]. The technical norms of User-Centers Design are developed by ANSI-ISO means American National Standards Institute, more properly by ISO (International Organization of Standardization). ISO 9241-210 provides a framework for human-centered design, complements existing design methodologies and presents a user-focused perspective that can be integrated into different development processes. This approach improves human well-being, accessibility and sustainability, increases efficiency and takes into account the different effects that these interactive systems can have on user health, safety and performance[36].

Table 3.1: Comparison of four approaches suggested by Saffer [2]

Approach	Overview	Users	Designer
User-Centred Design	Focus on the needs and user goals	Lead interface design	Reflects the needs and user goals
Activity Centred Design	Focus on tasks and activities that need to be fulfilled	Activities Practitioners	Tools creator for the actions
System Design	Focus on system components	Set of system goals	Ensure that all parts of the system are in place
Genius Design	Ability and gift of the designer used to make products	Validation Source	Inspiration Source

The User Experience Professionals Association defines user experience (UX) like this: "Every aspect of the user's interaction with a product, service, or company that make up the user's perceptions of the whole. User experience design as a discipline is concerned with all the elements that together make up that interface, including layout, visual design, text, brand, sound and interaction." [37] As already mentioned, it is extremely important to understand the user's needs, but the user experience is not focused only on these aspects. It is necessary to work with different teams (engineering, marketing, graphic and industrial design, interface design) to create the best possible user experience. [38]

When talking about user experience, it is necessary to talk about user interface, as these two concepts are often connected. The focus of the user interface is the graphical part of the design, the buttons, the paths that a user must follow. All interactivity of a product is framed in the user interface. [37] User experience is based on facts, it's important to see it as a whole.

The best way to create a good user experience is to test the product with the end user. This aspect has to be applied from the beginning of product development.

It is also important to distinguish User Experience from usability. Usability characterises the ease with which a user can interact with the final product. According to the International Standards Organization (ISO), usability is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a given context of use". [37] Usability, according to Nielsen [39] , focuses on all product features with which the user interacts.

Given the purpose of the application to be developed, the UCD methodology was followed.

This technology aims to create an environment where the user can learn and reproduce movements like physiotherapy at home interactively and safely. As mentioned in the previous section, users are the best source to indicate their needs and objectives, and the user-centered design methodology focuses on the final consumer and ensures that the user is satisfied with the final product from regular contact with the same throughout the development of the product. Still foreseeing the use of other approaches developed by Saffer (Table 3.1, as analyzed in the previous section, the User-Centered Design methodology was the one that was prioritized throughout the development of the entire project. To guarantee the satisfaction of the final consumer, it was strictly necessary to ensure the usability, accessibility, and functionality of the product. Adopting an approach resulting from the user-centered design process presented in the international standard 9241 (ISO 9241-210) [39], three distinct stages were followed: requirements gathering, prototyping, and evaluation, Figure 3.1.

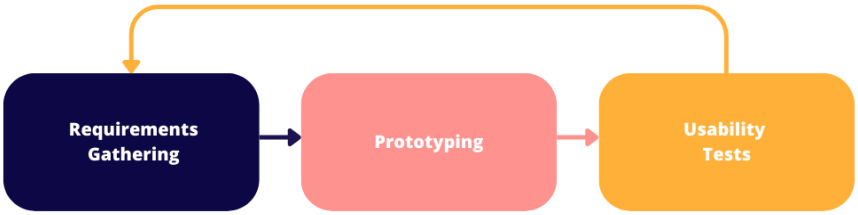

Figure 3.1: Methodological process adopted [1]

3.2 Methodological Approach

As seen in Chapter 2, for collecting requirements and testing the application's functionality and usability, the analyzed studies adopt different approaches, namely conducting questionnaires and interviews to understand patients' needs and creating different groups of rehabilitation, traditional rehabilitation, and new technologies, to test the effectiveness of the products.

Given the adoption of a User-Centered Design methodology, detailed in the previous section, and the period destined for this dissertation, it was decided to carry out interviews for the initial survey of requirements and to carry out different testing phases for the user to evaluate different types of prototypes and their usability.

3.2.1 Requirements Gathering

Part of the objective of this project is to identify the needs and objectives of the participants in their rehabilitation process to develop an effective and accessible product for all users. To complement the studies analyzed in Chapter 2, interviews were conducted with users who underwent a hip prosthesis and with health professionals.

The main objective of these interviews was to understand users' needs, difficulties, and goals during the traditional hip rehabilitation process to understand the main points to be covered in the product to be developed.

According to the interviewee's availability, the semi-strutured interviews were conducted in person or by telephone, lasting from twenty to thirty minutes.

These sessions were conducted during March 2023, and their participants were recruited for convenience, with no age restrictions being imposed in the selection process. All participants were informed about the purpose of the study and the confidentiality limits of their participation. In order to ensure that the same questions were asked to all participants, without variations between interviews, the guide available in the Appendix A of this document was developed.

3.2.2 Prototyping

Another objective of this project is the development of a prototype of a mobile application that fits all the requirements collected during the interview period. Prototyping is an investigation phase of a project, in which all defined idealizations are implemented [40]. In this project, different prototypes were developed to gradually progress until reaching the final product.

This prototyping testing was divided in three phases. It began by designing an initial low-fidelity prototype, which represents the initial version of *RehabApp*. The primary purpose of this prototype was to understand the best way to apply the entire information architecture, according to the data collected, leaving aside the visual aspect of the application. The first phase of testing took place with this prototype, and its testing was carried out remotely with a health professional in order to understand and validate the approaches defined therein. After the first testing phase, it was possible to rectify details exposed by the health professional, allowing the development of a high-fidelity prototype, more interactive and similar to the expected final representation of the interface in the mobile application. In this prototyping stage all the graphic design, graphical interface prototyping, and UX/UI was already developed. For this it was used the platform Figma.

The second prototype corresponds to the second phase of testing and includes evaluating the usability system with potential end users, which was carried out in person. In this phase it was possible to evaluate User-App Interaction and to do a questionnaire to the user about the app. The user's difficulties when using the application were recorded and, subsequently, improvements were made. The third phase focused on the evaluation of the last changes made.

The prototyping process was followed by Health professionals and users and was reformulated according to their contributions.

3.2.3 Usability tests

In order to make gradual improvements throughout the system, an interactive design model was applied. For this, there was constant contact with potential users to create a product that would satisfy their needs and expectations. The evaluation of the usability of the system was carried out when testing the prototypes.

In order to evaluate the application, test sessions were carried out with health professionals and users to guarantee the application's usability. Ideally, usability tests would take place throughout the rehabilitation process to better test the system's effectiveness. However, given the period in which this project was developed, it was decided to carry out as many tests as possible with users who have gone through or are going through a hip rehabilitation process and with a group of people who, despite not having undergone any hip intervention, fit all the other parameters.

Test sessions were divided into two phases: 1. User-App Interaction, 2. Post-Interaction Questionnaire. The first one aims to understand if the user can easily use the application, allowing him to handle it freely. While performing this phase, all faults made are pointed out. In the post-test questionnaire, several questions are asked about the application, present in Appendix C, to understand possible changes to be made. At this stage, a System Usability Scale (SUS) was also used to quantify, from zero to five, their degree of agreement with the context of the system. SUS proved to be a powerful and reliable tool for evaluating product usability [41].

They were also carried out with health professionals to complement the usability testing sessions with patients. These had as their primary objective the validation of the contents present in the final product. Given the area in which the final product falls, it is crucial to guarantee its security and legitimacy.

All data collected served to improve the prototypes already developed.

Chapter 4

Requirements Gathering

The analysis of the technologies developed in the context of this project, previously carried out in the systematic literature review, allowed a better understanding of the scenario in which this project fits. The developed review ensured a better understanding of the hip rehabilitation process and of the technologies developed so far to enable patient participation, thus emphasizing users' needs and challenges.

This dissertation aims to develop a technological solution that promotes the patient's participation in the rehabilitation process of the hip prosthesis operation. It undertakes to consider the opinion of end users at all times during its development. For this, moments of direct contact with users were created through interviews.

4.1 Survey Results

These initial interviews, to gather requirements, had a total of six participants, five users and one health professional. There was no restriction on recruiting these participants regarding age or educational level, an attempt was made to recruit a diverse sample of participants, considering the available contacts.

4.1.1 Patients

As previously mentioned, five users were recruited to conduct the survey of requirements to be applied in the mobile application to be developed.

Given the nature of the operation in which this dissertation is framed, the typical age range of users undergoing hip intervention is small and fits the population with more advanced ages. Even so, several attempts were made to obtain a larger sample, however, given the users who made themselves available to participate in these interviews, the age range continued to be reduced, which could be recognized as an obstacle to the study carried out. Despite these limitations, the group of users interviewed proved diverse, presenting different perspectives for the study.

It was essential to find out if the users already had a history of hip problems or had already undergone surgery to understand the knowledge level of each one. It was concluded that 80% of

the participants already had hip problems, mostly related to wear and tear in that area. Only one participant needed surgery due to an accident involving him.

Since the age group in this study involves more advanced ages, it was necessary to understand whether users had access to a mobile phone or tablet that supports the technology to be developed. These data can be found in Figure 4.1:

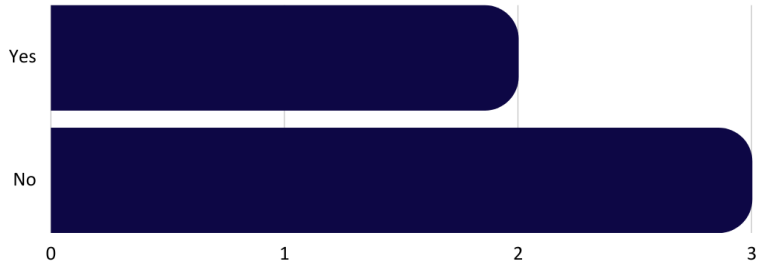

Figure 4.1: Statistical overview of user having mobile phones

Noting that 60% of the participants did not have any device that supports a mobile application, it was essential to understand whether they were accompanied at home by someone who could provide equipment daily. Only one participant said he did not have access to any equipment. Coincidentally, this is the only participant who showed no interest in using new technologies in their rehabilitation process.

Table 4.1 presents a summary of all the initial data collected and described so far in this study:

Table 4.1: Information collected during the interview

#	Age Group	Gender	Have Personal Device	Is there anyone to help	Interest in the Product
1	70-79	Male	No	No	No
2	80-89	Female	No	Yes	Yes
3	60-69	Female	No	Yes	Yes
4	60-69	Male	Yes	Yes	Yes
5	60-69	Male	Yes	Yes	Yes

Next, it was necessary to understand the habits that users have incorporated into their routine after THA in order to understand the best way to involve them in rehabilitation. Only one of the users interviewed was not accompanied by a physiotherapist in the postoperative period, justifying the lack of time. Instead, he chose to perform the exercises at home based on some knowledge previously acquired with other interventions already performed. However, he stated that having a platform with him would be more beneficial to help him correctly perform the exercises. The

remaining (80%) were all monitored in the rehabilitation process of the hip operation. The physiotherapy sessions that the users performed lasted about 60 minutes for 60% of the participants and 45 minutes for 20% of the user who performed the physiotherapy autonomously. This time could vary between 30 and 45 minutes. These presented data are exposed in the graph of Figure 4.2.

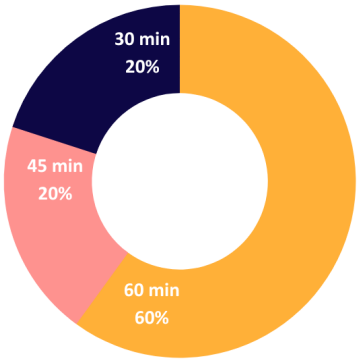

Figure 4.2: Physiotherapy time division

The exercises performed in the physiotherapy sessions mostly involved repeated movements, as illustrated in Figure 4.3:

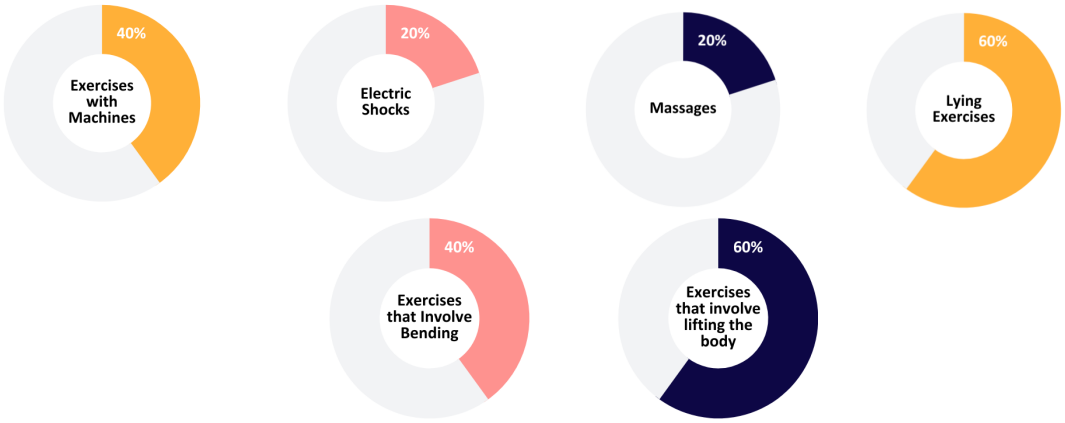

Figure 4.3: Exercises performed in the physiotherapy

Users who showed interest in the use of a new technology that allows them to have more active participation in the rehabilitation of the operation to which they were submitted mentioned the importance of clearly demonstrating some of the exercises performed in physiotherapy.

4.1.2 Health Professionals

In order to have a better understanding of all phases, difficulties involved, and points to be improved in the postoperative process of hip arthroplasty, it was essential to contact a health professional. This contact allowed a deeper understanding of the different ways the user can participate in the rehabilitation process and, in this way, collect relevant information to be included in the developed application.

The postoperative process of a hip intervention involves different moments:

- Scar care
- Containment, a decrease of inflammatory signs (edema, pain, temperature increase)
- Improved joint mobility. In an actively-assisted way, the joint is immobilized to increase the amplitudes.
- Muscle strengthening.
- Encourage the user to carry out loads on different types of floors, heights, and slopes
- Reinforcement of attention given to balance, ability to perform transfers (lie down and get up alone)
- Providing notions about essentials for a better recovery.

Physical therapy sessions are usually held daily. After some time and after a careful analysis by the health professional who accompanies the user, they can be carried out at intervals of one day.

From the point of view of carrying out some of the exercises outside the period allocated to the sessions to promote the user's participation in the postoperative process, this health professional highlighted the following exercises: flexion movements, standing up, sitting down, extension, and hip stabilization. The health professional highlighted the importance of understandable explanations to prevent complications in the rehabilitation process. He proposed that videos and a written explanation accompany the demonstration of the exercises, in this way, all age groups could perform what was presented to them.

4.1.3 Sample's Needs and Requirements

The interviews carried out with users undergoing hip surgery and with the health professional, who followed the guide available in Appendix A, allowed an understanding of the entire rehabilitation process, as well as the difficulties and needs of users during this period.

After a careful analysis of all the interviews, it was possible to verify that the presence of an explanation of the exercises that can be performed at home and without assistance by the patient is crucial. This point is essential to prevent complications in the rehabilitation process. The explanation associated with the exercises to be performed can come in two forms, a written explanation, where the movements are explained in detail, and a video explanation, in which the user would be able to visualize and learn how to do the movement in question.

Hip surgery is an intervention that leads to changes in the behavior of users and that leads to an increase in care, in addition to carrying out physiotherapy. That said, based on the information given by the health professional, it is necessary to transmit basic rules and care to the user in the postoperative process. This information will allow the user to be more aware of prohibited movements and the precautions to be taken during this period.

Chapter 5

Mobile Application: *RehabApp*

In order to promote user participation in the hip rehabilitation process, the *RehabApp* application was developed using the following platforms:

- Figma, a vector graphics editor, was used for the design and prototype;
- Android Studio was used for the development of the application. This platform is integrated development environment Android Studio and it was implemented with the Java language;
- Firebase, for authentication and database. This is a service provided by Google.

In this chapter, all stages of the development of this platform are presented.

5.1 Concept

Given the ease of access and use of mobile computing these days, this dissertation proposes "*RehabApp*," a platform that promotes user participation in the hip rehabilitation process in a dynamic, attractive, and safe way for its users, fulfilling one of the main objectives of this work: to be accessible to all users. This mobile application includes characteristic elements of gamification, which, as seen earlier, involves using game mechanisms in non-entertainment contexts to engage the user to participate.

The platform offers content produced in a user-centered way, where all the features and resources of the system were based on the literary study previously presented in this document and all the data acquired during direct contact with users who underwent the same intervention. As a result, three types of activities were incorporated, or "Tasks" as they are classified in the application. The purpose of these activities is to provide the user with sufficient knowledge about the attitudes, behaviors and movements to be aware of after hip surgery. The three activities to be performed by the user are detailed below:

- **(Learn)*"Aprender"*:** in this activity the user is introduced to basic rules and precautions to be taken during the postoperative period. All of this information is followed by an explanation and illustrative images or videos whenever necessary;

- **(Test)*"Testar"*:** the main objective of this activity is to test user knowledge about their behavior during rehabilitation processes. Here, some questions are made for the user to identify the correct way to do specific movements.

- **(Exercise)*"Exercitar"*:** In order for the user to be able to reproduce typical physical therapy movements at home and safely, this activity was created. Here, the user can reproduce various exercises based on written explanations and video demonstrations.

These activities are organized according to prior weekly planning, and their realization generates rewards in the form of points, which allow the user to move up in levels.

Since the target audience of this platform is the Portuguese population, the entire application was developed in Portuguese.

5.2 Mobile App Architecture

To develop well-structured mobile applications, it is necessary to use a set of technologies and models defined as application architecture. This type of architecture encompasses the following layers: [42]

- Presentation Layer: the way the application is presented to the end user is developed in this layer. It contains elements associated with the user interface (UI) and user experience (UX) concepts discussed earlier. This layer displays varied content, from graphics to text, to users, and interacts with the other layers from an application programming interface.

- Business Layer: this layer supports the application, allowing its execution. Includes logging, caching, and data validation systems, among many other features.

- Data Layer: this layer covers the application's database and is responsible for network communication, error reporting, and routing

Figure 5.3 illustrates the architecture of the *RehabApp* application.

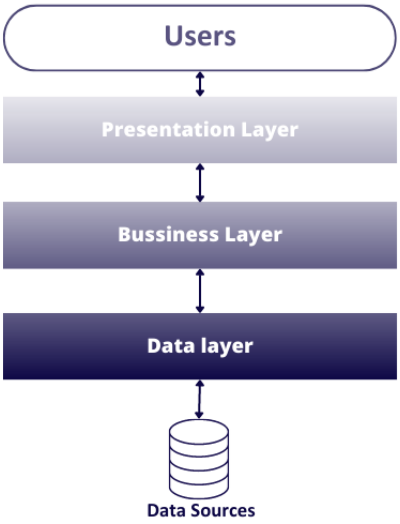

Figure 5.1: *RehabApp* Architecture

5.3 System Architecture

In order to be accessible to everyone, the *RehabApp* application benefits from its users' mobile devices, basing its operation on Wi-Fi, 4G, and 5G wireless communication technologies.

The architecture of a system represents the relationship between all system components and the data link between them. The system that surrounds the *RehabApp* application supports two components: the client and the server. The client promotes interaction between the user and the system from their mobile devices, allowing them to create accounts to use the application and carry out all proposed activities. The server provides services to the client. For this application, this component is represented by Google's Firebase platform, which provides a set of cloud-based tools and services designed to help create, maintain, and improve applications. This server has a database and a web server, as shown in Figure 5.3:

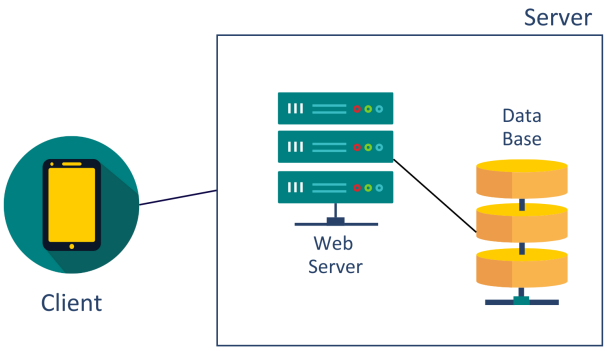

Figure 5.2: *RehabApp* System Architecture

5.4 Interface elements and concepts

As previously explained, the development of the *RehabApp* application consisted of different stages (prototyping and testing) to guarantee constant improvements and updates so that the final product corresponds to the users' needs.

Throughout this process, to predominate the system's usability and ensure that it had an intuitive, appealing, and easy interface, principles for interaction design developed by Nielsen [43] were followed. In these principles, Nielsen points out that users should be informed of what is happening through feedback; the author states that the language used should be the same as the user in order to generate better communication, as well as present clear actions so that the user does not make mistakes[43]. Given the age range of this application's target audience, the principles developed by Nielsen were given special attention, it was essential to create a product that anyone, having or not experience using mobile applications, could use.

5.4.1 Branding

To promote user participation in the rehabilitation process of a hip intervention and respond to their needs, the "*RehabApp*" application was developed. This name was established to allude to all types of rehabilitation since, in the future, this tool may be extended to various types of treatments. The logo adopts a minimalist and easily identifiable aesthetic, as does the entire graphical interface of *RehabApp*.

To ensure a harmonious interface design, it is crucial to carefully structure elements such as typography, color, and iconography.

For typography, the Inter font was designed for user interfaces with high readability of small to medium-sized text. Inter is a free font with a wide variety of thicknesses available, allowing different contrasts throughout the interface.

Regarding *RehabApp*'s visual identity, three attractive colors (pink, yellow, and blue) were chosen, which appeal to the use of the application and, in turn, convey the tranquility that the user needs for his rehabilitation.

About iconography, a free library from the Figma platform was used, which provides numerous icon designs, it was decided to apply a minimalist and intuitive set so that users can easily use and understand it.

As this application presents game dynamics, simple and dynamic graphic interfaces were designed to keep the user stimulated and involved in all proposed activities. It is important to remember that, for the range of ages in which this application fits, it is crucial that users easily understand the function of all components of the system. In this way, and following the User Interface concept developed in Chapter 3, great importance was given to making all interactive elements (buttons, text fields, menus, scroller) easy to understand, access, and intuitive.

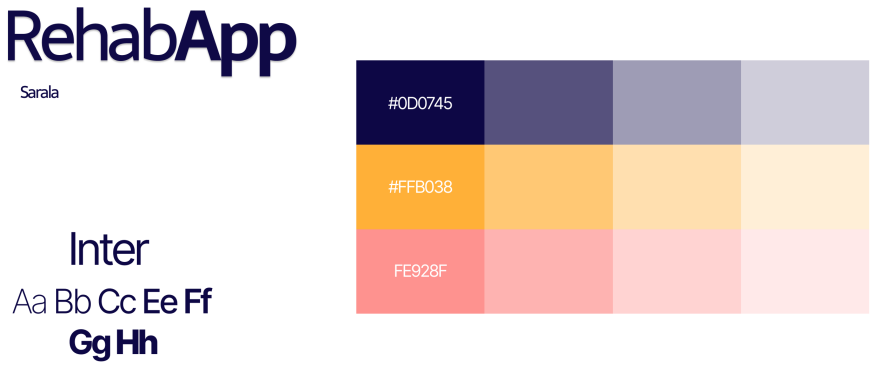

Figure 5.3: *RehabApp* Branding

5.4.2 Authentication

The connection with the user was a key topic in the development of *RehabApp*, and authentication is the first step to enhance future connections. [44]. Since there is a need to register to use the application since each user has a personal personalized page, the different methods were analyzed to understand which one is ideal.

Password-based authentication, Patterns, Digit-based Authentication, Biometric Authentication, and Social Login are different authentication methods. However, they all contain points that can make it difficult for the user to register for the application, which can cause disinterest and potential abandonment in the early stages. Given the age range of the users of this application, it was sought that, for the authentication phase, it was not necessary to memorize any password or PIN, nor that it involved any technologies that could prove to be challenging for the user. That said, One-Time Password (OTP)-based login was the initially chosen solution. This type of authentication sends the user an OTP, that is, a code, by message, so there is no need to set a password, patterns, or PIN to use the application.

Login and registration pages are the starting point for mobile applications; if they are tedious and difficult, users may want to avoid using them. [45] In this way, we tried to develop an interface that did not require many steps, was easy to interpret, and, above all, was fast. It started by implementing an OTP-based login with fictitious mobile phone numbers (test), moving later to simpler authentication, based on the introduction and verification of the respective mobile phone number, without OTP. Thus, authentication requires only two steps: entering and confirming the mobile phone number. For registration, the *RehabApp* user only needs to enter: name, surname, gender, and date of birth. To facilitate entry into the application, if the user authenticates through his mobile phone, he does not need to repeat the process of entering the contact. Instead, he is forwarded to the main page of *RehabApp*.

As mentioned, the login and registration pages are the gateways to creating personalized user experiences. Next, the interfaces referring to the authentication and registration pages are presented.

The user must insert his phone number on the first page to be checked in Firebase if this account already exists, and after that, he must click on the "Entrar" button. If the account exists, the user will be guided to "Home Page"; otherwise, the user will pass through verification to confirm his phone number; here, he has to select the right button, "Sim" or "Não." If the phone number is wrong, the user must insert it again; if he wrote the correct number, he would be conducted to the Create new account page. Here, as it is possible to see in Figure 5.4, the user must complete the designated places with his name, surname, gender, and date of birth. To terminate the creation of the new account, the user must click on the "Guardar" button.

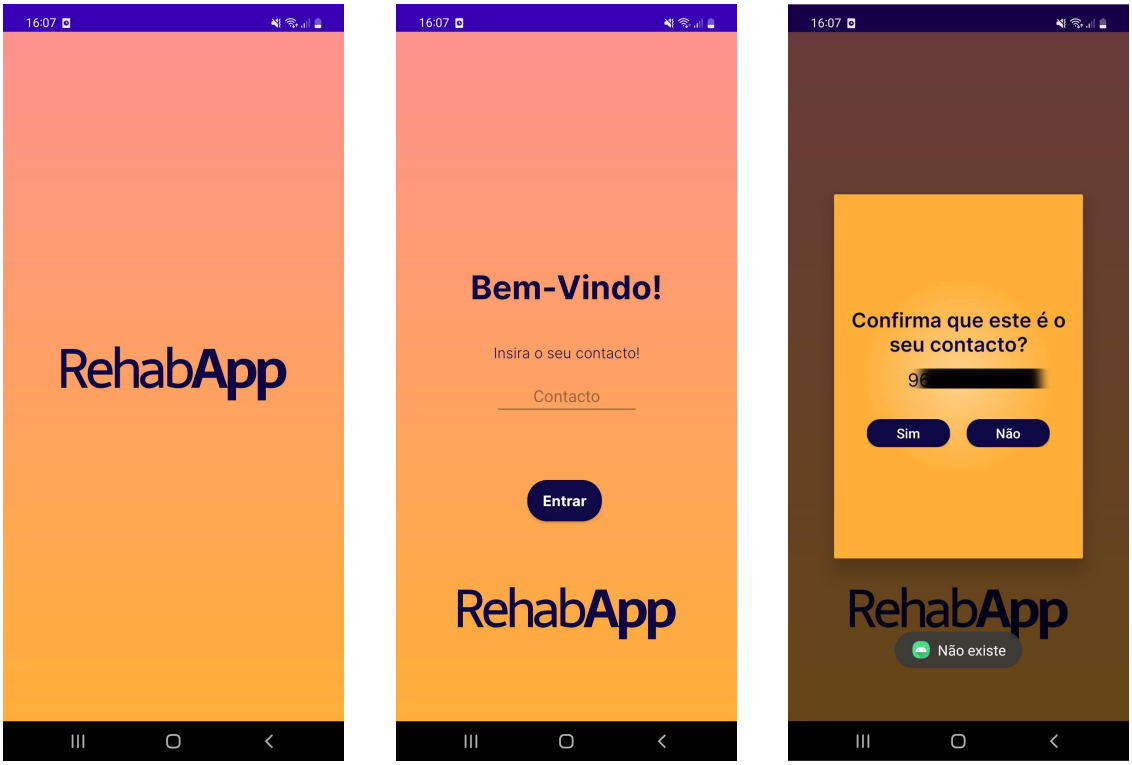

Figure 5.4: Authentication and Registration Pages

5.5 Registration and User Profile

On the registration page, Figure 5.5, the user must create a new account; he must complete the designated places with his name, surname, gender, and date of birth. To terminate the creation of the new account, the user must click on the "Guardar" button.

The user profile acts as a report of essential user information. The user can access and edit information previously entered in the application. Data such as name, date of birth, and contact can be found on this page, and only the last one cannot be edited for control and security reasons.

This page focuses on correcting the desired user data and, to save it in the database, click the “Guardar” button.

After clicking in "Guardar" button, he will be guided to the Home Page of *RehabApp*.

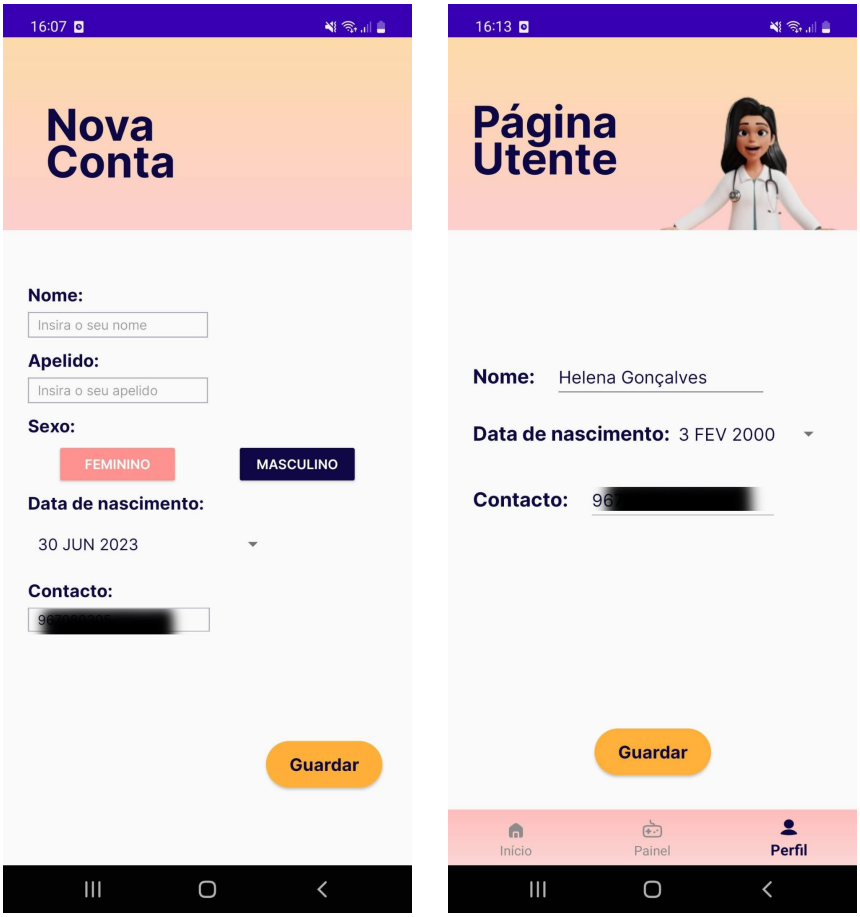

Figure 5.5: (a) Registration Page ; (b) User Profile

5.5.1 Home Page

The homepage is the first page of the application that the user has contact with after authenticating and registering. In this, it is possible to have an overview of the entire application and understand its main objectives.

Since *RehabApp* involves gamification, elements associated with the developed game dynamics, which will still be deepened in this chapter, are visible on this page. Here, the user can see his position in the game through levels and scores, gaining awareness of the work put into his rehabilitation and motivation to continue. Interactive means were also inserted so that the user could be logically guided to the activities to be carried out each day.

The main objective was to develop a customizable, attractive, intuitive interface to captivate the user. Throughout the initial interviews with users, the lack of knowledge and practice regarding

using applications was evident; thus, creating user-friendly interfaces for anyone was a significant focus throughout its development.

This page only exposes the user's status throughout the game and allows them to go, easily, to the tasks page. To do this, the user can do two different actions: click on the icon in the navigation bar corresponding to the tasks, or if he does not have much experience with mobile applications, click on the button that says "Vamos Começar."

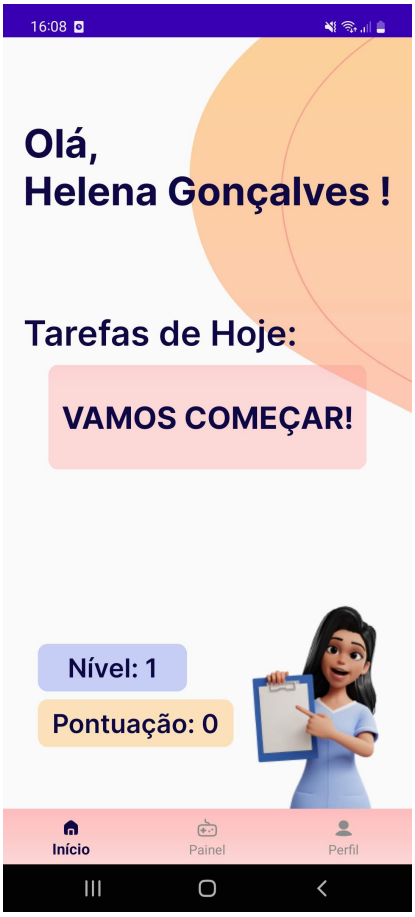

Figure 5.6: Home Page

5.5.2 Task Panel

The center of gamification in the *RehabApp* application is found in the task panel. In this are arranged the activities the user will carry out daily. The activities carried out are presented clearly and attractively. As previously mentioned, these activities aim to provide the user with the essential knowledge to have a more peaceful recovery after hip surgery.

In order to arouse interest and encourage the user, the three tasks developed weekly were organized. This way, the user knows what to do daily, and the process does not become monotonous. Associated with carrying out the tasks, there is the attribution of a score, determined by the time spent on each task; if the user reaches a specific score corresponding to the completion of all the proposed tasks in a week, he will move up to the next level.

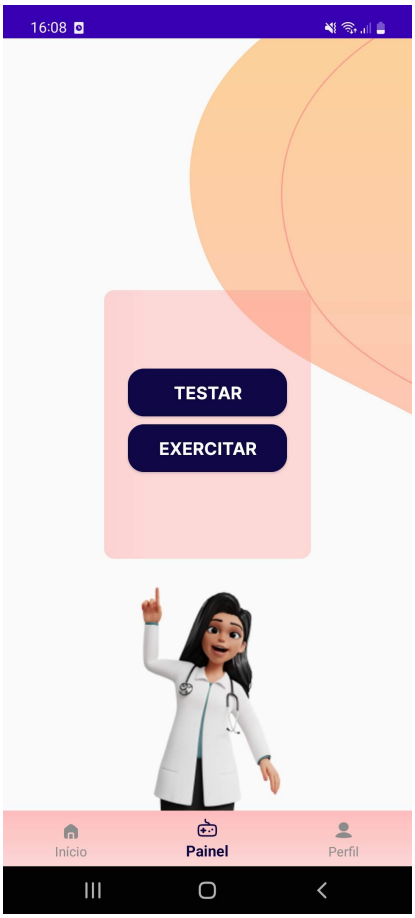

Figure 5.7: Task Panel

Communication and clear functionalities were a priority in the development of the tasks; for this, it was ensured that the user's language was being used, without unfamiliar terms or phrases, as indicated in one of the principles for the development of Google's app design [44]. This aspect does not only involve moments of exposure; the content on the buttons was designed to make the process straightforward so as not to raise doubts.

To start a task, the user has to press the corresponding button, and he will be directed to perform it. At the beginning of each task, there is an explanation of how they are carried out so that the user understands how to proceed. After reading the explanation, click the "Vamos Começar!" button to start the game.

It is essential to point out that all the visual contents present in the tasks were produced under the supervision of a health professional.

The three activities presented in *RehabApp* have three distinct objectives, learning, testing, and exercising. Then, each of the activities will be detailed.

5.5.2.1 *"Aprender"*

In contact with health professionals and users, the need to transmit fundamental knowledge to users was notorious. This knowledge involves actions and behaviors that must be adopted after the hip intervention.

Given this information, the *"Aprender"* task was developed to expose relevant information for the user's recovery. This information contains points such as: when to put ice on or when to drive again, explanations on how to carry out activities that would usually be assumed to be trivial and which, in these situations, must be carried out with the utmost care, how to go up and down stairs or how to sit in a car. In order to ensure a better understanding of the content by the user, some of the points are accompanied by photos or videos demonstrating the care or the rule explained in writing. To view the video, the user must click on the button "Ver Vídeo", correspondently, and he will be guided to a new page where the video is displayed on the entire screen.

This task is not intended to challenge the user, but to transmit knowledge, so, given the ease of the task, each point analyzed and understood is equivalent to five points for the final score.

After completing the task, the user is congratulated on the excellent work. This aspect is essential to maintain the motivation of the same in order to continue to carry out the tasks.

To finish and return to the task page, click the "Continuar" button in the final pop-up.

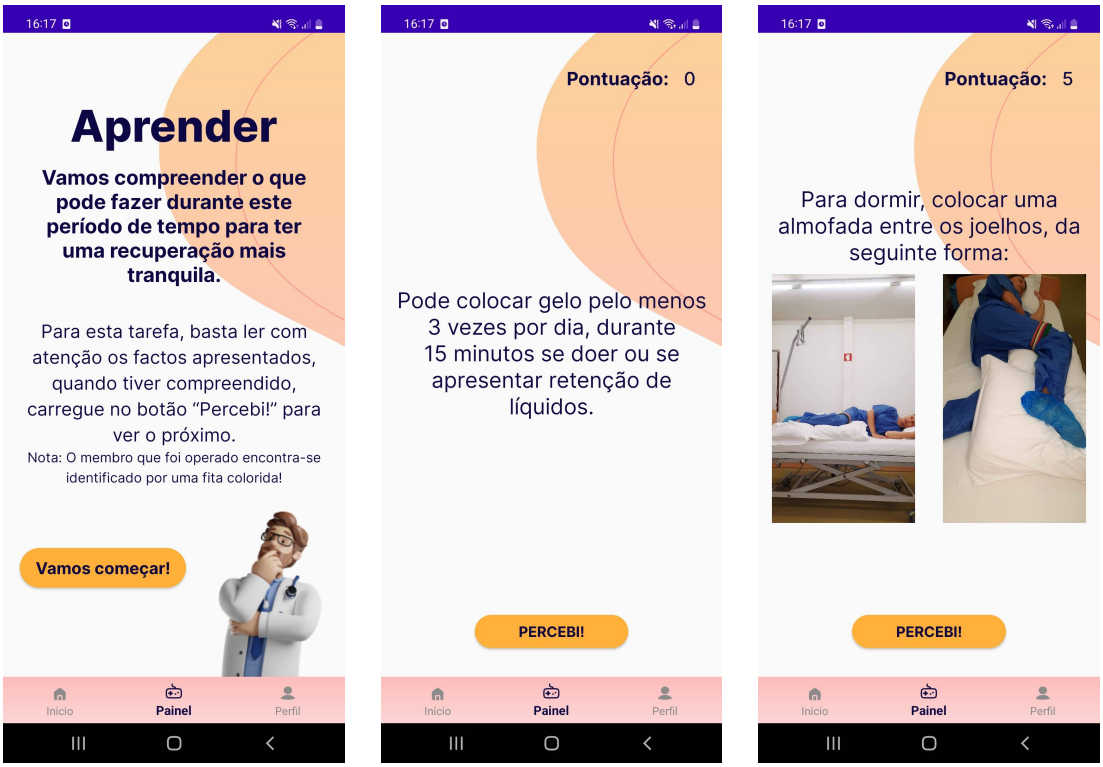

Figure 5.8: Task *"Aprender"* - 1

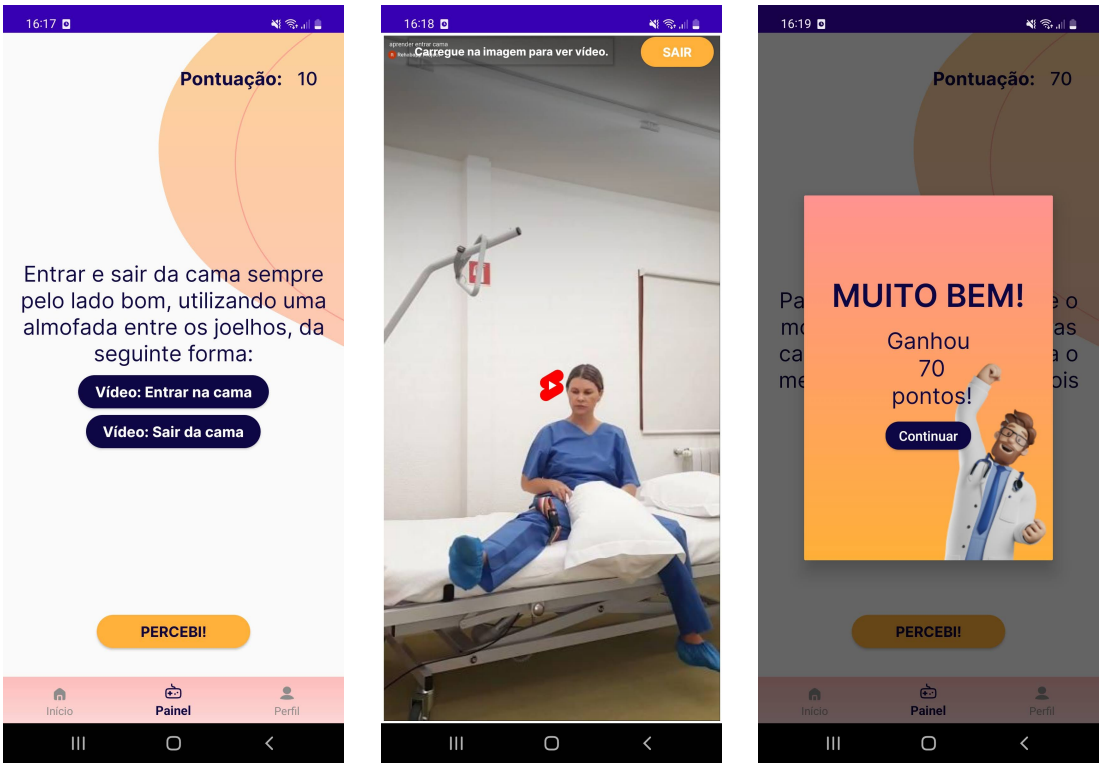

Figure 5.9: Task *"Aprender"* - 2

5.5.2.2 *"Testar"*

The second existing task in *RehabApp* is *"Testar"*; this arose from users' need to understand errors they might be committing. For this, Quizzes were developed, in which the user has to identify the right way to make specific movements typical of everyday life. In "Test," a question is asked, for example, "In which of the videos is the user picking up the object correctly?" choose the one you think is correct. To choose, the user must click on the desired image; if it is a video, click the corresponding button. This type of dynamics allows the user to understand what not to do; in this way, in his day-to-day, he can correct his behavior.

For each correct answer, the user earns ten points, and whether he is right or wrong, he is presented with an explanation of the correct way to perform the movement.

To finish and return to the "Tarefas" page, click on the "Continue" button in the final pop-up.

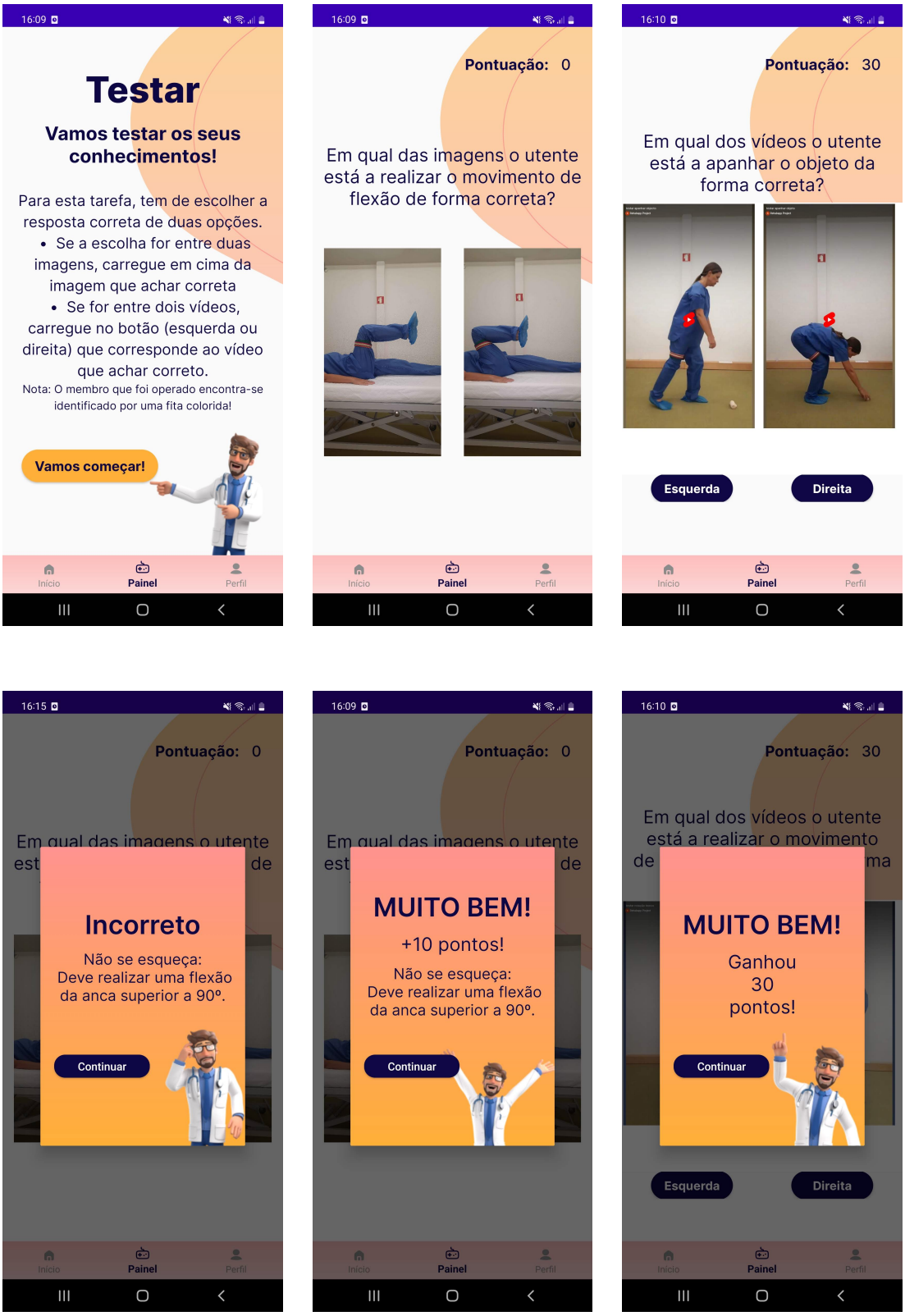

Figure 5.10: Task *"Testar"*

5.5.2.3 *"Exercitar"*

A significant uncertainty that users have about rehabilitation is which of the movements, typical of physiotherapy, they can do at home and how they should be carried out so as not to worsen their condition. This task resolves this issue. For a set of eight exercises, a written explanation of how to perform it is presented, the number of repetitions recommended, and a video illustrating the same to be done. To view the video, the user must click on "Ver Vídeo," and he will be guided to a new page where the video is displayed on the entire screen. All exercises performed in this task were indicated by a physiotherapist.

When executing each exercise, the user earns 10 points and, once again, at the end of the task, a message is displayed in pop-up format congratulating the excellent work. To exit, click on "Continuar."

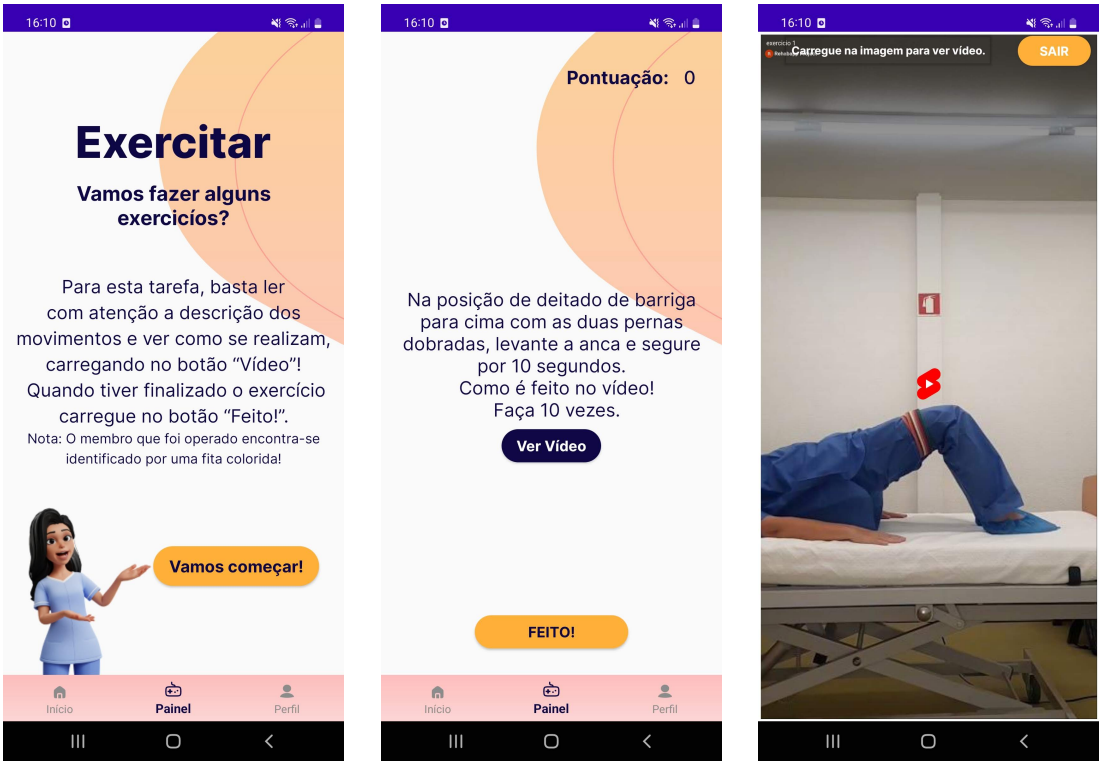

Figure 5.11: Task *"Exercitar"* - 1

Ensuring that the user has the best possible recovery and providing recommendations whenever necessary was an aspect to be considered in this task. For this purpose, the Borg scale of tiredness is presented at the end of the task. The Borg effort classification is a method that quantifies the level of physical activity. It is based on the physical sensations experienced by the user, the increase in breathing, and the level of muscle fatigue[46].The scale used in this project, presented in Appendix B, is an adaptation of the original, which presents a numerical scale from zero to

ten. Each selected level is accompanied by advice for a better recovery; either rest if the user has chosen the intermediate levels or contact a health professional or SNS24 in extreme cases.

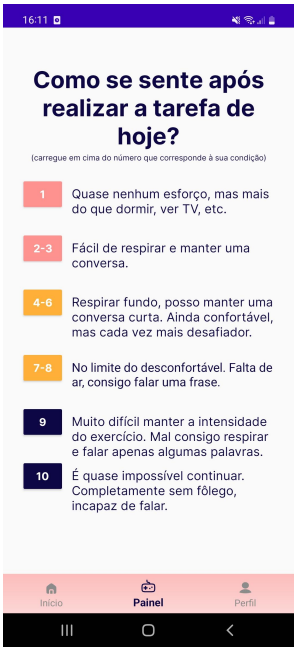

Figure 5.12: Task *"Exercitar"* - Borg scale of Tiredness 1

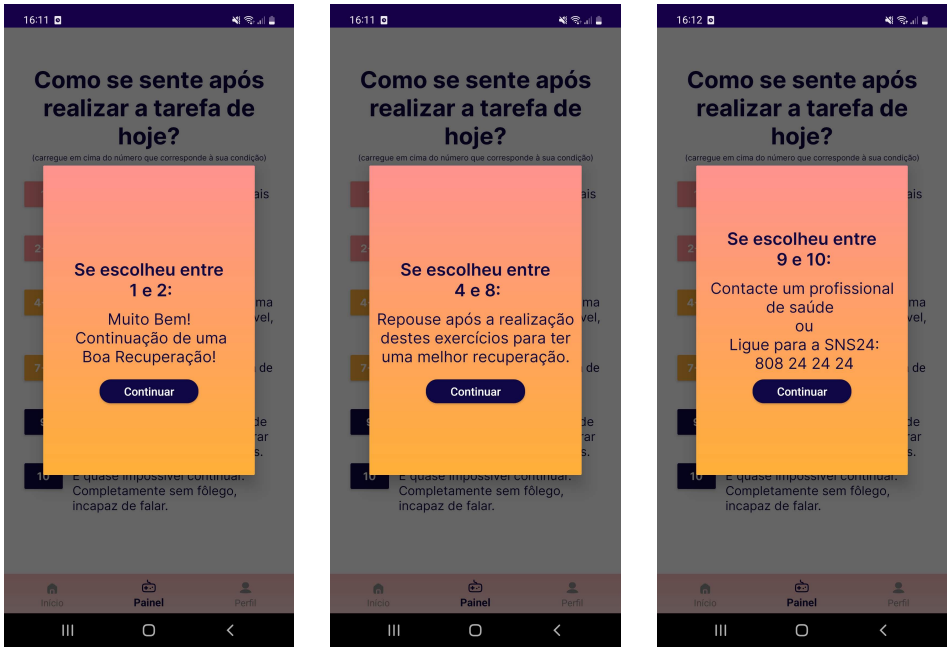

Figure 5.13: Task *"Exercitar"* - Borg scale of Tiredness 2

Chapter 6

Testing

The enhancement of the usability of a technological product results from the creation of a system that is gradually optimized. Rather than requiring users to adjust their behavior to learn and use a system, that system should be designed to adopt users' attitudes, needs, and behaviors [47]. As previously mentioned in this document, using a User-Centered Design methodology in a project provides the development of a product in which the surrounding experience becomes more efficient and satisfactory for the user, increasing their involvement [47].

The first testing phase focused on the application's low-fidelity prototype, a simple and interactive product version. With the information from the initial interviews, it was possible to define the entire concept and contents to be included in the application. This prototype began to establish the positioning and size of various elements, including navigation and basic clickability. The testing of this prototype was carried out remotely with a health professional in order to understand and validate the approaches defined in it. After the first testing phase, it was possible to rectify details exposed by the health professional, allowing the development of a high-fidelity prototype. This second prototype corresponds to the second testing phase and includes evaluating the system's usability with potential end users, which was carried out in person.

The high-fidelity prototype presents a high level of interactivity, including all the contents the final product can encompass. The users' perspective was added in this prototyping phase, allowing an improvement of the developed prototype. After all the improvements were made, users and health professionals in person tested the system's usability in a third test phase.

Aiming to quantitatively and qualitatively assess the usability and usefulness of the application promoting patient participation in rehabilitation after hip surgery, the second and third testing phases of the application had the following sub-phases in common:

- User-App Interaction

- Post-Interaction Questionnaire

6.1 First testing phase

In the first testing phase, a very early phase of the project, all the aspects that the application would have were already planned. This planning developed up to this moment was based on the interviews previously carried out and described in Chapter 4. These interviews, conducted with people who have already gone through or are going through the rehabilitation process of THA, made it possible to understand the needs and expectations of users in order to have an effective and peaceful recovery.

The aspects planned there consisted of sketching different games to pass on important information for the user's recovery and demonstrate the correct way to perform some exercises. Later, these sketches gave rise to the tasks *"Aprender"*, *"Testar"*, and *"Exercitar"* referred to in Chapter 5. The sketch, so far developed, corresponded to the low-fidelity prototype discussed earlier in this document.

The objective of this testing phase was for the competent health professional to observe, comment and validate the aspects that were idealized in order to be able to proceed. After a careful analysis, the health professional validated the approach taken and considered that using this type of game would undoubtedly be an added value for the patient and a precious aid for his recovery.

The most important details to be included in the respective games were described in detail by the health professional: exercises that the user can reproduce alone, precautions to be taken, and basic rules. It also verified the importance of creating a game to test the patients' knowledge to consolidate this learning. With the application of all this information, it is guaranteed that the system user has all the information necessary for a smooth recovery.

6.2 Second Testing Phase

After assimilating the data transmitted by the health professional, it was possible to format the application and develop a high-fidelity prototype. There, all the previously conceived games were already structured in their entirety, as well as all the points of interaction of the system, namely, the home page and the profile page.

At this point, testing the high-fidelity prototype with potential users was necessary.

Table 6.1: Sociodemographic Characterization of the Testing Sample

#	Age Group	Gender	Have Personal Device	Rehabilitation Historical
1	70-79	Female	No	Yes
2	40-49	Female	Yes	Yes
3	50-59	Male	No	Yes
4	60-69	Female	No	No

The participants in this testing phase, described in Table 6.1, were not the same as those in the initial interviews and, given the difficulty in finding individuals who would make themselves available to participate in this study, it was decided to divide this group of participants into two. The first involves a patient who has already undergone hip surgery, the second involves a group of participants who, despite not having undergone any type of hip intervention, were willing to participate. The latter covers a varied group of people, with different levels of practice in the use of mobile devices, with and without precedents for some type of rehabilitation and of different ages. In this way, it was possible to have a diversified sample, allowing for safer results.

The second testing phase intends to put the *RehabApp* application under analysis, in order to quantify and qualify the product's usability. This phase is extremely important in the development of the application, as it allows evaluating the design, observing how users interact with the product and detecting flaws and aspects to improve. This phase was divided into three distinct stages. The first consisted of users interacting with the application, the second a post-test questionnaire and the third a validation carried out by health professionals. All these steps were carried out in person and individually.

6.2.1 User-App Interaction

In this first stage, users interacted with the system interfaces. Here, participants were challenged to fulfill a set of eleven tasks, which fully correspond to all the functionalities of the *RehabApp* application. While performing the tasks, all failures made by the user were recorded. Table 6.3 was filled in, from zero to five, by the participants to assess the ease of performing the tasks.

As can be seen from the analysis of Table 6.3, the mechanisms associated with completing tasks and viewing videos proved to be critical points in the use of the application. Regarding the performance of the tasks, a significant part of the participants did not understand the functionality of the *"Boa"* button, which corresponds to the interaction that designates the exit from the page of the corresponding task. After explaining how it works, they revealed no associated difficulty. To avoid problems at this stage, it was decided to change the button's content from *"Boa"* to *"Continuar"*.

In viewing the videos, it is supposed to click on the video to start playback and, as soon as the user wants to leave the page, click on a button with a cross to return. Participants needed help understanding how to start the video and return to the previous page. Thus, it was decided to include an explanation of how to initialize video playback and, as previously done, change the button's content to go back.

Despite the mentioned problems, the participants of the test sessions performed the tasks in their entirety, and in the end, after an explanation of the points that they felt were difficult, they stated that they could use the application without problems. The tasks without demonstration of difficulties had an average rating of 4.75, demonstrating good usability of the system.

It should be remembered that none of the participants had had prior contact with the concept or prototype of the *RehabApp* application and that some of them are unfamiliar with using mobile applications, hence the need to clarify and simplify everything as much as possible.

Table 6.2: Level of dexterity in User-App interaction

Table 6.3: Quantitative assessment per task performed on the *RehabApp* prototype in the Second Testing Phase - First Step

#	Task Evaluated	Classification
1	The user was able to go to the tasks page to start the activities	4
2	User was able to Start *"Aprender"* activity	5
3	The user was able to perform all the activity	5
4	The user was able to end activity by clicking on the *"Boa!"* button	3
5	User was able to Start *"Testar"* activity	5
6	The user was able to perform all the activity	5
7	The user was able to end activity by clicking on the *"Boa!"* button	3
8	User was able to start *"Exercitar"* activity	5
9	The user was able to perform all the activity	5
10	The user was able to view the videos in all activities	3
11	The user was able to navigate to the *"Perfil"* page	4

6.2.2 Post-Interaction Questionnaire

After the first testing stage, a questionnaire, presented in Appendix C, was carried out to the participants to have more in-depth knowledge about their opinion about the use of the application. The completeness of the participants highlighted the usefulness and ease of the product.

Regarding the *"Aprender"* activity, participants in this testing phase expressed satisfaction with the simplicity of transmitting information, stating that if they did not have this application available, they might not understand all the rules and precautions to be transmitted here.

In the *"Testar"* activity, the participants demonstrated satisfaction with the dynamic created, emphasizing that the existence of rewards for getting the questions right makes the activity more challenging and stimulating. In addition, those who have already gone through rehabilitation stated that they sometimes had difficulties understanding the right way to perform specific movements, highlighting the usefulness of this activity.

Regarding the *"Exercitar"*activity, the participants pointed to its usefulness in rehabilitation and the need to know which exercises they can do and how to do them autonomously.

Participants also revealed that recurrent exposure to fundamental rehabilitation data would be essential to prevent errors and possible complications throughout the process. After the participants gave their opinion, they were asked to rate a set of statements based on the System Usability

Scale. Figure 6.2 shows the distribution of participants' ratings with System Usability Scale after using the application.

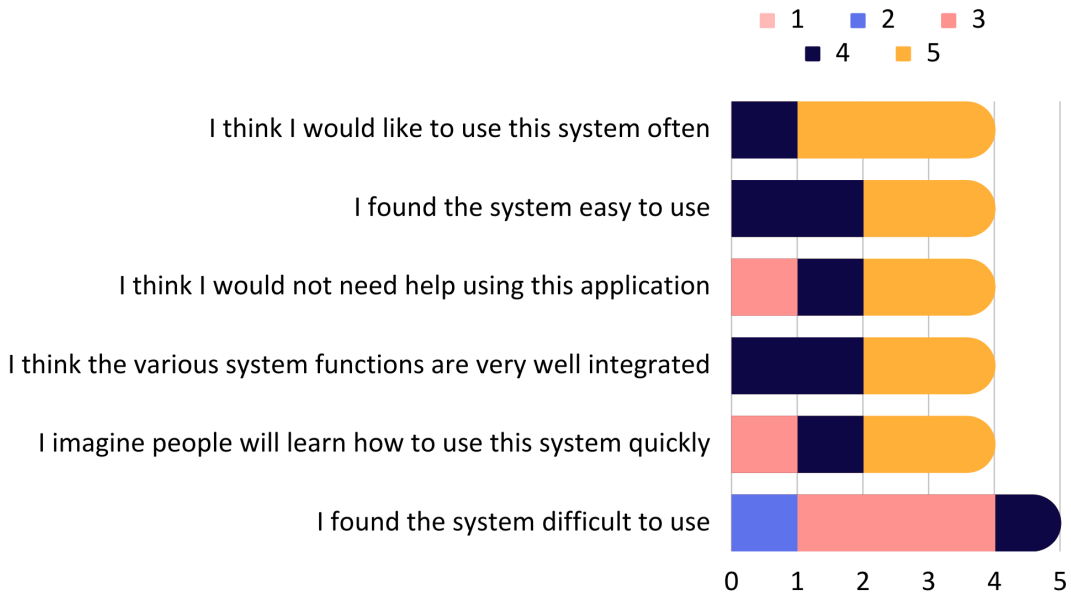

Figure 6.1: System Usability Scale1

6.2.3 Professional Health Validation

Although all the information in the *RehabApp* was provided by a health professional, in this phase of testing the high-fidelity prototype, contacting a physiotherapist for final validation became necessary.

In the same way, as the participants did in this testing phase, the health professional used the application in its entirety in order to evaluate all the content exposed to it. After thoroughly analyzing and completing the questionnaire in Appendix A, all contents were validated, stating that all followed the rules, needs, and criteria during the hip prosthesis rehabilitation.

As in the first testing phase, it reinforced the usefulness of this application and its importance for patients undergoing THA.

6.3 Third Testing Phase

In order to make it possible to evaluate the usability of the system after rectifications carried out after the second phase, the same 4 participants went through using the application again, going through the different testing stages previously explained.

6.3.1 User-App Interaction

As it was done before, in this step the users interacted with the improved interfaces of the whole system. They were, again, challenged to fulfill a set of eleven tasks, which fully correspond to all

the functionalities of the *RehabApp* application.

Table 6.4: Quantitative assessment per task performed on the *RehabApp* prototype in the Third Testing Phase - First Step

#	Task Evaluated	Classification
1	The user was able to go to the tasks page to start the activities	4.5
2	User was able to Start *"Aprender"* activity	5
3	The user was able to perform all the activity	5
4	The user was able to end activity by clicking on the *"Continuar!"* button	4.5
5	User was able to Start *"Testar"* activity	5
6	The user was able to perform all the activity	5
7	The user was able to end activity by clicking on the *"Continuar!"* button	4.5
8	User was able to start *"Exercitar"* activity	5
9	The user was able to perform all the activity	5
10	The user was able to view the videos in all activities	4
11	The user was able to navigate to the *"Perfil"* page	4

As it is possible to verify, the participants showed more dexterity in handling the application in this testing phase. They stated that the changes made were beneficial to increase the usability of the application, being able to perform the tasks without help.

6.3.2 Post-Interaction Questionnaire

After users' interaction with the application in the previous testing phase, they were again submitted to a questionnaire adapted from the System Usability Scale.

The results of this questionnaire, shown in Figure 6.2, legitimize the ease of interaction with the presented prototype of the *RehabApp* application. Participants again emphasized the usefulness of this application for participating in hip rehabilitation and the desire to be able to use it.

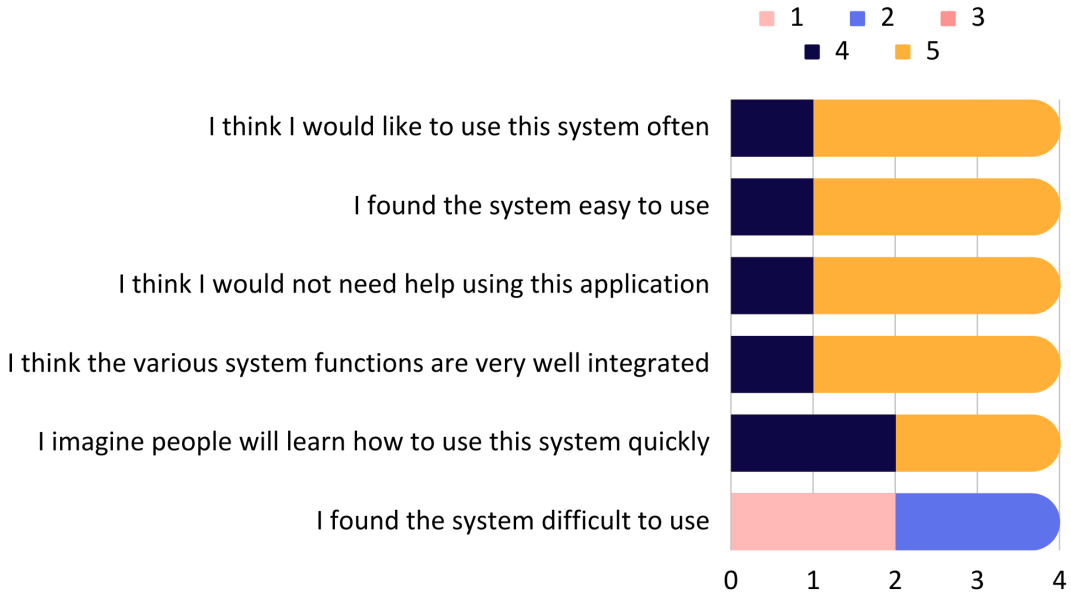

Figure 6.2: System Usability Scale 2

6.4 Discussion

In its entirety, the results of the evaluation of the usability of the system for promoting patient participation in hip rehabilitation, *RehabApp*, are very positive, highlighting the constant evolution of the platform centered on providing the information strictly necessary for a smooth recovery.

Data analysis collected in the third testing phase exposes the ease of execution of all tasks, with scores between 4 and 5 points. Verifying an improvement in the experiences between the last two testing phases is possible.

As mentioned earlier in this document, usability measures the user's interactive experience with an interface. An easy-to-understand design, which offers a solution to the user's needs efficiently and is attractive to use, is an interface with high levels of usability. After all the tests, it is possible to quantify the *RehabApp* system with high levels of usability; its potential users classified it as an application, helpful, easy to use, and stimulating for their participation in rehabilitation.

Although the content present in the *RehabApp* is transmitted by health professionals, the clarified and convenient exposition of all the existing information in the activities, *"Aprender"*, *"Testar"*, and *"Exercitar"*, was evoked as a justification for the future use of the application.

Chapter 7

Conclusions and Future Work

In the previous chapters of this document, the framework and objectives of this project were presented, a literary review was developed, and the necessary fundamental concepts were deepened. Additionally, a system capable of meeting the needs of all future users was produced.

This last chapter of this dissertation aims to detail the main conclusions and expose the contributions of this project to the existing literature. Additionally, the limitations and difficulties that arose in the development of this project are displayed, as well as proposals for future work.

7.1 Conclusions

This dissertation focuses on promoting patient participation in hip surgery rehabilitation and is divided into four objectives, previously mentioned in Chapter 1.

The first objective focused on the in-depth analysis of all existing content on the subject in question. This literature review had the following purposes: 1. To analyze different approaches used to promote user participation in the rehabilitation of THA, 2. To understand the impact of new approaches on the patient's recovery, and 3. To assess the receptivity of the same to its use. The result was positive, verifying that users are receptive to the use of new approaches as well as obtaining equal or better results than traditional rehabilitation. After a careful analysis, the lack of solutions that could be easily used by any user and that promoted their engagement in their use stood out. *RehabApp* presents a simple, clear and effective solution, which can be easily used by any patient, regardless of their education or age.

The second objective was to understand the needs and possible difficulties of users undergoing THA during rehabilitation. To obtain this information, interviews were conducted with a sample of patients, which allowed them to acquire the necessary knowledge to develop a well-structured, realistic, and valuable concept. The third objective focused on designing and developing a prototype of a teaching solution with gamification elements. Taking advantage of easy access to mobile devices, the *RehabApp* platform was developed, which aims to rehabilitate the patient during hip surgery. *RehabApp* is a mobile application that provides users with interactive and fundamental

content for a better recovery from total hip arthroplasty. Based on gamification techniques, it represents three games with different objectives:

- *"Aprender"* – whose main objective is to transmit essential rules and necessary precautions to be taken during the rehabilitation process;
- *"Testar"* – here, knowledge is put to the test; in this activity, the user has to answer a quiz and identify the right way to perform the movements;
- *"Exercitar"* – in this activity, the user has to reproduce the movements, typical of physiotherapy, displayed by the application;

All these activities are accompanied by rewards promoting and encouraging user participation.

The last objective concerns the evaluation of the usability of the *RehabApp* platform. Always focusing on the User-Centered Design methodology, several tests were carried out with users to quantitatively and qualitatively assess the platform's usability. In the end, the results were quite positive, achieving high levels of usability. The *RehabApp* platform was considered by the participants and health professionals involved in the whole process to be an application of enormous utility and importance.

After achieving all the objectives and acknowledging its success, the final objective of developing a game that promotes the user's participation in rehabilitation was achieved: the case of THA.

7.2 Limitations and Future Work

The purpose of this dissertation was divided into main objectives focused on promoting patient participation in the hip operation rehabilitation process, which were completed. In order to enable the continuation of this project, directions for carrying out this work are presented below. Although, in this dissertation, several usability tests were carried out, given the period that was carried out, it was not possible to test the application during the total period of the rehabilitation process. Thus, it is proposed to test the application developed during the weeks or months that a patient's rehabilitation takes place in order to be able to observe the effect on his recovery. In the same way, we propose an attempt at testing with a larger sample of participants, given that this was a limitation found in this work. As future work, it is also proposed to adapt this project to other types of rehabilitation, and the scaling of this application may be exciting and very useful.

Appendix A

Sample's Needs and Requirements

Health Professionals Interviews - Guide

General objectives:

- Legitimate the interview and motivate the interviewee to participate (block I)
- Understand and explore the rehabilitation process (block II)
- Explore ICT/eHealth solutions and how they can be applied (block III)
- Reflection and conclusion of the interview (block IV)

Block I

- Objectives:
    1. Make known the study and objectives of the interview
    2. Request collaboration from the interviewee
    3. Make people aware of the importance of their contribution to the study
    4. Ensure anonymity and confidentiality of data
    5. Encourage the asking of questions
- Questions:
    1. Explain interview context.
    2. Do you want to ask a question?

Block II

- Objectives:
    1. Understand what rehabilitation/physiotherapy sessions consist of, their frequency;
    2. Explore opinions issued

- Questions:

    1. In a normal situation, what does each physiotherapy session consist of?
    2. Are the exercises the same from session to session or do they change?
    3. How many sessions are usually held per week?
    4. How long does each one last?

Block III

- Objectives:

    1. Understand how these solutions can be applied in this situation.
    2. Understand what type of exercises can be applied, how and their duration.
    3. Fundamental aspects to be included in the solution.
    4. Understand better ways to encourage the user.
    5. Explore opinions issued

- Questions:

    1. ICT/eHealth solutions are increasingly used in the health sector. Do you think its use could be an asset in this hip rehabilitation process?
    2. Making videos explaining the exercises in detail so the user can replicate them safely could be a good approach.
    3. If so, what kind of exercises are essential to present?
    4. If not, what other approach could we take?
    5. Do you think this type of solution can be used right at the beginning of the rehabilitation process, or is it better to do it at a more advanced stage?
    6. Since they will be performed at home, how often should these exercises be done per week?
    7. Is there any aspect that is essential to present a solution like this?
    8. One of the objectives of these solutions is to keep the user motivated and ensure that he is in good shape mentally. How can these aspects be addressed/applied? (remember that this solution will be a game)

Block III

- Objectives:

    1. Reflection and conclusion of the interview
    2. Reflect on the main opinions issued

3. Complete the interview

- Questions:

1. Return some less clarifying questions
2. Review the interview
3. See if the record reflects the interviewee's ideas
4. See if the interviewee wants to change anything he said
5. Complete the interview
6. Reinforcing the importance of the interviewee for the study
7. Enforcing the availability of data or conclusions

Patient Interviews -Guide

General objectives:

- Legitimate the interview and motivate the interviewee to participate (block I)
- Understanding the preoperative context (block II)
- Explore the rehabilitation process (block III)
- Explore knowledge with ICT/ehealth solutions (block IV)
- Reflection and conclusion of the interview (block V)

Block I

- Objectives:

1. Make known the study and objectives of the interview
2. Request collaboration from the interviewee
3. Make people aware of the importance of their contribution to the study
4. Ensure anonymity and confidentiality of data
5. Encourage the asking of questions

- Questions:

1. Demographic issues, among others, in order to minimize constraints
2. Do you want to ask a question?

Block II

- Objectives:

1. Understand what led to the intervention on the hip;

2. Understand whether surgery was the only option
3. Explore opinions issued

- Questions:

1. I would like to know a little about your history until the hip operation. He always had problems, it happened for some specific reason, pain...

Block III

- Objectives:

1. Knowing the user's experience in this process.
2. Understand what you liked, what you didn't like, what you missed...
3. Explore opinions issued

- Questions:

1. Do you consider that you are having/had good monitoring throughout the entire process?
2. Do/did you practice some of the proposed exercises at home?
3. Is/was the duration of each session adequate?
4. Do you consider this treatment methodology adequate?
5. Would you like to have more opportunity to hold these sessions at home instead of going to a specific location frequently?
6. What are/were the positive aspects/that you liked the most throughout this process?
7. And the negative aspects?

Block IV

- Objectives:

1. Understand the user's knowledge of this topic
2. Understand if you find these applications interesting
3. Explore opinions issued

- Questions:

1. Are you familiar with ICT solutions? If not, give a brief presentation
2. Do you understand how they can be used in rehabilitation processes?
3. Have you used any of these solutions?
4. If so, what kind of solution was it and in what situation?

5. If not, would you like the opportunity to use these solutions in your rehabilitation process?
6. Do you have frequent access to mobile devices with Internet?
7. How would you like to obtain these solutions? Website, mobile apps...
8. Regarding your rehabilitation process, what do you think these solutions can involve/present?

Block V

- Objectives:
  1. Reflect on the main opinions issued
  2. complete the interview
- Questions:
  1. Return some less clarifying questions
  2. Review the interview
  3. See if the record reflects the interviewee's ideas
  4. See if the interviewee wants to change anything he said
  5. Complete the interview
  6. Reinforcing the importance of the interviewee for the study

Appendix B

Mobile Application: RehabApp

B.1 Borg Scale

Table B.1

1	Almost no effort, but more than sleeping, watching TV, etc.
2-3	Easy to breathe and hold a conversation.
4-6	Take a deep breath, I can keep the conversation short. Still comfortable, but increasingly challenging.
7-8	On the edge of uncomfortable. Shortness of breath, I can speak a sentence.
9	Very difficult to maintain the intensity of the exercise. I can barely breathe and speak just a few words.
10	It's almost impossible to continue. Completely out of breath, unable to speak.

Appendix C

Usability Tests

C.1 Testing Phase

C.1.1 Questions asked to participants after interacting with the system

- Task Page
    1. Did you realize objective Page Task?
    2. Did you understand objective tasks just by their name?
- "Aprender" Task
    1. Did you understand all the precautions related to the task?
    2. Is the content present in this task explained in a clear way?
- "Testar" Task
    1. Did you understand all the related questions in the task?
    2. Is the content present in this task explained in a clear way?
    3. Are the displayed images and videos clearly visible?
- "Exercitar" Task
    1. Did you understand all the video exercises in the task?
    2. Is the written explanation of the exercises understandable?
    3. Are the displayed videos clearly visible?

C.1.2 Questions asked to health professionals after interacting with the system

- "Aprender" Task
    1. Are the precautions to be taken relevant?
    2. Are the precautions to be taken clearly explained?

3. Should any point be taken out or added?

- "Testar" Task

1. Are the questions asked relevant?
2. Are they explained clearly?
3. Are the images and videos shown correctly executed?
4. Should any point be taken out or added?

- "Exercitar" Task

1. Are the exercises presented correctly performed?
2. Is the written explanation of the exercises correct?
3. Should any point be taken out or added?

C.1.3 System Usability Scale

Table C.1

Strongly Disagree					**Fully agree**
1	2	3	4	5	

1. I think I would like to use this system often;
2. I found the system easy to use;
3. I think I would need help using this application;
4. I think the various system functions are very well integrated;
5. I imagine people will learn how to use this system quickly;
6. I found the system difficult to use.

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