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Maria Francisca Rodrigues Laureano

Design and implementation of motivational and continued use strategies in a telerehabilitation application

Dissertation in the context of the Master in Design and Multimedia, advised by Paula Alexandra Silva and presented to the Department of Informatics Engineering of the Faculty of Sciences and Technology of the University of Coimbra.

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DEPARTMENT OF INFORMATICS ENGINEERING

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Abstract

Telerehabilitation is becoming increasingly important as it makes access to care more accessible and affordable. However, one of the current problems with telerehabilitation is the person's adherence to prescribed rehabilitation plans. As rehabilitation is essential for individuals to remain independent, and since telerehabilitation is a means to bring rehabilitation to everyone everywhere, it is important to find ways to make telerehabilitation systems attractive. This dissertation contributes to solving this problem by redesigning, developing and evaluating the user interface of a telerehabilitation application and by implementing a gamification strategy into that application. In accomplishing that, this work started by reviewing the previous version of the user interface. For this, a list of 33 heuristics was compiled that guided a heuristic evaluation performed by four evaluators. Next, the gamification strategy was defined. Afterwards, medium and high-fidelity prototypes were iteratively and incrementally designed, following a human-centred design methodology, and later implemented using React.js. Finally, a usability and user experience evaluation was carried out with 47 participants, divided into two groups, to validate the proof-of-concept of the telerehabilitation application. 13 representative tasks were evaluated, most of which participants were able to complete in a straightforward manner, with few to no errors. After completing the tasks in the systems, participants reported that the application was easy to use, where the application obtained an average score of 87.1 on the System Usability Scale and of 9.1 on the Net Promoter Score questionnaires. The results of this dissertation benefit people who need rehabilitation but are unable to access it regularly or lack motivation to continue to adhere to their treatment plans. Results further contribute to subjects concerning the design and use of user interfaces for telerehabilitation.

Keywords

Telerehabilitation, Motivation, Gamification, Usability, User Experience.

Resumo

A telereabilitação tem ganho especial importancia na medida em que facilita o acesso a cuidados de saúde, que por sua vez se tornam mais económicos. No entanto, um dos atuais problemas da telereabilitação é a fraca adesão da pessoa aos planos de reabilitação prescritos. Uma vez que a reabilitação é essencial para que os indivíduos se mantenham independentes, e sendo a telerreabilitação um meio de levar a reabilitação a todos e a qualquer lugar, é importante encontrar formas de tornar os sistemas de telerreabilitação atrativos. Esta dissertação contribui para a resolução deste problema ao redesenhar, desenvolver e avaliar a interface do utilizador de uma aplicação de telereabilitação e ao implementar uma estratégia de gamificação nessa aplicação. Para isso, este trabalho começou por rever a versão anterior da interface do utilizador, tendo sido compilada uma lista de 33 heurísticas que orientaram uma avaliação heurística realizada por quatro avaliadores. De seguida, foi definida a estratégia de gamificação, foram concebidos os protótipos de média e alta fidelidade de forma iterativa e incremental, seguindo uma metodologia de design centrada no ser humano, e posteriormente implementados utilizando React.js. Finalmente, para validar a prova de conceito da aplicação de telereabilitaçãof foi realizada uma avaliação da usabilidade e da experiência do utilizador com 47 participantes, divididos em dois grupos. Foram testadas 13 tarefas, que a maioria dos participantes foram capazes de completar de forma simples, com poucos ou nenhuns erros. Após completarem as tarefas no sistema desenvolvido, os participantes referiram que a aplicação era fácil de utilizar, tendo esta obtido uma pontuação média de 87,1 e 9,1 nos questionários de *System Usability Scale* e *Net Promoter Score*, respetivamente. Os resultados desta dissertação beneficiam as pessoas que necessitam de reabilitação, mas não conseguem ter acesso à mesma regularmente ou não têm motivação para continuar a realizar os seus planos de tratamento. Os resultados contribuem ainda para temas relacionados com o design e utilização de interfaces de utilizador para a telereabilitação.

Palavras-Chave

Telereabilitação, Motivação, Gamificação, Usabilidade, Experiência do Utilizador.

Contents

Acronyms

COTS Commercial Off-the-Shelf Games.

HCD Human-Centred Design.

HCI Human-Computer Interaction.

MDE Mechanics Dynamics and Emotions.

NPS Net Promoter Score.

PSD Persuasive System Design.

SUS System Usability Scale.

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Chapter 1

Introduction

According to the World Health Organisation, an "estimated 2.4 billion people currently live with a health condition that benefits from rehabilitation" (World Health Organization, 2023). This being said rehabilitation is an asset to our lives, allowing us to remain as independent as possible in carrying out tasks and activities of daily living. However, due to costs, and lack of means of transportation, among other limitations, not all people can take advantage of the benefits rehabilitation may provide (World Health Organization, 2023). Furthermore, the increase in average life expectancy, chronic diseases and a sedentary lifestyle will lead to a greater need for rehabilitation services (World Health Organization, 2023).

Telerehabilitation emerges as a promising field of rehabilitation, providing the means to address the challenges highlighted above. In this context, this branch of telemedicine arises as a complement to conventional rehabilitation, making it possible to provide rehabilitation services mediated by technology. However, even though telerehabilitation may have great potential to overcome rehabilitation problems, the success of this approach "depends on the patient's acceptance and adherence" (Cranen, Groothuis-Oudshoorn, Vollenbroek-Hutten, & IJzerman, 2017).

This dissertation investigates the issue of telerehabilitation services to identify the effective approaches to, through design, improve user engagement, resulting in adherence and continuing usage of a telerehabilitation application. The acquired knowledge will be used to redesign and evaluate a web user interface for the INPACT[1] project, within which this work will be developed.

1.1 Project background

This dissertation is being carried out as part of the INPACT project. INPACT - "Intelligent Platform for Autonomous Collaborative Telerehabilitation" research and innovation project funded by the Portugal 2020 program and European Union's structural funds. The goal of the project is to develop an innovative solution

[1] `https://www.careonics.com/inpact.html`

for monitoring in-home physiotherapy sessions, which tracks the user's performance and provides real-time feedback via an appealing and gamified interface. Feedback is generated by the system's machine learning, which recognises the user's movement and compares it to the ideal movement they should perform and provides feedback accordingly (Figure 1.1). The movement is tracked through a camera. The project started on January 2021 and since then progress has been achieved with regard to the machine learning model and the user interfaces aimed at the physiotherapists and at the person undergoing rehabilitation.

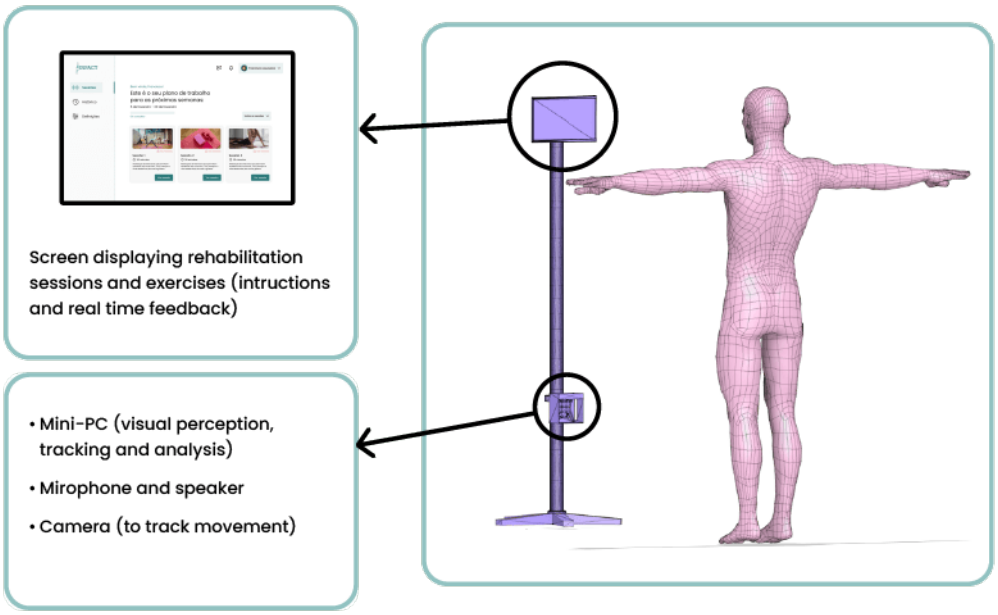

Figure 1.1: INPACT system model

The project involves the University of Coimbra and Salutec - Serviços e Equipamentos de Saúde, Lda. The team consists of a Physical Medicine and Rehabilitation physician, a physiotherapist, two designers, two research interns, and two senior researchers. The role of the author of this dissertation in the INPACT project is that of a user interface designer, whose responsibility is to redesign the user interface of the person undergoing rehabilitation that was developed in the course of the last year. In addition to the redesign, the role of the author is to create and implement a strategy for motivation and continued use of the INPACT platform. The screens of the previous user interface can be found in Appendix A.

1.2 Motivation

As previously mentioned, telerehabilitation aims to address challenges associated with traditional rehabilitation. The increased use of technology and its incorporation into people's lives allows for rehabilitation interventions to be implemented more widely, which in turn, enables the population to gain access to rehabilitation without worrying about schedules or transportation.

Telerehabilitation allows people to access and conduct their rehabilitation sessions at home, when they have time, without being bound by the physiothera-

pist's schedule and without having to travel long distances every day (Klaassen, van Beijnum, & Hermens, 2016; Spindler et al., 2019). Additionally, telerehabilitation "can facilitate access and adherence to health interventions" (Cranen et al., 2017). However, one of the current issues to be addressed is the patients' progressive loss of interest and focus. As noble as telerehabilitation intentions are, what has been done thus far, often time, is insufficient to entice people to use this tool and regard it as indispensable.

Accordingly, the motivation for this dissertation lies in leveraging user interface design to redesign the current version of the INPACT system to increase users' motivation, both to perform and while performing rehabilitation.

1.3 Objectives and contribution

Rehabilitation is commonly thought to benefit people with long-term disabilities, but it is also beneficial to anyone who has a health problem, illness, or injury that limits their ability to function normally (World Health Organization, 2023). As a result, it is critical to investigate and improve it in areas where we can contribute to making rehabilitation more engaging and persuasive through design approaches that enable it. This dissertation aims to redesign and implement an online application for telerehabilitation that, through design strategies, engages users and promotes adherence, so that they feel motivated to use the application and perform the rehabilitation sessions on a regular basis.

Our goal is then to redesign an existing user interface, develop, and evaluate a gamified system that people enjoy using and will motivate them to continue using it. The necessary steps to achieve this include: understanding the context and challenges of rehabilitation and telerehabilitation; evaluating the existing user interface with experts; analysing the evaluation results to define the necessary redesigns; creating a design strategy for continuous use; iteratively redesigning the prototype of the user interface and consequent front-end implementation; and, finally, carrying out a summative evaluation with end-users to assess the quality of the user interface developed.

The outcome of our work will contribute to the area of remote physical rehabilitation systems design. This dissertation will contribute in particular to the redesign and a strategy for continued use of the INPACT system.

1.4 Dissertation outline

This document is divided into eight chapters: Introduction, Background and Literature Review, Methodology and Work Plan, Evaluation of the Previous User Interface, Gamification Strategy Proposal, Prototype Development, User Interface Evaluation and Conclusions and Future Work.

This chapter, the **Introduction**, set the scene for the work by introducing the con-

text, motivation, objectives, contribution and methodology of the project, as well as the structure of this document.

The second chapter, **Background and Literature Review**, provides the reader with the main issues and concepts for understanding the problem of the project, as well as what has been done in this field so far.

The third chapter, **Methodology and Work Plan**, sets out the objectives, steps and phases, and the design approach used for project implementation.

The fourth chapter, **Evaluation of the Previous User Interface**, refers to the heuristic evaluation with experts done with INPACT's previous user interface and displays the new requirement list of the INPACT telerehabilitation application.

The fifth chapter, **Gamification Strategy Proposal**, presents the gamification strategy and the six steps to develop the strategy.

The sixth chapter, **Prototype Development**, shows the graphic identity of the new INPACT application, the medium and high fidelity prototypes developed and explains the implementation of the proof-of-concept.

The seventh chapter, **User Interface Evaluation**, sets the procedures and results of the new user interface evaluation and a reflection upon the results.

The eighth and final chapter, **Conclusions and Future Work**, concludes the work carried out and sets out the plan for future work.

Chapter 2

Background and Literature Review

After a general overview of the context, motivation, objectives and main stages of the work of this dissertation, this chapter provides an overview of the main concepts for the development of the dissertation. This includes a more in-depth exploration of the key aspects of rehabilitation, such as its goals and challenges. It also discusses the current benefits and challenges of telerehabilitation. Following, it is addressed digital solutions for remote physical rehabilitation, such as gamification, serious games and persuasive technology. Existing solutions that take these into account are also presented. Chapter 2 concludes with a discussion on the design and evaluation of remote physical rehabilitation systems with a view to identifying general principles for user interface design, guidelines and methods for measuring user experience and usability.

2.1 Rehabilitation and telerehabilitation

This section covers the most important aspects of rehabilitation. These include the goals, the areas of application, the process and the challenges of rehabilitation. In addition, we will discuss how telerehabilitation can help promote rehabilitation and the benefits and challenges it brings.

World Health Organization (2023) defines rehabilitation as "a set of measures that assist individuals who experience, or are likely to experience, disability to achieve and maintain optimal functioning in interaction with their environments", enabling individuals to lead the life they desire. Given the current strain on health services, online physical rehabilitation, commonly known as telerehabilitation, is becoming increasingly important in everyday life and consists of the use of information and communication technologies to provide rehabilitation services remotely (Brennan et al., 2010; Spindler et al., 2019). Telerehabilitation enables individuals to access services from a distance, in the comfort of their homes, improve access to care and information, and manage health resources (Brennan et al., 2010).

2.1.1 Key aspects of rehabilitation

Every individual is a unique being with their own characteristics and qualities. When these abilities are impaired, it can be overwhelming (Mauk, 2011). Rehabilitation is a person-centred approach that helps people to regain their qualities and independence (World Health Organization, 2023). The goal is to improve people's quality of life by giving support for their reintegration into society (European Physical and Rehabilitation Medicine Bodies Alliance, 2018).

Rehabilitation involves a range of treatments and therapies from physical, to occupational and speech therapy, cognitive rehabilitation, recreational therapy, music or art therapy and rehabilitation in hospitals, long-term care facilities and home-based (National Institute of Health, 2022). These treatments help improve and restore functional abilities, slow down the disabling effects of chronic health conditions, manage pain, or create solutions to overcome disabilities (European Physical and Rehabilitation Medicine Bodies Alliance, 2018).

As rehabilitation is a person-centred approach, the chosen treatment is unique to each individual and depends on their goals and needs (World Health Organization, 2023). Rehabilitation begins with an examination in which the therapists learn more about the patient's condition. A diagnosis of the problem is then made and finally, a treatment plan is drawn up, in which the goals for the patient's treatment are established, according to their characteristics and needs. However, the plan may change according to the progression of the disease (European Physical and Rehabilitation Medicine Bodies Alliance, 2018).

Having provided an overview of the key aspects of rehabilitation, from its goals and application areas to the overall process it involves, we next introduce the topic of telerehabilitation.

2.1.2 From rehabilitation to telerehabilitation

Although it is desirable to gain previous skills and independence, the current rehabilitation format is not able to ensure long-term motivation (Sailer, Hense, Mayr, & Mandl, 2017; Spindler et al., 2019). The repetitive nature of exercises, the failure to adopt new behaviours in their daily lives and timetable incompatibilities can influence this loss of interest. Besides, the daily commute to rehabilitation centres can be complicated for some, especially financially, in addition to the environmental impact it has on our planet (Spindler et al., 2019).

The global demand for rehabilitation is expected to increase. More interventions will be required as life expectancy rises and more people are currently living with chronic diseases such as diabetes, stroke, and cancer (World Health Organization, 2023). These health issues can affect a person's ability to function and are associated with higher levels of impairment, for which rehabilitation may be appropriate (World Health Organization, 2023). Therefore, a new and more flexible system that can reach everyone everywhere is important.

Camp (2018) states that "The rising use of technology, the increased expansion of

data networks worldwide, and the growing confidence and interest of the general population to incorporate technology into their day-to-day lives via the Internet, smartphones and wearables provide fertile ground for many rehabilitation interventions". Online physical rehabilitation practices appear as complements to the typical rehabilitation session (Cranen et al., 2017). This facilitates the delivery of physiotherapy services remotely, improves access to care and information, and allows each individual to learn to self-manage their own health (Lee, 2020).

The use of telerehabilitation, which provides remote delivery of rehabilitative services via the internet and communication technology, has increased significantly in recent years (Cranen et al., 2017). Telerehabilitation "is intended to overcome some of the obstacles of traditional rehabilitation" (Spindler et al., 2019), offering "great promise to improve access to rehabilitation care" (Camp, 2018). Nevertheless, online physical rehabilitation does not emerge as a replacement for in-person rehabilitation. There are conditions that require specific treatments or specialised equipment that can only be handled in-person (Cranen et al., 2017). However, it allows individuals to still receive treatment when they are not able to travel or meet the therapist's schedule (Spindler et al., 2019).

Cranen et al. (2017) notes that "Although telemedicine is assumed to be improving efficient allocation of resources, its actual success depends on the patients' acceptance and adherence. Therefore, future telemedicine services need to be designed with the patients' perspective in mind". As the previous statement highlights, one of the biggest challenges in both rehabilitation and telerehabilitation is to promote engagement and consequently adherence. Buckingham et al. (2022) adds other problems such as technological, due to poor internet connection and lack of technical skills or people's confidence. Additionally, people are concerned about the lack of personal interaction between them and the physiotherapist that these systems can bring (Fiani, Siddiqi, Lee, & Dhillon, 2020).

This dissertation is concerned with the problem of lack of motivation and adherence to use a telerehabilitation application. In the following, we will look at strategies to promote adherence and continued use.

2.2 Strategies to promote adherence and continued use

The increasing use and integration of technologies in our lives offer opportunities for possible rehabilitative interventions (Camp, 2018). However, approaches like telerehabilitation are no 'magic bullets' if not properly implemented (Spindler et al., 2019). There is no point in exploring and creating new systems if we do not take into account the problems with the current approaches, like the lack of adherence.

Designing systems that engage users is a common goal when designing products, systems or services (Doherty & Doherty, 2018) because if this is not done, the product will not be used. Therefore, it is crucial to understand the users we are designing for in order to achieve the desired results (Doherty & Doherty, 2018). Gamification, serious games, and persuasive technologies are strategies used to

improve user engagement and motivation (Aldenaini, Alqahtani, Orji, & Sampalli, 2020; Antunes & Madeira, 2022) which we will explore below.

2.2.1 Gamification

The term "gamification" originated in the early 2000s but has only gained popularity since the early 2010s (Sailer et al., 2017). Its main purpose is to apply game design principles to contexts that are not gaming-related in order to maximise the motivational potential that video games have (Domínguez et al., 2013). "The central idea is to take the 'building blocks' of games, and to implement these in real-world situations" (Sailer et al., 2017), being the most general definition used "“gamification” as the use of game design elements in non-game contexts." (Deterding, Dixon, Khaled, & Nacke, 2011; Domínguez et al., 2013; Sailer et al., 2017). Sailer et al. (2017) deconstruct this definition into four semantic components to better understand gamification:

1. **Game**. A game is "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2004).
2. **Elements**. Gamification involves using elements from games that are important for the purpose of the game.
3. **Design**. Gamification includes following the design process of a game, while not including the technical aspects of a game.
4. **Non-game contexts**. The term "non-game contexts" leaves room for interpretation, as this term does not indicate the context in which gamification can be used, however, refers to what can be excluded. These situations are "within the games themselves or throughout the game design process".

Having a clearer understanding of gamification, we will next look at how the use of gamification in rehabilitation can promote adherence and motivation.

Given the present obstacles of remote physical therapy in terms of adherence and motivation, gamification appears to be a promising concept for addressing these issues by "motivating specific behaviours within the gamified situation" (Sailer et al., 2017). To harness the potential of gamification, we need to understand how to use it to create a unique user experience (Robson et al., 2015). The literature provides different approaches for the creation of a gamification strategy, namely the Mechanics Dynamics and Emotions framework by Robson et al. (2015) and the Six steps to Gamification by Werbach and Hunter (2012), detailed next.

The Mechanics Dynamics and Emotions framework

For a person to use an application continuously, this use must become a "habit". To form a habit, an action must be repeated several times, and for a person to

repeat the same action several times, it must have a desirable outcome (Robson et al., 2015). By providing the person with the means to achieve the desired result, each time they use the application, they will use it more often to achieve those results again and thereby change their behaviour. In addition to creating the desired outcomes, reinforcements and emotions can also influence human behaviour (Robson et al., 2015). Gamification can produce the desired behaviour change through the formation of habits by reinforcing the reward and emotional response of the individuals participating in the experience. In other words, in order for gamification to produce the desired behaviour change through habit formation, it must reinforce the experience's reward and emotional response (Robson et al., 2015). To achieve this, Robson et al. (2015) presents the **Mechanics Dynamics and Emotions (MDE)** framework (Figure 2.1) that describes how to create gamified experiences and elicit the fundamental concepts underlying gamification: mechanics, dynamics, and emotions.

Mechanics concern the decisions that designers make to establish the objectives, rules, setting, context, types of interactions and boundaries of the gamified experience. The mechanics never change over time or between players, remaining constant throughout the experience. Setup, rule, and progression mechanics are the three types of mechanics. The components that shape the environment of the experience are referred to as setup mechanics," including the setting, what objects are needed, and how the objects are to be distributed among players". Rule mechanics concerns the actions, along with their constraints (limiting those actions), to shape the concept or goal of the gamified experience to be pursued. Progression mechanics encapsulates various instruments that designers incorporated into the user experience to reinforce it. In other words, since actions that result in positive reinforcement are more likely to be repeated, it is possible to make particular actions more likely to be repeated in the future by using the right progression mechanics. To sum up, gamification mechanics are the fundamental components of a gamified experience. They choose the main players, how they interact, how to win or lose, and the location and timing of the event.

While designers determine the mechanics, **dynamics** are created by "how players follow the mechanics chosen by the designer". These dynamics define the behaviours that occur in games as well as the strategic choices and exchanges that occur while playing. As the dynamics depend on the users' actions, it is difficult to foresee their actions and the outcomes. Designers face the challenge of foreseeing dynamics and crafting mechanics accurately for the intended experience.

Gamification **emotions** consist of the mental emotional states and behaviours that each player experiences when taking part in a gamified experience. "Emotions are a product of how players follow the mechanics and then generate dynamics". Assuming that players will stop playing if they are not having fun, the top priority of gamification in terms of player engagement should be to promote user enjoyment.

In conclusion, the Mechanics Dynamics and Emotions (MDE) framework describes how the gamification principles of mechanics, dynamics, and emotions are interrelated, demonstrating as well, how one change in one principle can affect all of them. Furthermore, it demonstrates how these concepts can be used in

combination, to develop and improve the player experience.

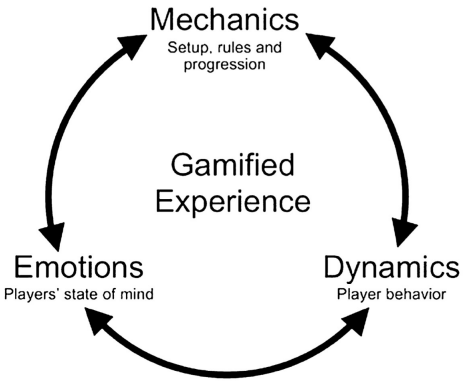

Figure 2.1: The Mechanics Dynamics and Emotions (MDE) framework from Robson et al. (2015)

Six steps to gamification

To develop a gamification strategy, we cannot start by thinking about the final elements that the user will get from performing a task or completing a series of tasks. This process requires a more careful strategy before we can determine those elements. According to Werbach and Hunter (2012) there are six essential steps to create a gamified experience, being those: (1) define, (2) delineate, (3) describe, (4) devise, (5) don't forget the fun and (6) deploy.

1. **Define** the business objectives is the first step. Werbach and Hunter (2012) state that the objectives must be as precise and clear as possible, in order to implement gamification properly.

2. The second step, **delineate** target behaviours, considers what actions users must do in the gamified product. These actions should respond to the business objectives.

3. **Describe** your players, the third phase, is where the needs of the users who will use the product have to be observed, where both motivations and demotivations need to be defined.

4. The **devise** of activity cycles is addressed in step four. Werbach and Hunter (2012) state that there are two types of activity cycles: engagement loops and progression stairs. The engagement loops describe the motivations of the player and the responses of the system to their actions (feedback). The progression stair describes the player's path and evolution through the system.

5. **Don't forget the fun** is a reflection phase, in which the team needs to look back and understand if what has been developed so far is fun.

6. The final step, **deployment** of the appropriate tools, relates to deploying the software platforms, applications, or frameworks that are best suited to implement the gamification strategy.

Six steps gamification by Werbach and Hunter (2012) provides us with a structured way of thinking and creating gamified products and will be important for the further course of the dissertation.

Game design elements

Within gamification, there are numerous game design elements that can be used. Having in mind the Mechanics Dynamics and Emotions (MDE) framework and the six steps to gamification we are aware that the use of game design elements needs to be carefully thought out, always bearing in mind the aims of the target users. The most typical game design elements are points, badges, leaderboards, performance graphs, meaningful stories, avatars and teammates (Sailer et al., 2017). Analysing and researching the motivational potential of the aforementioned game design aspects is necessary to effectively choose the desired outcome of a gamified experience. Sailer et al. (2017) accomplishes this by looking more closely at motivational studies.

Sailer et al. (2017) on their paper focuses on the **self-determination perspective**. There are other perspectives, however, a wide range of motivational mechanisms, some of which overlap with these other views, is included in the self-determination perspective. Within this theory, three fundamental psychological and essential needs are addressed: (1) the need for competence, (2) the need for autonomy and (3) the need for social relatedness.

1. "The need for competence refers to feelings of efficiency and success while interacting with the environment".
2. "The need for autonomy refers to psychological freedom and to volition to fulfil a certain task".
3. "The need for social relatedness refers to one's feelings of belonging, attachment, and care in relation to a group of significant others".

Taking these three pillars of self-determination theory into account, we can connect them to the specific game design elements presented above.

Points, performance graphs, badges, or leaderboards can all be used to satisfy the **need for competence**. Points give the gamer detailed feedback that is measurable and related to their actions. Performance charts show the player's development over time and offer consistent feedback. Badges and leaderboards evaluate a series of player behaviours and deliver continuous feedback in the process. The presence of feedback appears to be the common link in all of the elements presented above. As a result, we can conclude that it is the feedback on these game design elements that can generate feelings of competence.

Experiences of decision freedom and experiences of task meaningfulness are two components of the **need for autonomy**. Regarding the experiences of decision freedom, "avatars are relevant, as they offer the players freedom of choice". In experiences of task meaningfulness, "stories play an important role". Whether players have real choices, stories can help them feel that their own actions are important. If a story has a narrative and gives the player a significant role, this can also affect the **need for social relatedness**.

In summary, different features of gamification produce different motivational outcomes. Gamification can be an effective tool for addressing motivational problems if it is well-designed and built on proven implementation methods (Sailer et al., 2017). As a result, it is important to keep in mind both the Mechanics Dynamics and Emotions (MDE) framework and the psychological needs that each game design element satisfies, in order to create the best-gamified experience for the user.

2.2.2 Serious games

It has been proven that user functioning improves through intensive training, which is broken down into smaller tasks to achieve their end goal (Antunes & Madeira, 2022). The problem with this system is that people often get bored of doing the same rehabilitation exercise repeatedly and consequently end up leaving the treatment (Antunes & Madeira, 2022; Palazzo et al., 2016). Because of this ongoing desire to find solutions to promote engagement in physical activity, serious games have emerged as a viable solution to current rehabilitation problems (Afyouni, Einea, & Murad, 2019; Antunes & Madeira, 2022).

Serious Games are games whose primary goal is not entertainment (Afyouni et al., 2019; Antunes & Madeira, 2022). This concept's aim is to help users achieve their goals by making exercises, that would otherwise be long and tedious, more effective and interesting (Afyouni et al., 2019). To better understand the types of games that can be implemented in rehabilitation we will discuss game design features (game genre, game nature and game development strategy) and different types of serious games (Commercial Off-the-Shelf Games (COTS) and custom-designed serious games). For the following discussion, two articles are going to be analysed in greater detail as each presents a detailed review of serious game characteristics.

Game genre refers to the type or style of a game. Lu and Kharrazi (2018) states that game genre can be classified as active/rhythm, book/movie, driving, fighting, puzzle, role-playing, shooter, simple/casual interactive application, simulation, sports, strategy and trivial/quiz. The most used game genre are puzzle, casual and simulation games and the one with most successful improvements in rehabilitation are casual games (Lu & Kharrazi, 2018; Vieira, Ferreira da Silva Pais-Vieira, Novais, & Perrotta, 2021). This game shows the best results as players do not require previous game expertise, including any video game that needs the player to execute simple tasks (Lu & Kharrazi, 2018), like drag & drop and point & click (Vieira et al., 2021). Both articles, Vieira et al. (2021) and Perrotta,

Vieira, Novais, and Pais-Vieira (2020), states that point & click and drag & drop games are the most popular ones in rehabilitation. Point & click are games where the user has to move the cursor to a certain place in the game and press a button in order to trigger an action (Perrotta et al., 2020). Drag & drop is similar, but instead of pressing a button, the player simulates grabbing a virtual object and then drags it to a specific location to trigger an action (Perrotta et al., 2020).

Game nature feature also refers to the design of a game, concerning the game perspective (first or third person), game-play mode (multi or single player) and the type of scenery (realistic, fantasy-themed or simple) (Vieira et al., 2021). Vieira et al. (2021) noticed that most studies opted for single-player having only one opted for multiplayer, however, this study did not present significant clinical outcomes. The aesthetic of the game did not seem to have any link to the outcomes; the environment of two of the studies was described as simple, three described it as real and three as fantasy.

Game development strategy can be divided into Commercial Off-the-Shelf Games (COTS) and custom-made games. COTS are games designed for entertainment that can be bought and used by anyone (Alshaya & Beck, 2021), though they can be adapted to serious games; one example is Nintendo Wii games (Vieira et al., 2021). Custom-made games are created specifically for serious games with a specific goal in mind (Vieira, Perrotta, & Pais-Vieira, 2022). Perrotta et al. (2020) states that custom-made games for therapy, at this point, fail to embody the key characteristics of a playful video game. Though clinically custom-made games showed better results, patients prefer COTS as they notice more improvements when doing those games (Perrotta et al., 2020).

To conclude, both articles state that custom-made serious games are clinically better than COTS, However, more research is needed on the design side of custom-made games to make them more engaging (Perrotta et al., 2020). In addition, regarding the game genre and nature, we conclude that casual games are more appreciated and the environment of the game does not seem to have any impact on the outcome of the experience.

2.2.3 Persuasive technology

Our manner of life has become increasingly sedentary, which is a major public health concern. "A sedentary lifestyle is associated with health complications such as obesity, diabetes, cancer, and cardiovascular diseases, among other conditions" (Aldenaini et al., 2020), so it has been a major concern for persuasive technology to reduce these sedentary habits by increasing physical activity.

Persuasive technology refers to interactive computer systems that help and motivate people to change their attitudes and behaviours by raising their awareness of unhealthy behaviours (Aldenaini et al., 2020; Aldenaini, Alslaity, Sampalli, & Orji, 2023). This can be used on several technology platforms, including "social networking sites, ambient public displays, mobile phones and handheld devices, wearable gadgets, and games," (Aldenaini et al., 2023) and has been gaining traction in the health sector. This technology relies on psychological and social theo-

ries to urge people to modify their behaviour. To better understand how persuasive technology has been used to achieve these outcomes we are going to analyse Aldenaini et al. (2023) and Aldenaini et al. (2020), that provides a summary of the major technology platforms employed to design persuasive technologies.

One model created to evaluate the persuasiveness of a system is the **Persuasive System Design (PSD)** model (Oinas-Kukkonen & Harjumaa, 2009). This model is built on previous frameworks and theoretical constructs such as Ajzen's theory of reasoned planned behaviour, Locke and Latham's goal-setting theory, and the elaboration likelihood model (Petty & Cacioppo). According to the research, the PSD model provides an appropriate framework for investigating, designing, and assessing the persuasion context and its associated methods (Aldenaini et al., 2023).

Both articles observed that the five most effective persuasive strategies implemented in persuasive technology were tracking/self-monitoring, reminders, penalisation, goal-setting and rewards. Although not among the top five praise strategies, tailoring, reduction, tunnelling, social competition, suggestion and social cooperation were also effective. According to Aldenaini et al. (2020), the high ranking of tracking/self-monitoring and reminders strategy indicates that a simple reminder to do exercise, or to get up, if they have been sitting for too long, could drive people to boost their physical activity. This is understandable because people nowadays are usually busy, so even if they had planned to exercise that day, they are likely to forget, making a simple reminder a great way to persuade individuals to get moving.

Another important aspect that seemed to motivate users in doing physical activity was to give accurate feedback, especially feedback using sensors and activity trackers and monitors. These devices were the most dominant technologies employed in the reviewed studies. Other successful implementations of persuasive technology identified in the research included mobile and handheld devices, games, as well as websites and social networking sites. Because of their pervasiveness, these technologies appear to be appealing and promising for delivering therapy (Aldenaini et al., 2020).

Overall, both publications indicated that the trials were successful, proving that persuasive technology can enhance physical activity while decreasing sedentary behaviour. When combined with the appropriate persuasive method, the use of persuasive technology has the potential to achieve desired behaviour change.

2.3 Existing solutions for physical telerehabilitation

After providing a contextualisation of key aspects of rehabilitation and having introduced specific strategies to promote adherence and continued use, existing online rehabilitation solutions will be introduced. In what follows we will discuss four existing solutions. We have considered two factors in our selection. First, whether they offer physical rehabilitation programmes, which is a mandatory criterion, and second, whether they incorporate gamification and/or serious

games, which is not a mandatory criterion. Thereafter we will examine each of these solutions. We pay particular attention to the technology used, whether or not it includes gamification or serious games, as well as user-relevant features, such as if it allows communication with the physiotherapist.

2.3.1 Clynx

Clynx is a Portuguese startup with a digital health solution called **Motiphy+**. The application assists patients in recovering from musculoskeletal injuries by implementing video games into their systems [1]. This technology enables patients to do rehabilitation at home or in a gym, and it can be used in conjunction with face-to-face sessions, weakly [2].

The user's movements are tracked by a camera, which allows users to work without having to wear any extra equipment on their bodies to receive feedback (Figure 2.2). The camera's motion tracking can detect where the person's body and articulations are, detecting posture errors while playing the game [2].

The Motiphy + physiotherapy exercises are based on serious games. The serious game scenarios present environments and situations that could represent our everyday actions, such as painting a canvas or exercising in a gym, but also more unrealistic scenarios, such as driving a trolley through a mine.

Figure 2.2: Patient using Motiphy+ (Clynx, 2023)

2.3.2 Kaia Health

Kaia Health is a back pain and chronic obstructive pulmonary disease digital therapy application. Everyone can use the digital application to access these therapies whenever and wherever they want.

The application technology, combined with computer vision technology, allows users to do the exercises and receive feedback, using solely their mobile phones

[1] https://www.dinheirovivo.pt/fazedores/clynx-videojogos-portugueses-levam-fisioterapia-ainda-mais-a-serio-14397101.html

[2] https://www.clynx.io/

(Figure 2.3). People do not need to use a camera or any sensor on their body for the programme to accurately track their movements. Not only does the application not require any additional equipment, as it also does not need to be connected to the internet to work [3]. This technology can control people's movements, ensure correct movements and measure progress in mobility [3].

In addition, Kaia introduces gamification features. The warm-up training includes the use of gamification. People can earn points in these training sessions by hitting certain points on the screen [4]. Besides, this application allows the user to communicate with the physiotherapist through video calls [4].

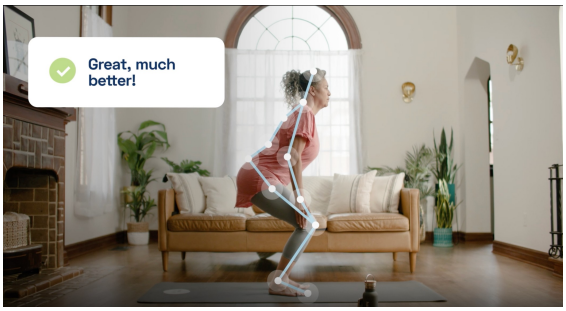

Figure 2.3: Body movement tracker with feedback (Kaia Health, 2023)

2.3.3 Sword Health

Sword Health, a Porto-based startup, has created the first digital physiotherapy system that combines artificial intelligence and clinical teams [5]. This system assists patients in recovering from musculoskeletal injuries. This solution can provide patients with real-time feedback (Figure 2.4) on their performance through the use of advanced sensors and artificial technology [6]. The difference from the previous solutions is that these sensors must be in the person's body to detect his/her movement (Figure 2.5).

In addition, the system allows the patients to communicate with their physiotherapist on average three times a week. Besides, SWORD has a 24-hour text-based support chat for their patients [6].

2.3.4 Omada

Omada is a company specialised in virtual care, being **"Omada Joint & Muscle Health"** one of their applications. This application was designed to treat musculoskeletal care, through personalised treatment plans taking into consideration each member's diagnosis [7].

[3] https://kaiahealth.com/technology/
[4] https://kaiahealth.com/
[5] https://scaleupporto.pt/sword-health-doubles-series-a-8-6-million-new-round/
[6] https://swordhealth.com/solutions/digital-therapy
[7] https://www.omadahealth.com/musculoskeletal

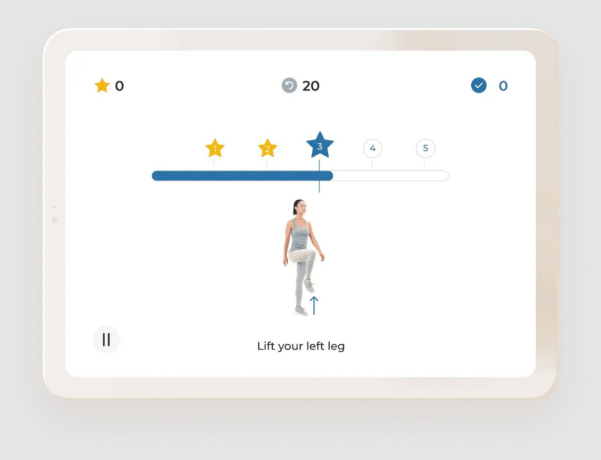

Figure 2.4: Sword user interface (Sword, 2023)

Figure 2.5: Sword body sensors (Sword, 2023)

Like Kaia Health and Mortiphy +, Omada uses computer vision technology to capture and measure the range of motion and track a person's progress. The application includes 3D animations of the workout exercises so members understand what they need to do. Members can also communicate with their physiotherapist at any time via video call or chat through the application[7] (Figure 2.6).

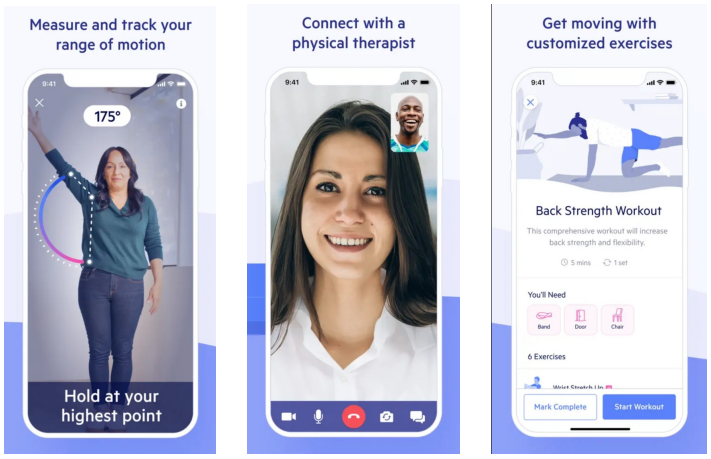

Figure 2.6: Omada user interface (Omada Joint & Muscle Health, 2023)

Further research is needed on the implementation of telerehabilitation and ways to promote adherence and continued use (Spindler et al., 2019). Nonetheless, four solutions are presented above that combine a number of features and functions that seem important to address. All solutions allow patients to talk to their physiotherapists via chat and/or video call. This is important because one of the concerns of patients is the lack of a relationship between them and the physiotherapist (Fiani et al., 2020). However, apps like Kaia and Omada Health are limited to people who own a smartphone. Additionally, the use of gamification is rare, which is considered a limitation. However, Motiphy + uses serious games to perform the rehabilitation exercises. On a technological level, INPACT's system will be similar to Motiphy +, as INPACT system will use a camera to track people's movements in real-time. The solution we aim to develop will also leverage gamification principles with a view to promoting continued use, as will be discussed further in this dissertation.

2.4 Design and evaluation of systems for remote physical rehabilitation

Understanding how to analyse, develop and evaluate systems for remote physical rehabilitation is essential if we are to develop appropriate solutions for this purpose (Klaassen et al., 2016). This section provides an overview of how these can be addressed in the development cycle, with a particular focus on user interface evaluation, as this is a central theme of this dissertation.

2.4.1 User interface design principles and guidelines

Design principles are statements that define the goals of a product. In this way, they help designers to make good design and consistent decisions in projects (Rosala, 2020). Design guidelines, in this context, are instructions that designers use to apply a set of principles to a product in order to improve its design (Interaction Design Foundation, 2023a). There are several design principles and guidelines (e.g. Nielsen's 10 heuristics (Nielsen, 1994a), Norman's design principles (Norman, 2013) and Shneiderman's eight golden rules (Shneiderman et al., 2016)). For this reason, it is crucial for a designer to keep the fundamental principles of design in mind. Pioneers in this field, such as Nielsen and Schneiderman, established a set of basic design principles that have had a significant impact on the design world. To summarise, these principles state that design must: provide clear feedback, and keep the user informed; be consistent, clear, and minimalist, avoiding unnecessary information; be simple to understand; anticipate errors that users may make; be intuitive so that users do not have to memorise actions; and be precise and objective in their language (Nielsen, 1994a; Shneiderman et al., 2016).

There are also frameworks for developing and evaluating persuasive technologies. Oinas-Kukkonen and Harjumaa (2009) proposed the **Persuasive System Design (PSD)** model, which provides an approach for investigating, designing, and assessing the persuasion context and its associated methods (Aldenaini et al., 2023). The PSD model divides persuasive technology aspects into four major categories: primary task support, dialogue support, system credibility support and social support (Oinas-Kukkonen & Harjumaa, 2009). The strategies in the **primary task support** category assist users in carrying out their primary behaviour modification task and include: reduction, tunneling, tailoring, personalisation, self-monitoring, simulation and rehearsal (Oinas-Kukkonen & Harjumaa, 2009). The **dialogue support** category comprises ways for using computer-human dialogue to encourage users to keep working and progressing toward their target behaviour or intended goal. These principles include: praise, rewards, reminders, suggestion, similarity, liking and social role (Oinas-Kukkonen & Harjumaa, 2009). The **system credibility support** category encompasses tactics used in the design of persuasive technological systems to increase their credibility and persuasiveness and include: trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements, and verifiability (Oinas-Kukkonen & Harjumaa, 2009). The **social support** category comprises tactics that employ social influence to motivate people to perform the desired behaviour. Social learning, social comparison, normative influence, social facilitation, cooperation, competitiveness, and recognition are all examples of social support tactics. This set of principles includes: social learning, social comparison, normative influence, social facilitation, cooperation, competition and recognition. A complete list of these principles and their definitions can be found in Appendix B

There are also principles to keep in mind when designing a game. Again, this field of **game design principles** is very vast, but there is a particularly interesting article that presents a collection of principles from different authors (Herne et al., 2020). The authors of this article believe that keeping game design principles

in mind when designing serious games helps to create games that are more engaging. Herne et al. (2020) conducted a study to better understand which game design principles would lead to a better outcome in terms of engagement. They concluded that the principles that need to be addressed further in the future are awareness, feedback, interactivity, flow and challenge. The full list of game design principles by Herne et al. (2020) can be seen in Appendix C.

Having provided an overview of possible design principles to consider when designing a gamified solution for telerehabilitation, the next section will focus on evaluation.

2.4.2 Measuring usability and user experience

The large field of usability evaluation already provides a number of ways for performing user interface evaluation, however, not all are appropriate for all systems (Silva, Jordan, & Holden, 2014). Before delving into the methods used to evaluate systems we first need to clarify what usability and user experience mean.

According to ISO/IEC 9126-1: 2000, **usability** is defined as "the capability of the software or product to be understood, learned, used and attractive to the user, when used under specified conditions" (Hassan & Galal-Edeen, 2017) and usability measures how simple it is to use user interfaces (Vermeeren et al., 2010), and the following five qualities describe usability: **learnability** ("How easy is it for users to accomplish basic tasks the first time they encounter the design?" (Nielsen, 2012)); **efficiency** ("Once users have learned the design, how quickly can they perform tasks?" (Nielsen, 2012)); **memorability** ("When users return to the design after a period of not using it, how easily can they reestablish proficiency?" (Nielsen, 2012)); **errors** ("How many errors do users make, how severe are these errors, and how easily can they recover from the errors?" (Nielsen, 2012)); and **satisfaction** ("How pleasant is it to use the design?" (Nielsen, 2012))(Durães Dourado & Canedo, 2018; Nielsen, 2012).

ISO 9241-110:2010 (clause 2.15) defines **user experience** as "a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service" (Hassan & Galal-Edeen, 2017; Vermeeren et al., 2010). User experience refers to how the user feels about the product as a whole. It takes into account the whole process of interacting with the product, as well as what happens before and after interaction (Vermeeren et al., 2010).

Usability is more concerned with task performance, being more objective, whereas user experience is more concerned with the lived experience while using the product (Vermeeren et al., 2010). There are numerous approaches for measuring a system's usability and user experience (McNamara & Kirakowski, 2006). Before delving into the specifics of each, we must consider the different types of evaluation. First, it is important to consider that evaluations can be done by experts (or professionals in the field), (e.g. through a heuristic evaluation or cognitive walkthrough (Silva et al., 2014)), or with users, (e.g. through usability testing (Silva et al., 2014)). In this work, both these types of evaluation will be employed, the first to review the current version of the existing system and identify areas of the

interface in need of improvement and the other, that, once finalised the redesign, will involve end-users.

Evaluation can also be formative or summative. **Formative evaluation** refers to the ongoing iterative evaluation that occurs during product development. The purpose of this type of evaluation is to identify issues with the current iteration of the product (Joyce, 2019; Tullis & Albert, 2013). **Summative evaluation**, on the other hand, is limited to the finished product. The purpose of this evaluation is to assess the overall experience of a completed product (Joyce, 2019; Tullis & Albert, 2013). The methods used in formative assessment are mainly qualitative, and in summative evaluation, quantitative (Joyce, 2019). However there are exceptions, and quantitative methods can be used in a formative evaluation (Joyce, 2019). In the context of this work, both formative and summative evaluations will be conducted for the development of the project. Formative evaluation will take place during the iterative and incremental design phases of the prototype and the summative evaluation will be carried out with the implemented version of the application.

The methods used to evaluate the system can also be classified as qualitative, quantitative and heuristics evaluation (Maramba, Chatterjee, & Newman, 2019). **Qualitative methods** deal with the data of a system that cannot be quantified, such as emotions, feelings and opinions (e.g. through a think-aloud protocol, interviews and focus groups) (Budiu, 2017; Maramba et al., 2019). Qualitative methods are usually used to measure user experience. **Quantitative methods** collects and analyses numerical data, providing objective methods to measure the usability of a product (e.g. task completion rates, task times or success rates) (Budiu, 2017; Maramba et al., 2019). Even though quantitative methods are usually used to measure usability, and qualitative methods to measure user experience, both methods can be used to measure usability and user experience. The quantitative methods will be used in the summative evaluation, which will be carried out when the application is implemented.

The field of usability and user evaluation is vast and there is a wealth of methods that can be applied to assess them. Listing these methods is beyond the scope of this work, still, the next section introduces the methods which will be used in this work and its main aspects.

2.4.3 Heuristic evaluation

This article describes a survey that we undertook to investigate whether professionals would be able to recognise serious interface problems in simple but realistic dialogues.

Molich and Nielsen (1990) published an article that investigates whether professionals in the field would be able to recognise serious interface problems through the use of a set of principles (the heuristics). Heuristic evaluation is a method of usability engineering in which more than one expert evaluates a product according to a set of principles with the aim of identifying problems in a user interface. There is no set procedure for conducting a heuristic evaluation, although it is

recommended that the evaluator walks through the user interface at least twice (Nielsen, 1994b). The first time to get a feel for the overall flow of the application, so that the second time the evaluator can focus on individual parts of the interface (Nielsen, 1994b). Before starting the evaluation, a list of principles for performing the evaluation must be given. The final result of the evaluation is a list of design problems with references to the violated heuristic principles. Each problem is listed individually (Nielsen, 1994b). At the end, a briefing session may take place. In these sessions, the experts discuss the problems found and give design advice (Nielsen, 1994b).

The set of principles, created by Nielsen, is commonly known as Nielsen's heuristics (Nielsen, 1994a). The principles are as follows:

1. **Visibility of system status**: "The design should always keep users informed about what is going on, through appropriate feedback (e.g. textual, visual, or through sound or music) within a reasonable amount of time".

2. **Match between system and the real world**: "The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon. Follow real-world conventions, making information appear in a natural and logical order".

3. **User control and freedom**: "Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process".

4. **Consistency and standards**: "Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions".

5. **Error prevention**: "Good error messages are important, but the best designs carefully prevent problems from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action".

6. **Recognition rather than recall**: "Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design (e.g. field labels or menu items) should be visible or easily retrievable when needed".

7. **Flexibility and efficiency of use**: "Shortcuts, hidden from novice users, may speed up the interaction for the expert user such that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions".

8. **Aesthetic and minimalist design**: "Interfaces should not contain information that is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility".

9. **Help users recognize, diagnose, and recover from errors**: "Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution".

10. **Help and documentation**: "It's best if the system does not need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks".

2.4.4 Usability and user experience testing

Usability and user experience testing is an effective way of identifying user interface issues from the standpoint of the intended audience. This technique is used to evaluate user interfaces that require end-users to do a sequence of specified tasks in a given product, allowing the evaluator to monitor the user's real behaviour while performing the tasks (Silva et al., 2014). According to Tullis and Albert (2013), different types of metrics allow us to measure usability and user experience: performance metrics, issued-based metrics, self-reported metrics and behaviour and psychological metrics. Although all metrics are important, the performance metrics and self-reported metrics will be discussed in more detail, as they are the most commonly used metrics in the evaluation of rehabilitation systems, as analysed by Maramba et al. (2019) and Klaassen et al. (2016). The following information is taken from Tullis and Albert (2013).

Performance metrics

Performance metrics are used to evaluate the usability of a product. These metrics are collected based on user's behaviour and tend to be more objective. There are five different types of performance measures: (1) task success, (2) time on a task, (3) errors, (4) efficiency and (5) learnability.

Task success can be measured as long as the user has a task to complete. To measure the success of a task, each task needs to be defined and have a clear goal and definition of what is the task's "success". The most simple way to measure success is by using binary success. To use this metric, the user needs to perform the task, if he/she succeeds scores 1, and if he/she fails scores 0. When there are reasonable shades of grey associated with task completion we can identify levels of success. This method is very similar to binary success, but in this case, the various levels of success must be defined. There are typically three to six levels of success, the most common approach has three levels: complete success, partial success, and complete failure. To get this information, we just need to define what we mean by "complete success" and "complete failure"; everything in between is considered a partial success. To distinguish between these experiences we can use a four-point scoring method for each task: 1 - no problem, when the user completes the task without any problem; 2 - minor problem, when the user completes the task but encountered a minor problem; 3 - major problem, when the user completes the task but encounters major problems; and 4 - failure/gave up, when the user provides the wrong answer or gives up.

The **time it takes the user to complete a task** is a way of measuring the efficiency of a product. The faster a user completes a task, the better the experience usually is. To measure it, if there is a moderator he can use a device that can measure time from the moment the user starts till he ends the task. Then we need to define when to turn on and off the clock.

Errors are actions performed incorrectly that can lead to the failure of a task. It is useful to identify errors to determine which action(s) caused the participant to fail a task. However, even if the user completes a task successfully, they may make mistakes along the way that must be identified. Another factor to consider is whether a task offers single or multiple error opportunities. To measure error data we must provide the number of errors for each task. If there is only one possibility for an error, in a task, the number is 1 (one error) or 0 (no error).

Efficiency can be measured in numerous ways. One of them is by counting the actions a user has taken in performing each task, with more actions taken indicating greater effort. There are two types of effort: cognitive and physical. Finding the correct area to conduct an action, selecting what action is required, and evaluating the outcomes of the activity all require cognitive effort. The physical activity required to perform an action is referred to as physical effort. Therefore, in order to get the best results from efficiency metrics, we must consider the amount of cognitive and physical effort involved, in addition to the time spent on a task. To measure efficiency, we must first identify the action(s) to be measured. Define the start and end of an action, count the actions and have into consideration that actions must be meaningful. After clearly defining the actions, counting them is simple. For simple products, it can be done manually by counting page views or button pushes. For more complex ones, an automated data collection technique is preferable, as there may be multiple actions occurring.

Learnability concerns the ease with which something can be learned. It can be measured by examining how much time and effort it takes to become competent, and eventually expert, in using something. The amount of time and effort required to achieve this level of competence is an important factor to consider. The process of learning can take place in either a short (minutes, hours or days) or long (weeks, months, or years) period of time. Measuring learnability entails collecting data many times, with each occurrence of data collection serving as a trial. The most common way to measure learnability is through efficiency, this is because the more you learn the more efficient you become.

Self-reported and postsession metrics

User experience, as mentioned earlier, focus on measuring the emotions and feelings a person experiences while interacting with a product. The experience could be assessed by analysing the user as they perform the tasks, by measuring their heartbeat or by observing how their pupils change. Although this would be ideal, we cannot always evaluate this information. So we have to find other ways to measure the user experience. One solution is to ask the user directly how their experience was. Self-reported metrics and postsession metrics make this possible.

Self-reported metrics encompass the feelings and emotions users experienced while using the product. For this, there are different types of questions we can form, such as rating scales, lists of attributes and open-ended questions.

Regarding **rating scales**, the two most common types are the likert scale and the semantic differential scale. Likert scales consist of a statement with a rating scale to which each user responds by indicating their level of agreement. The level of agreement is usually classified using a five-point scale such as the following: 1. Strongly disagree; 2. Disagree; 3. Neither agree nor disagree; 4. Agree; 5. Strongly agree. Semantic differential scales are characterised by presenting pairs of opposite adjectives at the extremities of a scale (e.g. ugly/beautiful and weak/strong), with a seven-point scale between the adjectives.

Post-task ratings allow us to understand where the user may have encountered a problem. Some techniques used to collect this data are ease of use, after-scenario questionnaire and expectation measure. Ease of use asks participants to rate how easy or difficult each task was by using a five, or seven, point scale. The after-scenario questionnaire is composed of three statements, regarding how satisfied the user felt regarding the ease, time spent and support information given when completing a task. Each of these sentences is accompanied by a seven-point rating scale of “Strongly Disagree” to “Strongly Agree”. The expectation measure is concerned with the difficulty of the task taking into consideration how the user thought it would be ("expectation rating") versus how it actually was ("experience rating"). These assessments use a seven-point rating scale, where 1 is very difficult and 7 is very easy. **Postsession ratings** allow us to measure the user experience of the entire product. There are standard techniques that aggregate individual task ratings; System Usability Scale (SUS); Computer System Usability Questionnaire (CSUQ); questionnaire for user interface satisfaction; usefulness, satisfaction, and ease-of-use questionnaire; product reaction cards; and net promoter score. Following we will look in more detail at SUS because is the most used technique in rehabilitation evaluations, according to Maramba et al. (2019) and Klaassen et al. (2016). The System Usability Scale, developed by John Brooke, is composed of 10 statements (half positive and half negative), each having associated a rate from 1 to 5, being 1 "strongly disagree" and 5 "strongly agree", as shown in Appendix D.

Besides the rating scales presented above, most studies include **open-ended questions**. One frequent strategy is to allow the user to submit comments to any of the individual rating scales. Another typical open-ended question is to ask users to mention three to five things they appreciate best and three to five things they dislike the most about the product.

2.5 Summary of the chapter

This chapter covered the key background subjects of this dissertation. The topic of rehabilitation and telerehabilitation was covered, addressing the main aspects and challenges. Strategies to promote adherence and continued use were also covered, addressing topics such as gamification, serious games and persuasive

technology, as well as existing solutions for remote physical rehabilitation. Finally, this chapter also addresses the design and evaluation of systems for remote physical rehabilitation, which reviews design principles and guidelines as well as ways to measure usability and user experience, with a particular focus on heuristic evaluation. The following chapter addresses the methodology and work plan of the dissertation.

Chapter 3

Methodology and Work Plan

The goal of this dissertation is to redesign an existing user interface, the INPACT user interface for people underdoing physiotherapy. The redesign includes the graphical rearrangement of the current user interface screens, as well as the inclusion of gamification to make the application as engaging as possible. Another important aspect of the dissertation is the formative and summative evaluations and the intention to conduct the evaluations with experts in the field and end-users. This chapter presents the methodology and the work plan set out for the development of the work.

3.1 Human-Centred Design

With the rise of digital products and their increasing presence in our daily lives, there is a growing need to create products and services which foster user satisfaction and ease of use. With this in mind, we chose to follow a Human-Centred Design (HCD) approach to guide this research as this is a methodology that primarily reflects the needs of the user.

HCD is an iterative and incremental design and development approach that places users at the centre of product development and incorporates them in each phase of the design process (Abras, Maloney-Krichmar, & Preece, 2004). The designer's responsibility is to ensure that the user can use the product as intended and with minimal effort to learn how to use it (Abras et al., 2004). A HCD methodology has four crucial phases: understanding the context, the definition of the user requirements, design of solutions, and the evaluation phase (Figure 3.1) (Bevan & Curson, 1999). Since this process is iterative, the team repeats these phases until the desired product is developed and meets the user requirements initially defined.

In this dissertation, a greater emphasis is placed on the third and fourth phases, as the outputs of the project are the redesign and the evaluation of the final proof-of-concept. The reason for this is that many of the critical tasks of the first and second phases have already been carried out by the INPACT project team.

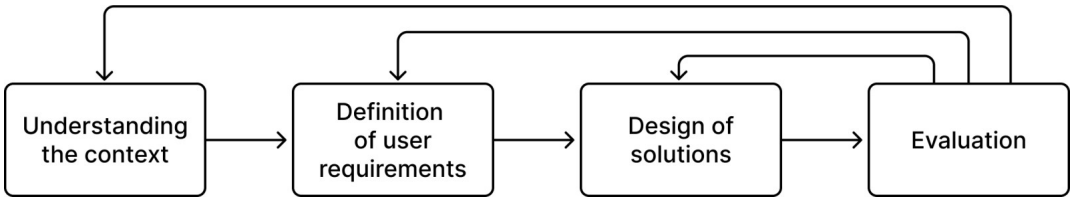

Figure 3.1: Human-Centred Design (HCD) process (adapted from Interaction Design Foundation (2023b))

3.2 Participants and ethical considerations

As we follow a Human-Centred Design (HCD) process, users play an essential role in the development of the project, being their inclusion in all phases of design important. INPACT is an ongoing project that had already started before the beginning of this dissertation. Thus, important matters such as the recruitment of people, the definition of the techniques to use and the ethical approval (CE-UBI-Pj-2020-070:ID2177) have already been established and granted. For this project, this means that ethical considerations are observed at all times, namely through gathering informed consent statements whenever the user is involved. The participants are also free to abandon the study at any stage, shall they desire to do so.

In this project, two types of participants are involved: experts and end-users. For the expert evaluation, the recruitment of evaluators was based on the personal networks of the members of the project. Recruitment of end-users is done in cooperation with the clinics working alongside the project and outside volunteers. Being aware of the fragility of depending on outside participants to complete the tasks, for this dissertation, the necessary precautions, however, have already been taken.

3.3 Research phases

The first step in the research phase of the project was to understand the context and problems of rehabilitation and telerehabilitation. One of the problems addressed was the lack of motivation and adherence to treatment. In light of the concepts discussed in chapter 2 and as a result of a discussion held among the project team, it was determined that gamification is the ideal strategy to address these issues.

In the second phase, we looked at what had already been done for the previous INPACT user interface. An expert evaluation was conducted to better understand the problems with the current user interface. Once the evaluations were completed, the results were analysed and the problems that needed to be fixed were identified.

The design and development phases follow. The first step was to define a strategy for continued use, which included integrating gamification into the new design.

This was followed by an iterative phase in which the medium and high-fidelity prototype of the new interface was designed. Once the prototype was approved, the development process began.

Once the front-end development of the user interface was complete, the summative evaluation phase followed. This evaluation was conducted with end-users from the clinics collaborating on the project and external volunteers. The collected data were analysed at the end of the evaluations. With the analysis of the results we identified problems and what needed to be changed in the next iteration.

3.4 Work plan

This section presents the work plan (Figure 3.2) for the entire dissertation. The work started in September and ended in July. The work plan includes five main tasks:

1. Literature review and understanding of the current state of the art
2. Evaluation of the previous telerehabilitation user interface
3. Redesign of the previous telerehabilitation user interface
4. Summative evaluation of the interface proposal with end-users
5. Writing and presentation of dissertation

Researching and gathering information as well as selecting and analysing documents for the dissertation is part of the **literature review and understanding of the current state of the art**. In addition, the identification of similar existing telerehabilitation solutions is also considered.

The task regarding the **evaluation of the previous telerehabilitation user interface** considers the aspects of conducting an expert evaluation. This concerns the identification of heuristic principles, the definition of evaluation procedures and the recruitment of evaluators. An examination of the evaluation results is also included.

The design and implementation of the user interface prototype are covered in the **redesign of the previous telerehabilitation user interface**. This involves defining a strategy for continued use that incorporates elements of gamification. This task also includes brainstorming new design ideas and an iterative prototyping process, in Figma[1], a software for creating interactive prototypes, of the new user interface. Finally, it includes the development of the front-end of the new user interface in React.js[2], a JavaScript framework for creating component-based user interfaces.

[1] `https://www.figma.com/about/`
[2] `https://legacy.reactjs.org/`

The **summative evaluation of the interface proposal with end-users** entails the development of the evaluation procedures, recruitment of participants and conducting the evaluation with the selected users. It also includes an analysis of the data gathered during the evaluation.

At last, the **writing and presentation of dissertation** involves, as the name implies, the writing of the dissertation chapters and the preparation for the intermediate and final defence.

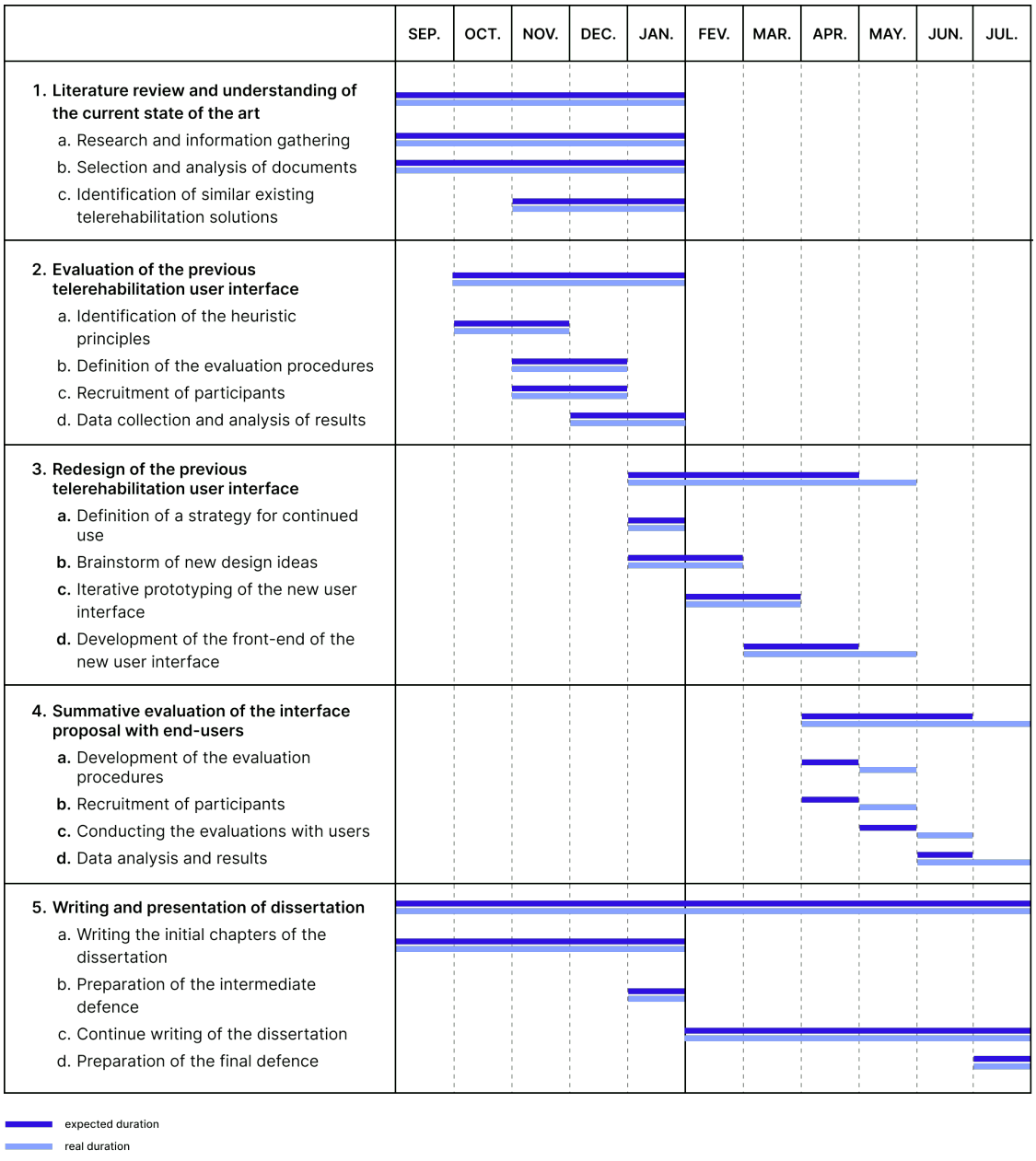

Figure 3.2: Work plan for the dissertation

3.4.1 Revised Plan

Figure 3.2 shows that the plan could not be carried out as originally planned. As the legend of the figure shows, the darker blue represents the expected duration

and the light blue the real duration. The delay occurred because, at the beginning of the development phase, we had trouble accessing the previously developed code for the previous user interface. We had to restart this work from scratch because the recovery process was taking too long. In addition, the author of the dissertation had an extra required subject in the second semester, so adjustments had to be made. This caused a delay in the application's implementation, which caused the remaining tasks to be delayed as well. In addition, the summative assessment was also delayed due to the contact with the clinics taking longer than expected.

3.5 Summary of the chapter

This chapter presented and explained the methodology to be followed in the project, which will follow a Human-Centred Design approach. It also discussed the participants and ethical considerations for recruiting them. In addition, the chapter discussed the research phases and the work plan of the project. In the following chapter, we will see what has already been done on the practical level of the dissertation.

Chapter 4

Evaluation of the Previous User Interface

The goal of this dissertation is to redesign an existing telerehabilitation application to improve the user experience and engagement, which in turn will lead to improved adherence and continued use. To achieve this goal, a number of actions need to be taken prior to the redesign, such as evaluating the previous user interface and defining a strategy for continued use.

First, we evaluated the previous user interface. The plan was to evaluate the interface to determine what needed to be redesigned before implementing the gamification strategy. The previous version of the INPACT system can be found at: https://inpact.vercel.app/. Below we present the procedure used for the evaluation, the results of the user interface and heuristic list evaluation, and the conclusions drawn after analysing the results. Images showing the previous state of the interface are shown below (subsection 4.1.4).

4.1 Heuristic evaluation

For the evaluation of the previous user interface, it was decided to conduct a heuristic evaluation with four evaluators.

Heuristic evaluation is an inspection method used to find usability problems in an interface (Molich & Nielsen, 1990). This method was developed by Jakob Nielsen and Rolf Molich. A heuristic evaluation of a user interface requires the participation of more than one expert. This is because a single person, no matter how good, cannot identify all the problems (Nielsen, 1994b). Each evaluator should inspect the user interface on their own and go through the interface at least twice during the evaluation. The first time is to get a feel for the overall flow of the application (preliminary evaluation), so that the second time the evaluator can focus on individual parts of the interface (in-depth evaluation).

For this evaluation, because we have not been able to locate a set of heuristics that could apply to the specific context of gamified telerehabilitation applications, the

heuristic principles were first identified, as we describe in the next section. Then the evaluation procedure was written. This described how the evaluators should proceed with the assessment, including the heuristics identified, the key screens to look out for in order not to get lost, and the presentation of the evaluation report in which the evaluators must report any problems encountered.

4.1.1 Identification of the heuristic principles

To identify the heuristic principles to guide the heuristic evaluation, 14 articles were reviewed. When searching for articles, care was taken to ensure that they related to telemedicine applications, involved physical rehabilitation or included serious games or gamification. In reviewing the articles, we noticed that most used Nielsen's heuristics (8 articles), either alone or in combination with other principles. For this reason, we added the original list of Nielsen's principles to our set of heuristics.

As we are developing an application with game design elements that should be compelling and engaging, the need arose to look beyond general user interface design principles and identify other principles that assessed these specific elements. In our search for principles to promote engagement and adherence that can be applied to technology-mediated health systems, we came across the Persuasive System Design (PSD) and the game design principles, already covered in subsection 2.4.1. After examining both these sets of principles, we concluded that some principles did not fit the project requirements and that others were overlapping between the two groups. As a result, some principles were combined, others were eliminated and some were adjusted to better fit the goals of the INPACT project. The final list of principles contains 33 heuristics:

- H1 - Visibility of the system status
- H2 - Match between the system and the real world
- H3 - User control and freedom
- H4 - Consistency and standards
- H5 - Error prevention
- H6 - recognition rather than recall
- H7 - Flexibility and efficiency of use
- H8 - Recognition rather than recall
- H9 - Help users recognize, diagnose, and recover from errors
- H10 - help and documentation
- H11 - reduction
- H12 - Tunneling

- H13 - Tailoring
- H14 - Personalization
- H15 - Self-monitoring
- H16 - Simulation
- H17 - Rehearsal
- H18 - Praise
- H19 - Rewards
- H20 - Reminders
- H21 - Suggestion
- H22 - Similarity
- H23 - Social role
- H24 - Trustworthiness
- H25 - Social learning
- H26 - Social comparison
- H27 - Normative influence
- H28 - Social facilitation
- H29 - Cooperation
- H30 - Recognition
- H31 - Novelty
- H32 - Story
- H33 - Ambient Sounds and Music

A detailed definition of each heuristic can be found in Appendix E. The definitions are taken almost entirely gathered from Nielsen (1994a), Oinas-Kukkonen and Harjumaa (2009) and Herne et al. (2020).

The deleted and combined principles from the PSD model, the game design principles and Nielsen's heuristics are presented below with the corresponding justifications (Table 4.1 and Table 4.2).

From the Persuasive System Design (PSD) model:

Principle Name	**Removed /Combined**	**Justification**
Liking	Removed	Already covered in H8 (Aesthetic and minimalist design)
Expertise	Combined	Combined with H24 (Trustworthiness)
Surface Credibility	Combined	Combined with H8 (Aesthetic and minimalist design)
Real-world feel	Combined	Combined with H10 (Help and documentation)
Authority		
Third-party endorsements	Removed	Does not fit into the theme of the application
Verifiability		
Social learning	-	These principles refer to the interaction between users. Since this will not be the case in our application, we have changed them to an interaction between the user and the physiotherapist.
Social comparison		
Normative influence		
Social facilitation		
Competition	Removed	This could be bad in the context of the topic of rehabilitation, as it could lead to comparisons and resulting injuries.

Table 4.1: Heuristic principles: Persuasive System Design removed and combined principles

From the game design principles:

Principle Name	**Removed /Combined**	**Justification**
Arousal	Removed	It will not be implemented. It has more to do with games than with persuasion.
Attention	Combined	Combined with H13 (Tailoring)
Interest		
Immersion	Removed	It has more to do with games. It is out of scope.
Involvement	Combined	Combined with H32 (Story)
Presence	Removed	It has more to do with games. It is out of scope.
Psychological Absorption		
Motivation	Removed	Too wide and it is already captured in the remaining principles
Effort	Removed	Already covered in other principles: H15 (Self-monitoring), H16 (Simulation), H17 (Rehearsal), H18 (Praise), H19 (Rewards) and H20 (Reminders)
Delight	Removed	Already covered by "liking" from Persuasive System Design model
Enjoyment	Removed	Already covered by H12 (Tunneling)
Coolness	Combined	Combined with H14 (Personalization)
Awareness	Removed	Already covered by H1 (Visibility of system status)
Feedback	Removed	Similar to H15 (Self-monitoring), H1 (Visibility of system status), H25 (Social learning), H26 (Social comparison), H27 (Normative influence) and H28 (Social facilitation)
Clear Instructions	Combined	Combined with H3 (User control and freedom)
Improvisation	Removed	Out of scope
Usability	Removed	Too wide and already captured in Nielsen's principles

Principle Name	**Removed /Combined**	**Justification**
Interactivity	Removed	Too wide and already captured in Nielsen's principles and Persuasive System Design model
Choice	Combined	Combined with H3 (user control and freedom)
Perceived Control Flow	Removed	Already covered by H12 (Tunneling)
Challenge	Removed	Can cause injury specially if unaccompanied
Purpose	Combined	Combined with H16 (simulation)
Fun	Combined	Combined with H14 (personalization)
Reward	Removed	Already covered by H19 (rewards)
Socialisation	Removed	Already covered by H25 (social learning), H26 (social comparison), H27 (normative influence) and H28 (social facilitation)
Emotional Connection		
Safe Environment	Removed	Already covered by H24 (trustworthiness)
Low vs. High Fidelity Graphs	Removed	Out of scope
First vs. Third Person View	Removed	Out of scope
Feedback Sounds	Combined	Combined with H1 (visibility of system status)
Feedback Music		
Ambient Music	Combined	Combined with H33 (ambient sounds)

Table 4.2: Heuristic principles: Game design removed and combined principles

4.1.2 Heuristic evaluation procedures

For the evaluation, we provided the evaluators with a script, the "Heuristic evaluation procedure" (Appendix F), which described in detail how to carry out the evaluation and which areas were most important. It also included the list of heuristics (Appendix E) to conduct the assessment and the evaluation report (Appendix G). The evaluation report started by giving instructions to the evaluator

regarding how to proceed. First, the evaluators must complete a questionnaire about their background and experience (Appendix H). Then they explore the application twice and report the problems discovered in the evaluation report. The report served for evaluators to indicate the time spent on the evaluation and identify the problems they detected with a short description, a detailed description and an illustrative screenshot, the heuristic(s) violated, a solution proposal and the degree of priority and severity (Appendix G). Finally, they have a post-evaluation questionnaire to report their experience using the heuristics list (Appendix I).

4.1.3 Expert evaluators profile

The evaluation was carried out by four evaluators all recruited through the author's or the INPACT project team's personal networks: one Human-Computer Interaction (HCI) student, two HCI researchers, and one HCI professional. All stated that they have little or some experience with heuristic evaluation; all are reasonably familiar with user interface design principles. Regarding the experience with the design of telerehabilitation systems, one stated that have no experience or knowledge, two answered that they have little experience and one that has some experience. Finally, all participants indicated that they have little experience with the use of telerehabilitation systems.

4.1.4 Analysis of the results

After receiving the results from each evaluator, we analysed the results. Table 4.3 provides an overview of the number of problems and violated heuristics per evaluator. Table 4.4 displays the number of problems and violated heuristics per screen, in which the number in parentheses represents the number of times the heuristic was violated. Appendix J, presents a table with the number of times a heuristic was violated, per screen, with the corresponding degree of severity.

Evaluator	**Number of Problems Found**	**Number of Heuristic(s) Violated**
1	18	20
2	9	19
3	6	7
4	18	14

Table 4.3: Heuristic evaluation: Numbers of problems and violated heuristics per evaluator

As shown in Table 4.4, the five most violated heuristics were:

H8 - 26 violations

Page	**Number of Problems**	**Heuristic(s) Violated**
Login	3	H1(2), H3(2),H4, H8(3), H9(2)
My session	2	H6, H8, H10(2), H11, H16
Session Details	7	H1(2), H2(2), H3(3), H7(2), H8(2), H10, H11(2), H17
Settings	9	H1(2), H3, H4(3), H2, H6, H7(2), H8(4), H9(2), H11, H16(2), H17, H22, H30, H33
Menu	2	H1, H3, H6(2), H8, H11
Notifications	2	H3, H6, H9(2)
Profile	3	H1(2), H3(2), H6, H7(2), H8, H11(2), H14, H25, H26
Session performance	9	H2, H4, H7, H8(4), H9, H11(2), H12, H13, H14, H18, H22(3), H30, H32(4), H33
Exercise evaluation	7	H1, H4, H8(5), H11, H24
Message to the physiotherapist	4	H1(2), H7(2), H8(2), H11(*3)
Leave the session	3	H8(3), H11, H18, H19, H21(2)
Session Hisotry	1	H4, H15, H19
Sum	**52**	**H8(26), H11(14), H1(12), H3(10), H7(9), H9(8), H4(7), H6(6), H2(4), H22(4), H32(4), H10(3), H16(3), H14(2), H17(2), H18(2), H19(2), H21(2), H30(2), H33(2), H12, H13, H15, H24, H25, H26**

Table 4.4: Heuristic evaluation: Numbers of problems and heuristics violated per page, in which the number within parentheses represents the repetitions

H11 - 14 violations

H1 - 12 violations

H3 - 10 violations

H7 - 9 violations

According to the tables, Nielsen's heuristics are the most frequently violated. This is possible because most of the other principles listed, regarding the Persuasive System Design (PSD) model and the game design principles, have yet to be implemented.

Login

On the "login" screen (Figure 4.1), evaluators 2 and 4 identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.5):

1. There is no button to confirm the login code in order to proceed to the next page;
2. You can only proceed if you know you can by pressing the "enter" key;
3. There are no error messages in any action;
4. When the code is entered, we do not have confirmation of how many numbers have already been inputted;
5. We cannot delete numbers if we make an error;
6. It is not possible to see the numbers on the screen;
7. It is not clear what to do or what code to insert;
8. Design enhancements are required, such as aligning the numbers inside the buttons and filling the entire background with the background colour;
9. Lack of feedback when you hover the mouse over the buttons;
10. There is no way to tell whether or not the correct code was entered.

My sessions

On the "my sessions" screen (Figure 4.2), evaluators 2 and 4 discovered the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.6).

The problems stated by the evaluators were the following:

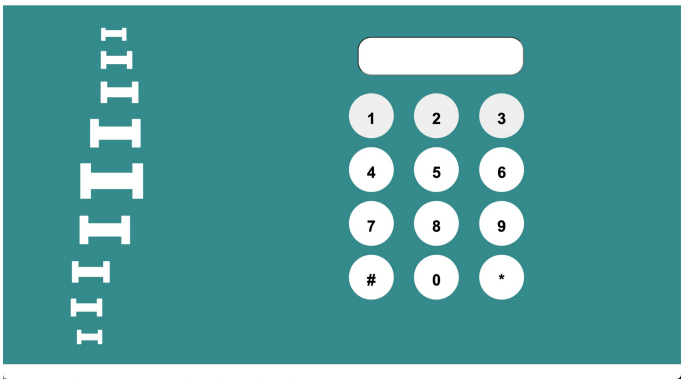

Figure 4.1: Previous user interface: "Login" screen

Evaluator	Severity	Priority	Heuristic(s) Violated
2	high (3)	high (3)	H1, H3, H8, H9
4	medium (2)	medium (2)	H8
	very high (4)	high (3)	H1, H3, H4, H8, H9

Table 4.5: Violated heuristics and problems severity and priority on the “login” screen

1. When starting the session there is no confirmation before the exercise actually starts;
2. The application is not visually pleasing, the elements are not aligned and the colours do not match;
3. The buttons are not consistent throughout the application;
4. Since the sessions do not have names or identifications, users will not be able to know why they have to do them;
5. There is no understanding of what can be accomplished with the application, besides the sessions.

Figure 4.2: Previous user interface: "My session" screen

Evaluator	Severity	Priority	Heuristic(s) Violated
2	high (3)	medium (2)	H6, H8, H10, H16
4	medium (2)	medium (2)	H10, H11

Table 4.6: Violated heuristics and problems severity and priority on the "my session" screen

Sessions details

On the "sessions details" screen (Figure 4.3), the evaluators found the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.7).

The problems stated by the evaluators were the following:

1. It is not clear how we should return to the previous page;
2. For those who are unfamiliar with rehabilitation terminology, the terms used in the cards may make it difficult to understand what is expected;
3. There is a large gap between the end of the card and the end of the page, which may cause the user discomfort;
4. Users may not know what the repetition icon means and therefore not perform the exercise correctly;
5. Going to the session without trying the exercise before may be harmful to the user;
6. The way the cards are built, it appears that the 'ver mais' buttons are poorly done, as they appear to be filled in all the way to the end of the card.

Figure 4.3: Previous user interface: "Session details" screen

Evaluator	Severity	Priority	Heuristic(s) Violated
1	high (3)	medium (2)	H1, H7, H11
	high (3)	medium (2)	H8
2	high (3)	high (3)	H2, H3, H10, H17
3	very high (4)	high (3)	H3
4	medium (2)	medium (2)	H2
	low (1)	low (1)	H8
	high (3)	medium (2)	H1, H3, H7, H11

Table 4.7: Violated heuristics and problems severity and priority on the "session details" screen

Settings

On the "settings" screen (Figure 4.4), the evaluators identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.8).

The problems stated by the evaluators were the following:

1. Must take into account the issue of responsiveness in the alignment of the contents, for example, the title 'sessão personalizada' is out of place and the 'guardar' button is above the librarian speech, which makes it impossible for us to select this type of speech;

2. Might be better to choose between 'selecionar' or 'escolher' (standardise speech);

3. More realistic images could be used to make it easier to understand, even for users who don't read much;

4. When a specific option is selected, no confirmation appears, and the icon does not change to indicate that it has been marked (show example);

5. The lack of a button to return to the previous page;

6. Does not allow the user to choose music or an ambience sound;

7. It would be interesting to see a preview of how a new option would look before saving the changes;

8. The buttons, as stated on the "session details" page, are not correctly implemented because they do not fill the card all the way to the bottom.

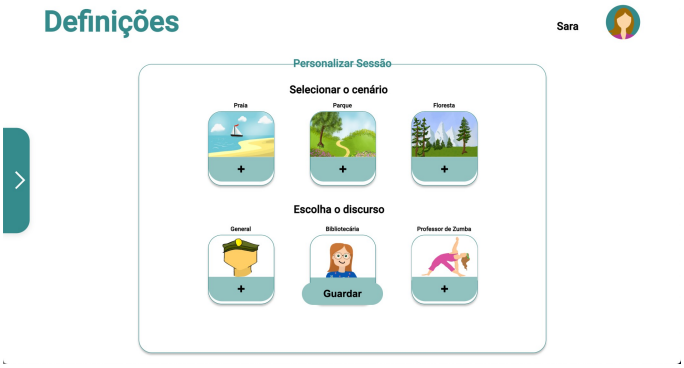

Figure 4.4: Previous user interface: "Settings" screen

Evaluator	**Severity**	**Priority**	**Heuristic(s) Violated**
1	very high (4)	medium (2)	H4, H8
	low (1)	low (1)	H4
	medium (2)	low (1)	H2, H6, H7, H17 H9, H16, H22, H30
	very high (4)	medium (2)	H1, H3, H9
2	medium (2)	low (1)	H8, H33
3	low (1)	very low (0)	H16
4	high (3)	very high (4)	H4, H8
	medium (2)	low (1)	H8

Table 4.8: Violated heuristics and problems severity and priority on the "settings" screen

Profile

On the "profile" screen (Figure 4.5), evaluators 1, 2 and 4 identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.9).

The problems stated by the evaluators were the following:

1. There is no button that allows you to return to the previous page;
2. The system does not create any link between the user and the rehabilitation professional;
3. Does not allow to change of information;
4. Does not promote any social link;
5. It is not straightforward how to reach this page;

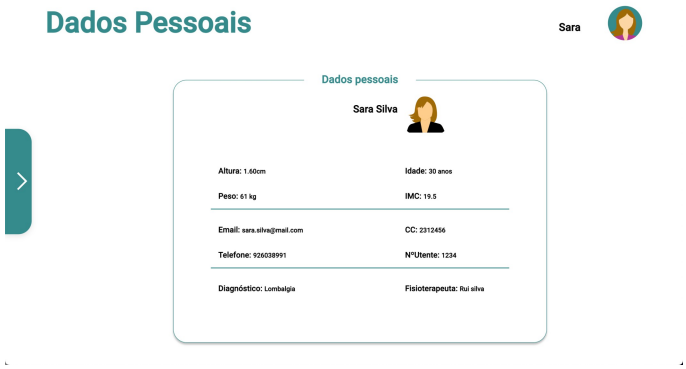

Figure 4.5: Previous user interface: "Profile" screen

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
1	low (1)	low (1)	H1, H7, H11
2	low (1)	low (1)	H3, H8, H14, H25, H26, H25
4	high (3)	high (3)	H1, H3, H6, H7, H11

Table 4.9: Violated heuristics and problems severity and priority on the "profile" screen

Notifications

On the "notifications" screen (Figure 4.6), evaluators 2 and 4 identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.10).

The only problem noted by the evaluators was that the user receives no instructions on how to close the notifications.

Figure 4.6: Previous user interface: "Notifications" screen

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
2	medium (2)	low (1)	H9
4	medium (2)	low (1)	H3, H6, H9

Table 4.10: Violated heuristics and problems severity and priority on the "notifications" screen

Menu

On the "menu" screen (Figure 4.7), evaluators 2 and 3 identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.11).

The problems stated by the evaluators were the following:

1. User has to remember the information hidden on the menu, instead of it being visible on the screen;
2. The info layout is very condensed and overwrites the information that was already on the screen;
3. Could not find where I wanted to go fast.

Figure 4.7: Previous user interface: "Menu" screen

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
2	medium (2)	medium (2)	H1, H6, H8, H11
3	medium (2)	medium (2)	H3, H6

Table 4.11: Violated heuristics and problems severity and priority on the "menu" screen

Session performance

On the "session performance" screen (Figure 4.8), the evaluators identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.12).

The problems stated by the evaluators were the following:

1. The user may struggle to identify with a black puppet or with the scenario itself;

2. Given that it is a black dummy on a beach performing the exercise on top of a boat (second evaluator) or, in the case of evaluator four, on top of the water, this is an unrealistic scenario. This also allows us to confirm that there is a lack of responsiveness on this page, as the dummy appears in two different places for two different users, which is not supposed to happen;

3. There is a large gap between the end of the content and the bottom of the page, which may cause the user discomfort;

4. Because red warning signals imply something serious, the use of sound mechanisms could be beneficial;

5. It was indicated that the user take a 10-second break. After the first ten seconds, the user should not have to press any buttons to proceed to the next exercise;

6. The performance is not accompanied by a narrative;

7. Confusing and unfriendly because the visual assistance is on one page and the steps and descriptions are on another;

8. In terms of design, the image does not cover the entire background of the screen and the text messages that appear are never aligned vertically with the background rectangle in which they are inserted;

9. During the exercises, the black dummy should always be present. Because the text explaining the exercise says the same thing as the dummy, it becomes redundant and may confuse users by giving the impression that they are two different things.

Figure 4.8: Previous user interface: "Session performance" screens

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
1	low (1)	low (1)	H2, H14, H18, H22, H30, H32
	very high (4)	medium (2)	H8
	very high (4)	medium (2)	H9, H33
	medium (2)	low (1)	H7, H11, H12
2	high (3)	very high (4)	H8, H22, H32
3	medium (2)	low (1)	H11, H32
4	high (3)	medium (2)	H13, H22, H32
	low (1)	low (1)	H8
	high (3)	high (3)	H4, H8

Table 4.12: Violated heuristics and problems severity and priority on the "session performance" screen

Exercise evaluation

On the "exercise evaluation" screen (Figure 4.9), evaluators 1, 3 and 4 identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.13).

The problems stated by the evaluators were the following:

1. There is no way of knowing whether or not the inserted evaluation was saved;
2. The icons numbered 0 to 10 are not completely aligned with the subtitles;
3. The buttons 'ver sessão' and 'próximo exercício' are useless because they take us nowhere. Besides 'avançar' makes the exact same thing as 'próximo

exercício';

4. In some background colours it is difficult to see the numbers when selecting one of the options, as they turn white;

5. The buttons are not aligned horizontally with each other;

6. In the satisfaction evaluation when we select the degree of satisfaction we no longer see the associated star. Besides this screen maybe should be more similar to the others.

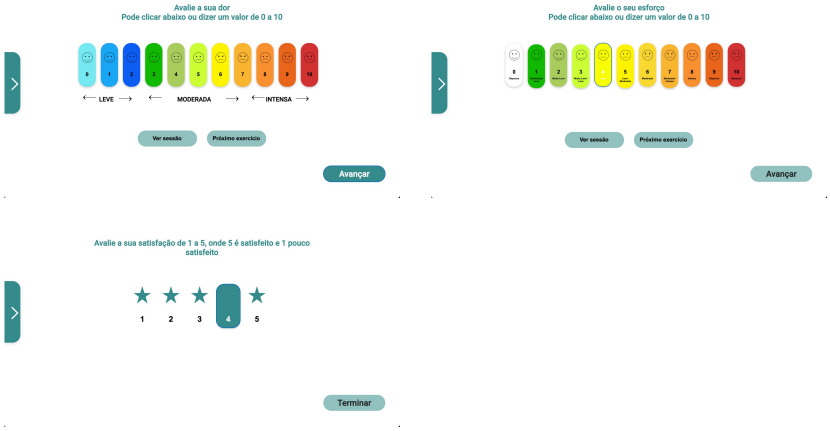

Figure 4.9: Previous user interface: "Exercise evaluation" screens

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
1	very high (4)	medium (2)	H8
3	very high (4)	high (3)	H1
4	medium (2)	low (1)	H8, H11
	high (3)	high (3)	H24
	medium (2)	medium (2)	H8
	medium (2)	low (1)	H4, H8
	low (1)	very low (0)	H8

Table 4.13: Violated heuristics and problems severity and priority on the "exercise evaluation" screen

Message to the physiotherapist

On the "message to the physiotherapist" screen (Figure 4.10), evaluators 1, 3 and 4 identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.14).

The problems stated by the evaluators were the following:

1. It is not clear how to access the previous screen;
2. It is not clear what can be expected by tapping on 'ver sessão';
3. The presence of the 'próximo exercício' button causes the user to not fill in anything we want;
4. Unable to record, or write (as an alternative), a message to the physiotherapist;
5. Buttons 'ver sessão' and 'próximo exercício' are redundant as they don't take us anywhere.

Figure 4.10: Previous user interface: "Message to the physiotherapist" screen

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
1	high (3)	medium (2)	H1, H7, H11
	high (3)	medium (2)	H8, H11
3	very high (4)	very high (1)	H1, H7
4	medium (2)	low (1)	H8, H11

Table 4.14: Violated heuristics and problems severity and priority on the "message to the physiotherapist" screen

Leave the session

On the "leave the session" screen (Figure 4.11), one of the evaluators identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.15).

The problems stated by the evaluators were the following:

1. The 'saltar' button on the page shown below does not tell us where to jump to;

2. The recommendations should be more emphasised so that the user understands their importance;

3. When the session is finished, part of the saved data could be displayed and presented as a summary of the activity or "badges" obtained.

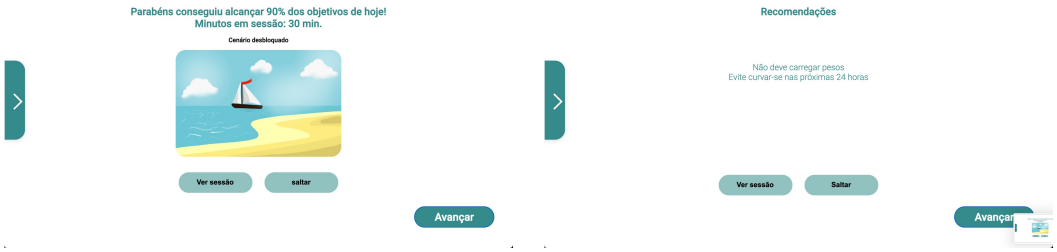

Figure 4.11: Previous user interface: "Leave the session" screens

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
1	high (3)	medium (2)	H8, H11
	medium (2)	low (1)	H8, H21
	medium (2)	low (1)	H8, H18, H19, H21

Table 4.15: Violated heuristics and problems severity and priority on the "leave the session" screen

Session history

On the "session history" screen (Figure 4.12), only one evaluator one of the evaluators identified the following problems, to which they attributed different degrees of severity and priority of correction (Table 4.16).

The problems stated by the evaluators were the following:

1. The layout of this information is inconsistent with the cards of the session;
2. Given that this is the history section, it should include all statistical results from previous sessions as well as any pertinent information.

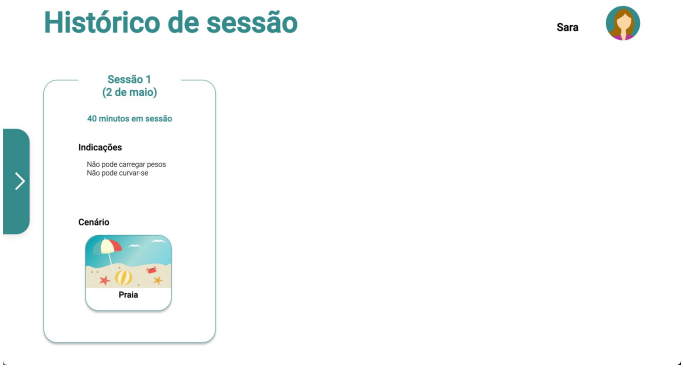

Figure 4.12: Previous user interface: "Session history" screen

Evaluator	Degree of Severity	Degree of Priority	Heuristic(s) Violated
2	very high (4)	high (3)	H4, H15, H19

Table 4.16: Violated heuristics and problems severity and priority on the "session history" screen

In summary, there are problems with the current version of the INPACT user interface. The overall design of the user interface is inconsistent on all pages and between pages; buttons to go back are missing throughout the interface; the menu allows the user to use the application, but the way it is designed is not accessible and causes confusion. In addition, the narrative when performing the exercises of a session is unrealistic and there is no storytelling; there are inconsistencies between buttons and buttons that do not work or are redundant. These are the main problems identified in the analysis of the evaluation results. All the problems identified will be taken into account in the redesign of the user interface.

4.1.5 Evaluation of the heuristics list

We also aimed to evaluate the appropriateness, completeness, usefulness and clarity of the proposed list of heuristics. Therefore, the evaluators were asked to

fill in a post-evaluation questionnaire (Appendix I) that would allow us to evaluate the list of developed heuristics. The questionnaire included five multiple-choice questions and one open-ended question. The multiple-choice questions asked the evaluators to rate the list of heuristics on their appropriateness, completeness, usefulness and clarity. There was also one question to determine whether the evaluators believe that the list of heuristics helped them find problems that would otherwise have gone unnoticed. The open question asked the evaluators to give feedback on how the heuristics list can be improved.

Concerning the five multiple-choice questions, when asked about the **appropriateness** of the list of heuristics to evaluate a telerehabilitation system three evaluators answered that the list is very appropriate, all or almost all heuristics (90% or more) are appropriate, and one indicated that it is reasonably appropriate, there were a few (30% or less) that are not appropriate. Regarding the **completeness** of the heuristic list, all evaluators answered that the list is very complete and could not think of any other(s) to add. When asked about the **usefulness** of the list, three evaluators answered it was very useful and that they would use it again in future projects and one stated that it was reasonably useful and would consider using it in future projects. Regarding the **clarity** of the heuristic list, all evaluators answered that the list was very clear, and all or almost all heuristics (90% or more) are easily understood. Finally, when asked whether they had identified problems that they would have overlooked without the list, all evaluators said yes, whereas three said that happened three to four times and one, once or twice.

Regarding the final open-end question that asked evaluators to leave any suggestions or comments towards improving the list of heuristics only two evaluators answered. One of them stated that some items caused confusion because they appeared too close to other items. The other evaluator stated that everything was fine.

In summary, we conclude that the list is appropriate and useful for the evaluators to identify the problems with the current user interface. However, as mentioned by one evaluator, it is necessary to review the heuristics list to see if there are any repetitions. Taking into account what was discussed in this section, the list of requirements was reviewed and modified, as we will see in section 4.2.

4.2 List of requirements

Taking into account the problems encountered in the previous user interface, through the heuristic evaluation, and the idea of implementing gamification in the new user interface the previously established list of requirements was modified. The current list of requirements, as the following tables show, covers aspects of motivation and gamification (Table 4.17); feedback (Table 4.18); progress monitoring (Table 4.19); patient empowerment (Table 4.20); patient-physiotherapist relationship (Table 4.21); instructions (Table 4.22); monitoring (Table 4.23); and authentication, navigation and trust in the system (Table 4.24). Some of the requirements are linked to redesign activities while others require the design of features from scratch; the vast majority of these requirements relate to the gami-

fication part of the system.

Motivation and gamification	
Present a realistic narrative (e.g. countryside, beach, forest, park), with scenes and instructions adapted to the narrative	Redesign
Creating coherence throughout the application via a relevant and aggregator theme/concept (e.g. vitality, health, energy)	New
Set individualised goals for each user using gamification (e.g. 3 weeks to be able to raise the arm to 90º)	New
Show a list of reward systems, dates, and accomplished objectives (rewards achieved, unachieved and unlocked)	New
Display the reward system at the end of each session - unlock missing rewards or objectives to achieve an unlock	Redesign
Limit the number of messages the user can send. User must earn the right to send messages	New
Alert for inactivity	New
Use motivational statements (positive reinforcement), in moderate quantities, throughout the session (collected from the thematic analysis and structured according to the phase of the exercise/session)	Redesign

Table 4.17: Motivation and gamification requirements

Feedback	
Provide feedback on user performance at the end of each exercise (as an evaluation)	Redesign
Enable visualisation of errors/feedback from completed sessions/exercises	Redesign

Table 4.18: Feedback requirements

4.3 Summary of the chapter

This chapter presented the heuristic evaluation that was carried out as part of the practical work of the project. The chapter started by outlining the process we undertook to arrive at the final set of principles for the heuristic evaluation. The final list of principles that guided the heuristic evaluation was also presented. The chapter then looked at how the evaluation process went and talked about the documents that were handed out to the evaluators and what they contained. Next, the analysis of the evaluation results was presented, focusing on the problems found per screen with the respective heuristics violated. In addition, the list

Progress monitoring	
Display common and constant errors in all sessions	New
Measure the session execution time	Redesign
Display corrections and which were implemented	Redesign
Present a monthly, weekly, and daily summary	New
Compare the before and after of an achieved goal(e.g. 3 months ago you could not walk consistently and now you walk 800m)	New

Table 4.19: Progress monitoring requirements

Patient empowerment	
Present the physiotherapist recommendations related to the session (if there are any)	Redesign

Table 4.20: Patient empowerment requirement

of heuristics used by the evaluators was also analysed, taking into account their experience of using the list in the user interface assessment carried out previously. Finally, the chapter presented the current version of the list of user interface requirements, which have been implemented in the new user interface, as we will see in chapter 5 and 6.

Patient-physiotherapist relationship requirements	
Notify whenever there is a new message from the physiotherapist	New
Allow the user to communicate with the physiotherapist through a chat that allows sending text, images, video or sound	Redesign
Enable sending messages to the physiotherapist (record, listen, delete and send)	Redesign

Table 4.21: Patient-physiotherapist relationship requirements

Instructions	
Display instructions for correctly positioning yourself in relation to the screen and during exercise (visual and audible)	New
Show pop-up instructions, if it is the first time to perform an exercise (visual and auditory with plain and understandable language)	Redesign
Present the exercises that constitute the session in order before the beginning	Redesign
Play the exercise video example once. Additional playback is optional.	Redesign
Show essential and detailed information (optional) about each exercise before and during the performance (icons and values of number of series, number of repetitions, number of exercises, execution time, rest time and exercise name)	Redesign
Indicate that the exercise is starting (chronometer/voice input) and indicate the rest period between series/exercise (countdown timer)	Redesign
Auditory/visual accompaniment during the first series to establish the rhythm	Redesign
Notify when healthcare professional adds new session plans	Redesign
Notify changes to already assigned session plans	New

Table 4.22: Instructions requirements

Monitoring	
Enable the visualization and comparison of exercises done by physiotherapists	New
Self-assess pain, according to the Borg scale (voice control/selection on screen)	Redesign
Self-assessment of effort, according to EVA scale (voice control/selection on screen)	Redesign
Self-evaluate overall satisfaction (0 to 5)	Redesign
Show information about the user (name, date of birth, CC number, email, health number, diagnosis, weight, height, BMI, name of the physiotherapist)	Redesign

Table 4.23: Monitoring requirements

Authentication, navigation and trust in the system	
Allow login (through email and password)	Redesign

Table 4.24: Authentication, navigation and trust in the system requirements

Chapter 5

Gamification Strategy Proposal

The redesign of INPACT's interface for people undergoing physiotherapy and the implementation of a strategy for motivation and continuous use are the two main contributions of this dissertation. The INPACT team chose gamification as a strategy to increase user motivation and continuous use. In this chapter, we describe the process we followed to develop the gamification strategy and the strategy itself, by explaining the mechanics behind it.

5.1 Six steps to developing the strategy

After deciding to use gamification as a strategy for motivation and continued use, we moved on to determine the best approach for the project. To create the gamification strategy, we used the six steps created by Werbach and Hunter (2012), which we have covered in section 2.2.1. We chose this strategy because it takes the most sequential and ordered approach. As outlined in subsection 2.2.1, the six steps of this framework are: define; delineate; describe; devise; don't forget the fun and deploy. This section explains the process for defining the gamification strategy for INPACT's user interface, using these six steps.

Starting by **defining** the application's objectives, taking into account the main goal of motivating and encouraging users to regularly use the application, we have defined the following objectives. We want users to:

1. Use and visit the application regularly;
2. Feel motivated;
3. Complete the prescribed sessions;
4. Want to improve by achieving their goals;
5. Perform the exercises correctly.

Then, we proceed to **delineate** the target behaviours of our users. Taking into account the objectives defined above, the INPACT application target behaviours are to:

1. Visit the application according to the periodicity of the prescribed plan;
2. Complete the session exercises;
3. Complete the sessions;
4. Evaluate all sessions performed;
5. Follow and complete the prescribed plan.

Following, we **described** the INPACT target group. The user group of the INPACT application is aimed at people who usually start suffering from low back pain at the age of 25 and who then carry this condition with them throughout their lives (Kislaya & Net, 2014). Given the breadth of age and population, the application and gamified elements should be easy to use by people with different levels of technological proficiency and interests. Users want to improve their previous abilities, as discussed in section 2.1, but they are unmotivated to continue with their prescribed plan, being their motivation to be motivated to complete the prescribed plan.

To **devise** activity cycles, step four of the framework, we need to define the engagement loops and progression stairs of the application. First, we defined the general theme of the gamified application to get a better idea of the interactions we could develop. Before being part of the INPACT project, the team conducted interviews with the users of the partner clinics for the first version of the application. The questions in these interviews were intended to provide information about the users' experiences before, during and after physiotherapy treatment. At the end of each interview, each user was asked where would they do their physiotherapy sessions outside the clinic if they could. To select the theme for the application, we analysed the results of these interviews. Twelve people were interviewed, seven of whom said they would prefer to conduct their physiotherapy sessions in a green environment such as a garden or park, two answered outdoors, two were indifferent and one answered at the beach. As green spaces were mentioned most often, we defined 'garden' as our theme.

After defining the theme, we proceeded to develop the narrative we could build around the garden. Our inspiration came from Farmville[1], a social network game released in 2009 that simulates agriculture by requiring players to plant and harvest crops, unlock new features, and expand their land. With this in mind, we considered designing a garden that people could complete and keep alive if they demonstrated the desired behaviours. Werbach and Hunter (2012) say that the user must have short and long-term goals. These considerations resulted in the long-term goal being to finish the garden and the short-term goal being the acquisition of new garden elements (Figure 5.1), and keeping the garden green (Figure

[1] `https://play.google.com/store/apps/details?id=com.zynga.FarmVille2CountryEscape&hl=en`

5.2). Figure 5.2 shows the different stages of the life of the garden. In the next section, these interactions will be explained in more detail.

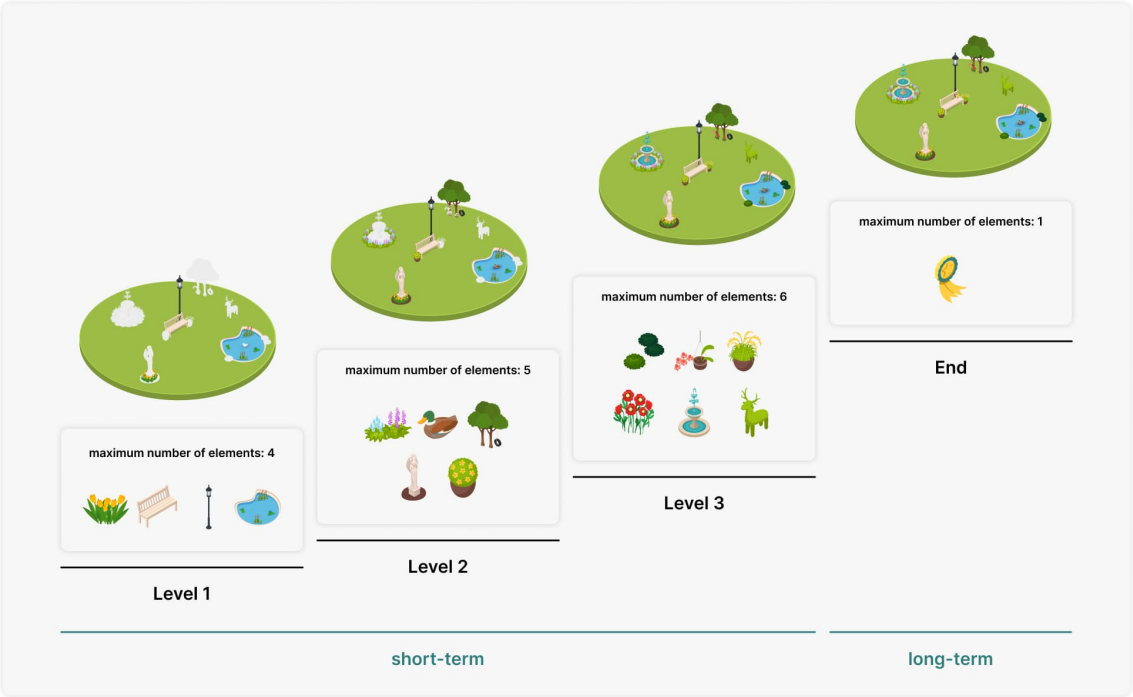

Figure 5.1: Gamification: Short and long-term goals

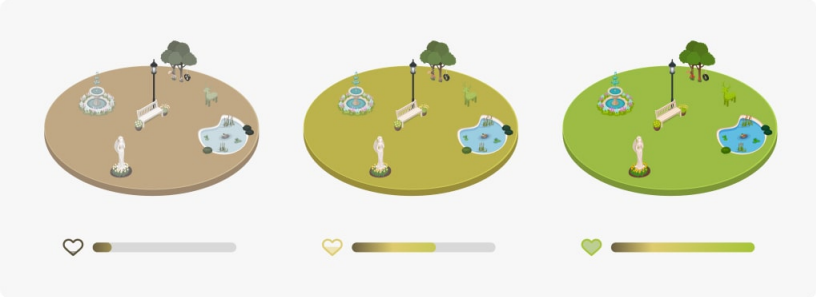

Figure 5.2: Gamification: The garden's Life

Don't forget the fun is the next phase. The gamified experience is not the main focus of the INPACT application. The emphasis is on completing the physiotherapy sessions, and the gamified experience is merely a motivator to do so. At this point, we must consider whether the gamified experience developed will be a sufficient motivator for users to return to the application on a regular basis. Regarding the **deployment of the appropriate tools** for the gamified application, the elements and the garden itself were designed in Adobe Illustrator[2], software to design vectorial elements, and then integrated into the React.js[3] application.

Each of the preceding stages was critical to the overall gamified experience. As we will see in the following section, the above steps were used to create the mechanics within the gamified experience.

[2] `https://www.adobe.com/pt/products/illustrator.html`
[3] `https://legacy.reactjs.org/`

5.2 Gamification strategy for INPACT

Based on the six steps presented we have developed the gamification strategy for the INPACT application. We have defined the goals of the application, the target behaviours and audience, the engagement loops and the progression stairs. In this section, we will outline the overall experience and the different interactions in more detail.

5.2.1 Gamification mechanics

As mentioned in section 5.1, the theme for this gamified application is a garden. Every user starts with grass, so users do not have to work to gain the grass. What players need to do is keep the grass alive (i.e.: green) and gain the elements that can be placed in their garden. These two goals are short-term while completing the garden with all the elements is the long-term goal.

The life of the garden, one of the short-term goals, depends on the activity of the user. The garden will stay green if the user visits the application according to the periodicity of the prescribed plan, check the notifications and messages, and participates in their physiotherapy sessions. If not, the garden gradually turns yellow and then brown (Figure 5.2). The other short-term goal is to acquire new elements for the garden. To unlock these elements, the user must complete the physiotherapy sessions. While the person underdoing rehabilitation does the exercises, of their physiotherapy session, they can see the element that they will gain being filled in, until it is eventually unlocked (Figure 5.3).

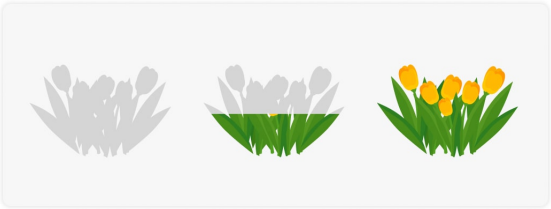

Figure 5.3: Gamification: Unlocking element

Users can also earn additional elements by rating the level of pain and effort experienced during each session exercise, as well as the session as a whole. By obtaining these elements, the user gradually completes the garden, which is the long-term goal (Figure 5.4). Also, at the end of each session, the user has the option to send messages to their physiotherapist. This feature is not always available as the physiotherapist may be overwhelmed with messages. Therefore, one has to earn the right to this privilege. To earn it, the user must complete their physiotherapy session. After the session, the user has two hours to send a new message to the physiotherapist. To finish, when the user ends their prescribed plan they gain a medal for their bench (Table 5.1).

In each session, the user unlocks different elements. The number of elements gained in each session depends on the number of sessions previously completed

Action	**General description**	**Points**	**Quest**	**Badge**
Performing the entire physiotherapy session	The user can see the element they will receive if they perform the exercise in question during their physiotherapy session. This element is grey at first but gradually becomes more coloured as the exercise is completed.	Fill in the elements gained during the exercise with colour.	Gain a complete element.	The gain element appears in the garden.
Evaluate pain and effort	The user is able to gain more elements by evaluating pain and effort.	-	Gain an exclusive element.	The gain element appears in the garden.
Evaluate the overall session	The user is able to gain more elements by evaluating the overall session.	-	Gain an exclusive element.	The gain element appears in the garden.
Send a message to the physiotherapist	The user can send a message to his physiotherapist if he/she completes an entire physiotherapy session.	Perform the exercises.	Complete the physiotherapy session.	Can send a message to the physiotherapist in the next two hours.
End of the prescribed plan	On finishing the plan the user receives a medal for their garden bench.	Perform a session of the prescribed plan.	Complete all the sessions of the prescribed plan.	The medal representing the end of the session appears on the garden bench.

Table 5.1: Gamification strategy

Figure 5.4: Gamification: Fulfilment of the prescribed plan

(e.g. for the first session the user earns two elements, for the second session three elements, and so on). The number of elements obtained per session is determined by the number of sessions in the overall plan, so a person with fewer sessions will not gain fewer elements than someone with more sessions in the overall plan. Also, as mentioned above, the user can obtain additional items, which are less frequent, by rating the different scales presented during the performance of the session. To motivate users to continue their sessions, they can see in advance all the elements they can gain for the garden. The elements are always present in the grass, but they are filled with grey colour (Figure 5.5). This informs the user if there are more elements to win and makes them curious to do so. Table 5.2 shows an example of the elements gained per activity, in the case of a prescribed plan with three sessions.

Figure 5.5: Gamification: No elements versus few elements gained

Session number	**Session performance**	**Evaluating the pain and effort**	**Evaluating the overall session**
1	Two elements	One element	One element
2	Three elements	One element	One element
3	Five elements	One element	One element

Table 5.2: Progression stairs: number of elements gained per activity

Furthermore, we defined "motivational" notifications to encourage users to return to the application on a regular basis. Notifications should be sent when the garden is dying, when a person ends a session, or when any other important information is received. For the notifications regarding the drying of the garden and its resulting loss of colour, we defined the following expressions:

1. "Your garden is perishing..."
2. "Your flowers are thirsty."
3. "The grass is turning yellow, come and give it life!"
4. "Your animals are hungry."
5. "Your animals are thirsty."
6. "Your bench is full of webs, it needs your attention!"

When a person ends a session they get a notification saying "You have gained new elements for your garden! Shall we have a look at them?". Additional information could be notifications from the physiotherapist, as follows:

1. "Your physiotherapist has added new sessions to your plan. Go see them!"
2. "You have a new message from your physiotherapist."

While the user performs each exercise there is a virtual assistant that gives feedback to the user about his performance. This feedback is interconnected with the overall experience of unlocking a new element for the garden. So, instead of saying "You are doing great. Keep it up!", the virtual assistant says" What a beautiful flower. Keep it up!", for example, so the user can get the perception that if he/she continues performing the exercise he/she can earn the flower.

With the mechanics described above, we aim to motivate the user to complete their physiotherapy plan, visit the application regularly and perform the behaviours we have defined. In the following section, we will revisit the requirements previously established in section 4.2 and discuss how this new gamified strategy fulfils them.

5.2.2 Motivation and gamification requirements

The gamification strategy that was created took into account the previously defined requirements. These are listed in Table 4.17 and we will analyse them one by one.

In response to point one of the requirements, the realistic narrative of the application is the garden. Care was taken to integrate the elements of the garden into fulfilling the main objective of the application, which is the completion of the prescribed plan. This is possible through personalised notifications (point 7 of the requirements) that the garden is losing life, sent when the user did not return to the

application on the day they had sessions to perform. In addition, when performing an exercise, the user can also see their elements being progressively unlocked (point 2 of the requirements). During the exercise, the user also receives auditory feedback from the physiotherapist's virtual assistant, whose feedback links to the evolution of the element, with messages such as "What a beautiful flower. Keep it up!" (item eight of the requirements). At the end of each session, the user receives feedback about the goals achieved and the elements the user was able to unlock during the session (points four and five of the requirements). All these mechanisms enable the fulfilment of point two of the requirements. Regarding the sixth point in Table 4.17, we limited the messages sent to the physiotherapist by only allowing the users to send a new one up to two hours after completing their session.

Above, we explained how we considered the previously established requirements while developing the gamification strategy. In the evaluation phase, we will check whether the users enjoy and think that the construction of the garden will motivate them to perform their physiotherapy sessions more regularly.

5.3 Summary of the chapter

We began this chapter by explaining the six steps we followed to develop INPACT's gamification strategy. Then we presented the ideas and mechanics of the gamification strategy, from the theme definition to the engagement loops and the short and long-term goals. Finally, we reviewed how the developed strategy meets the requirements defined. In the following chapter, we introduce the design of the garden and how the gamification strategy has been implemented throughout the application.

Chapter 6

Prototype Development

This chapter introduces our application redesign proposal. It begins with the new graphic identity, which includes colours, typography, icons, the layout grid, the components, and the garden, and then moves on to present the mid and high-fidelity prototypes. Finally, the implementation of the final prototype is presented.

6.1 Graphic identity

In this section, we will present the graphic identity for the new INPACT user interface. The identity was made with an optimal user experience in mind, taking into account the previous expert evaluation (chapter 4) and the new list of requirements (section 4.2). We aimed for a minimalist and straightforward design, as this application can be used by people of different ages and levels of technological proficiency.

6.1.1 Colours and logo

Colour and contrast, or the degree to which two colours differ, are vital for visual perception and hierarchy (O'Connor, 2015). When used correctly, the contrast between two colours allows the user to process visual data more readily and rapidly (O'Connor, 2015). The degree of contrast is expressed as a ratio; the highest the ratio, the greater the contrast.

When testing the existing colour palette, we noticed that the main colour had a poor contrast ratio, making it difficult to read as it was used as a background and text colour, so the main colour of the palette was changed to a darker tone (Figure 6.1). We also added a secondary and a tertiary colour to the palette, as well as three warning colours (green, yellow and red). The secondary and tertiary colours are only used to highlight important information when it is not possible to use the main colour. As the main colour changed, the colour of the logo changed as well. Figure 6.2 presents the new colour palette of the user interface.

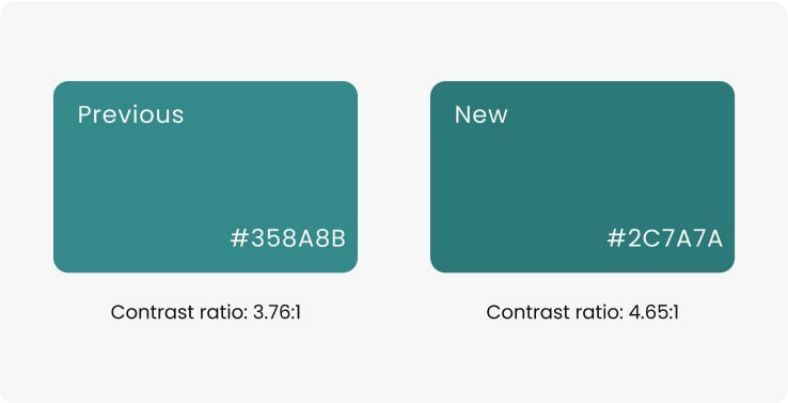

Figure 6.1: Graphic identity: Primary colour

Figure 6.2: Graphic identity: Colour Palette

6.1.2 Typography

Typography is an important part of applications. It should be simple and easy to read so that the user's interaction with the application is successful and efficient because we use typography to communicate with users within the application. A visual hierarchy, in addition to being a form of content organisation, helps readers read a document by emphasising significant content over others (Lupton, 2014). For font selection, we looked at Google Fonts[1], a web font service with free and open-source font families. This font is available in different weights, which allows for higher contrast and visual hierarchy. Figure 6.3 shows the different hierarchies between texts within the application.

[1] `https://fonts.google.com/`

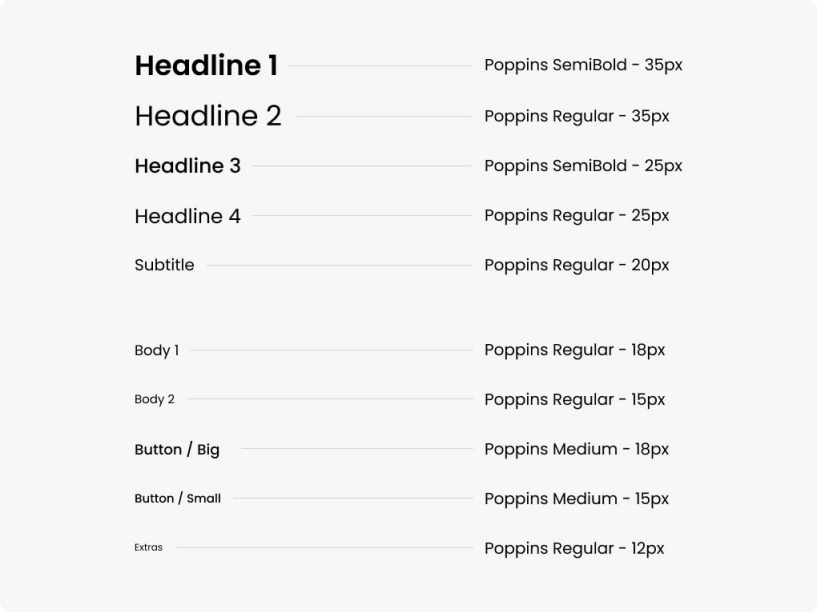

Figure 6.3: Graphic identity: Typography hierarchy

6.1.3 Layout grid

Grids help web designers in creating balanced and uniform web pages. The arrangement of elements in the grid structure organises and orders the overall composition (Elam, 2004). The column grid was the grid used in the user interface. The grid has 18 columns, 25 pixels of gutter and 50 pixels of margin (Figure 6.4).

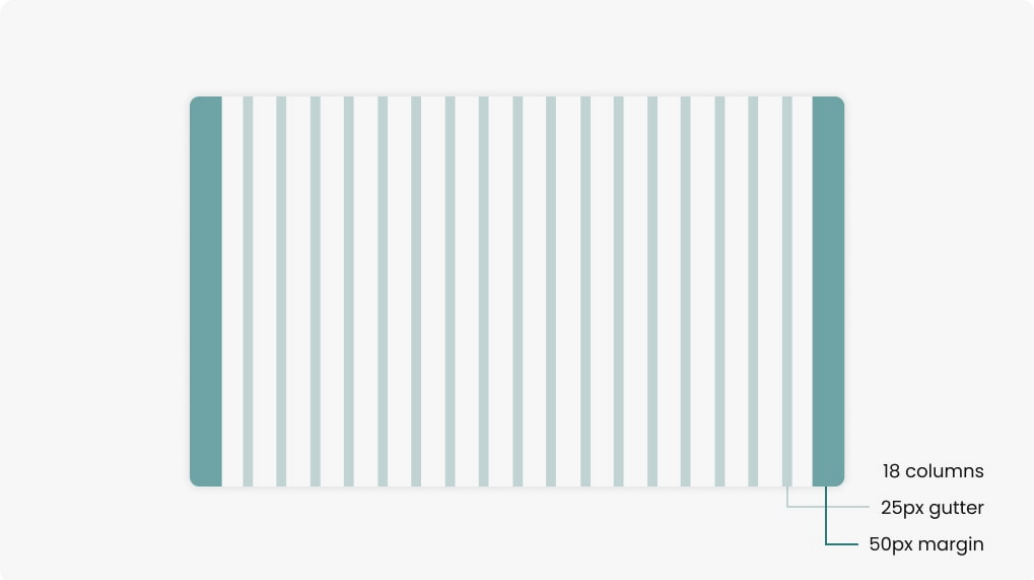

Figure 6.4: Graphic identity: Column grid

6.1.4 Icons

Icons, like typography, provide a clear and concise visual representation and are important elements to convey information. The use of icons in conjunction with text is crucial for effective information transmission, as it allows those who cannot read to understand the context and meaning of the content. In this way, a wider audience can be reached, regardless of reading ability or prior knowledge, which promotes accessibility and universal understanding of the content (Lupton, 2014). Icons must be carefully chosen because they must clearly convey the meaning of the text. To maintain coherence and avoid user confusion, text with the same meaning had to be accompanied by the same icon. Figure 6.5 shows the icons used in the user interface.

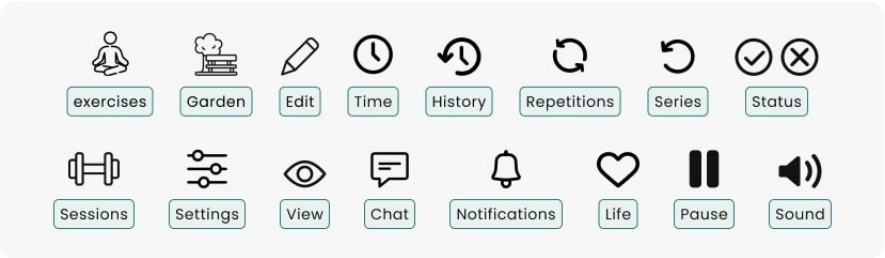

Figure 6.5: Graphic identity: Icons with labels

6.1.5 Components

Following the above decisions, we developed the components for the INPACT interface. Components are interactive elements used in the development of a user interface, as stated in Material Design[2], a guideline system for creating interfaces with best design practices in mind, developed by Google. They result in the combination of all the identity decisions previously made. These include, e.g. buttons, text fields, pop-ups, warnings, top and sidebars and a carrousel.

All components created for the application were designed in Figma[3], a software for creating interactive prototypes. The proportions of the previously created layout grid were taken into account (Figure 6.4). Figure 6.6 shows the components created for the application. Initially, there are two types of pop-ups. The first appears only on the session performance screen and is displayed when the user presses the session pause button. The second pop-up is a tutorial that appears when a user logs in for the first time. The dropdown hides information and is always accompanied by an arrow to alert the user that more information is hidden. The cards represent the prescribed plan sessions and can assume two states: 'já realizado' and 'não realizado', depending on whether the user has already completed the card's session or not yet. We then demonstrate the different buttons of the application and how the text fields change from their natural to tapped state. Then we show two types of progress bars: the left represents the life of the garden

[2] https://m3.material.io/
[3] https://www.figma.com/about/

and the right the completion of the prescribed plan. Finally, we demonstrate the two types of navigation within the application.

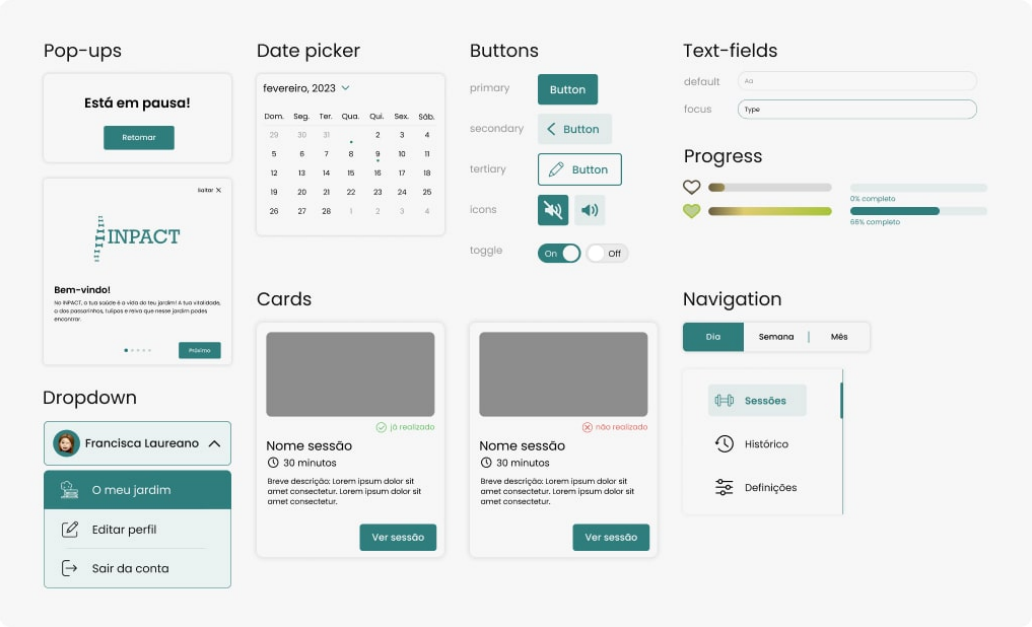

Figure 6.6: Graphic identity: Components

6.1.6 Garden

The garden is the visual product of INPACT's gamification strategy. The graphic elements were selected from Freepik[4], an image database website that provides free commercial resources. After selecting the elements for the garden, they were modified to be visually coherent. In Figure 6.7 we can see all the elements the user can win for their garden.

Figure 6.7: Graphic identity: Elements of the garden

[4] `https://br.freepik.com/`

Establishing these guidelines was crucial to the development of a coherent prototype. Therefore, we will find this identity in the following prototypes of the new user interface.

6.2 Prototype design

In this section, we address the process of the interface design, from the initial concepts to high-fidelity prototypes. We start by describing the application flow so we can better understand the different paths and the structure of the application. Then we present the first tests performed for the design of the application in wireframes (medium-fidelity prototypes), followed by the high-fidelity prototypes which were then implemented. All prototypes were created in Figma using the design guidelines mentioned in the previous section.

6.2.1 Application flow

An application flow is a visual representation of a product's interactions. The flow of the new INPACT user interface has not changed significantly from the previous one, because the sequence of the user actions has not changed and remains mostly adequate. However, as evidenced by the heuristic evaluation results (chapter 4), changes to the navigation of the application were necessary.

In the previous version, the user could begin a session without first reading the session details, this is no longer possible. Instead, the user must first navigate to the session page, to then start the session. Besides, the notifications and logout buttons are no longer inside the menu. Additionally within the history page now users can navigate through day, week and month. Figure 6.8 shows the new application flow.

Following the redefinition of the application's user flow, we develop the wireframes.

6.2.2 Medium-fidelity prototype

Prototypes allow us to explore and test new ideas and share them with the team or stakeholders. Medium-fidelity prototypes are a simpler representation of the final interface that we can use to test interactions (Dam & Siang, 2021). An example of a medium-fidelity prototype is wireframes. Wireframes have a similar appearance to the final prototype but lack detail (Guney, 2019).

During the wireframe design process, we felt the need to conduct informal tests to determine whether the elements created were straightforward. When running the tests, we asked five people to perform a specific activity in the wireframes, as shown in the following examples. First, we tested the location of the profile information. We asked the participants to access their profiles, which they all did.

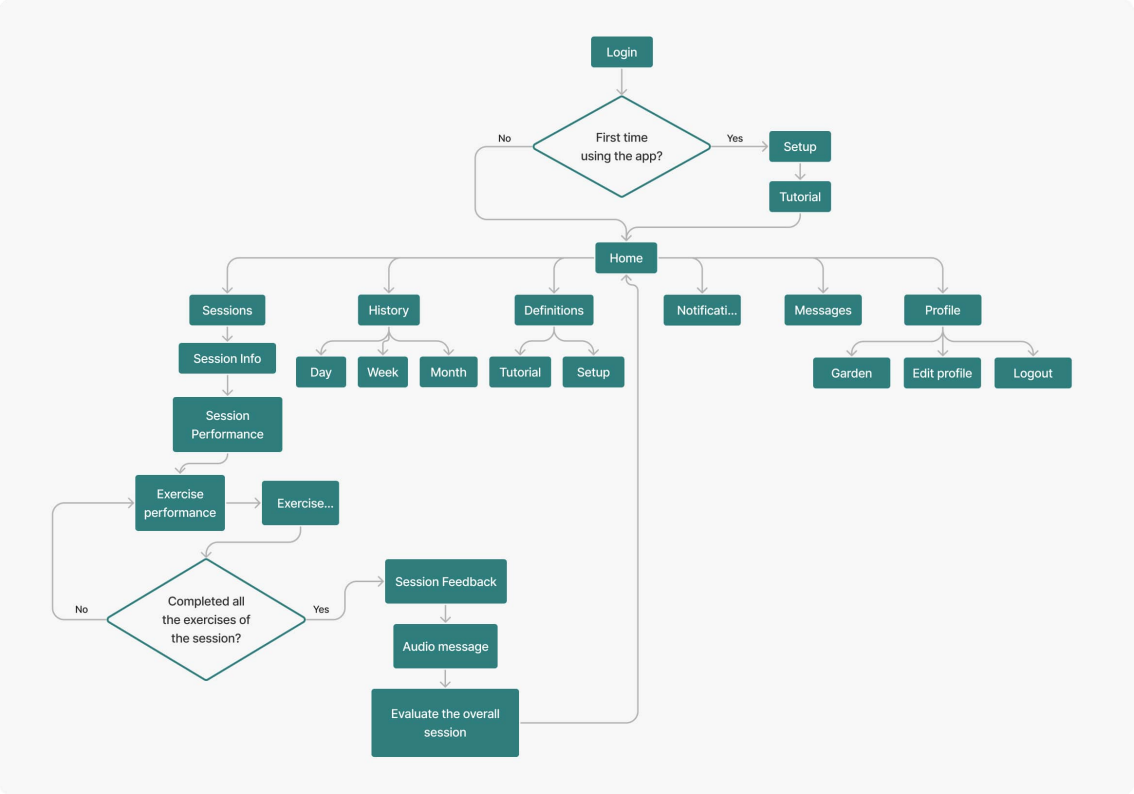

Figure 6.8: INPACT's user flow

This test was done because the option to edit the profile is not visible at first, so we wanted to know if the location was easily identified (Figure 6.9).

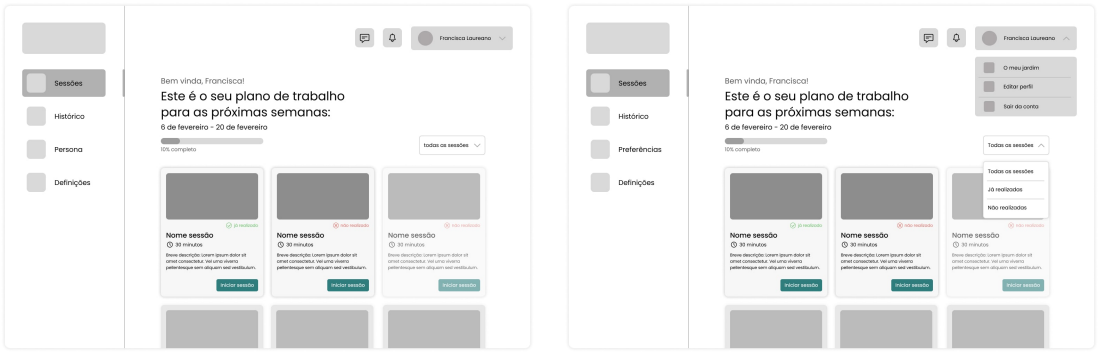

Figure 6.9: Wireframes: Profile location test

In addition, we tested whether users could identify how to start the physiotherapy session. In this test, errors were recorded. Users felt lost in the test because the button that was supposed to take them to the page with information about the session said 'Start session' and not 'View session' or 'View more'. On the session details page, the button at the bottom again said 'Start Session', which was a bit confusing because they had already pressed a button with the same purpose on the previous screen. After this test, the button was changed in the high-fidelity prototype. Figure 6.10 shows the wireframes of the home screen and the session info screen side to side.

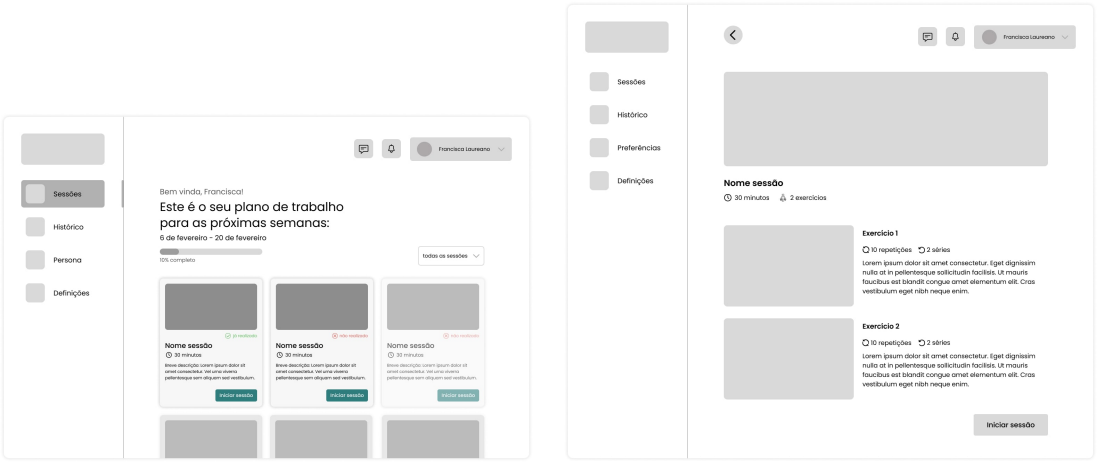

Figure 6.10: Wireframes: Start session test

All the developed wireframes can be found in Appendix K. After creating the wireframes for the user interface, we designed the high-fidelity prototype that we will see next. Some of the wireframes were changed during the transition to the final prototype.

6.2.3 High-fidelity prototype

A high-fidelity prototype has a similar design to the final product and more functionalities than a medium-fidelity prototype. It accurately represents what the solution will look like (Dam & Siang, 2021). This type of prototype is useful to test the final design before it is implemented and to get a more realistic visual representation of what we want to create (Preece, Rogers, & Sharp, 2007). Next, we will present the screens developed in this phase.

Login

As the heuristic evaluation results presented in chapter 4 have shown, the login was not straightforward. Based on the suggestions, and the requirement defined (Table 4.24) the "login" screen was redesigned to utilise the user's e-mail and password (Figure 6.11).

Setup

When the user uses the application for the first time after logging in, he/she is directed to an initial setup, as established in the requirements (Table 4.22). This part of the interface is a guide on how the users should position themselves in relation to the surrounding space to carry out the physiotherapy sessions (Figure 6.12). The top right image in Figure 6.12 indicates the minimum space the users need to perform the physiotherapy session, and the bottom left image states how far they need to be from the tablet. It also introduces a new feature, the phys-

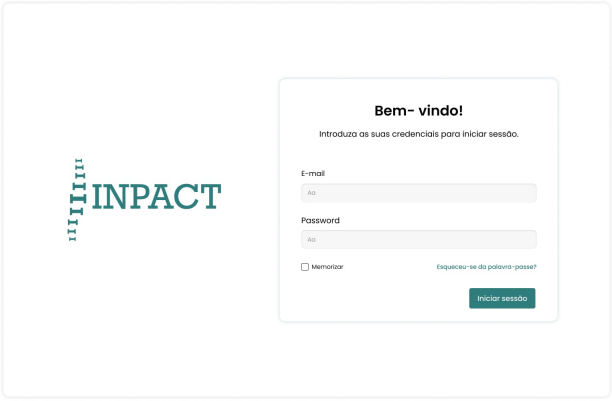

Figure 6.11: High-fidelity prototype: "Login" screen

iotherapist's virtual assistant (bottom right image in Figure 6.12). These screens were not present in the previous user interface.

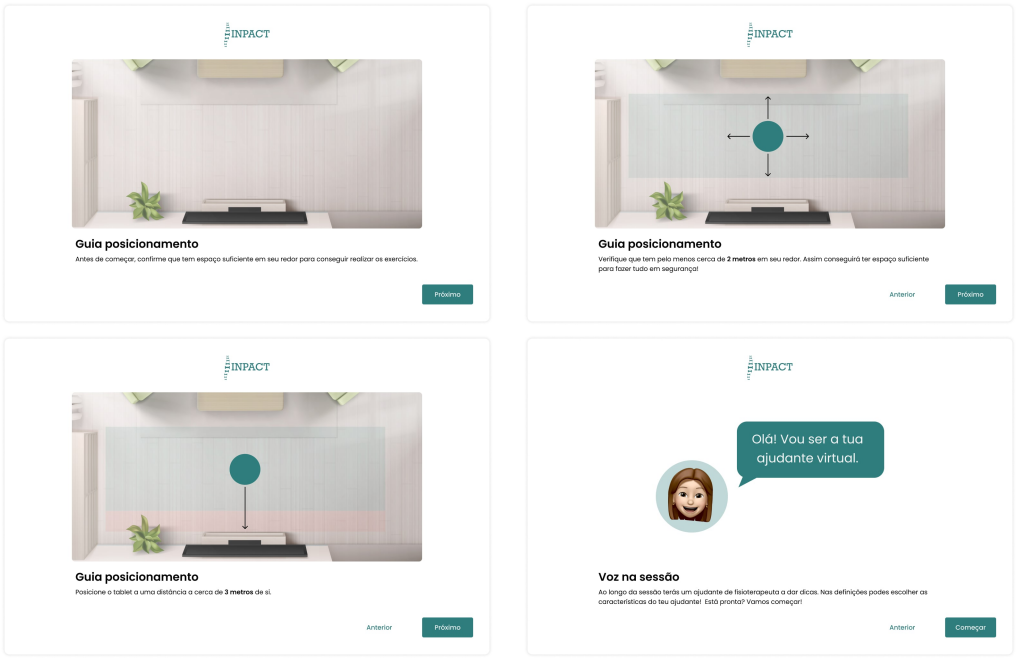

Figure 6.12: High-fidelity prototype: "Setup" screens

Tutorial

If the user is using the application for the first time, a tutorial on how the garden works is provided, after the setup screens. This tutorial explains the mechanics of the garden (Figure 6.13). The top left image welcomes the user and provides an overview of the garden and the top right image shows where the user can access the garden. The bottom left image explains that the garden has life and that this life depends on if the user performs physiotherapy sessions. At last, the bottom right image tells users they can earn new elements for their garden by doing a complete session. These screens were not present in the previous user interface.

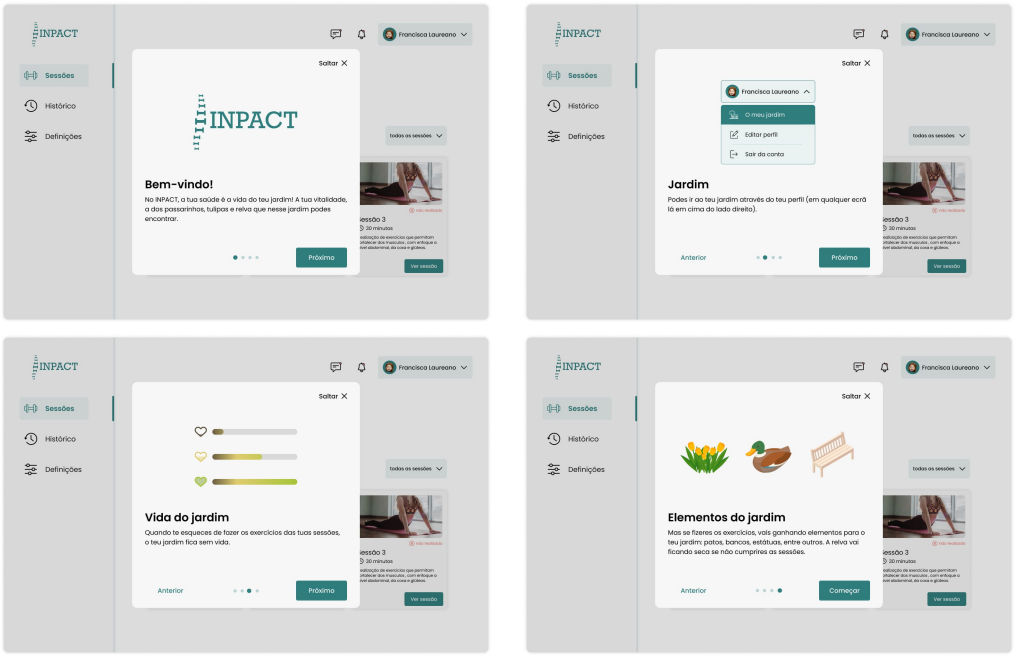

Figure 6.13: High-fidelity prototype: "Tutorial" screens

Home

After the tutorial, we go to the "home" screen of the application. If the user has already used the application, he/she will be redirected here directly after logging in. We kept the cards of the sessions on the "home" screen, just like in the previous version of the user interface (Figure A.2), with some design changes. One of the problems with the previous version was that the session cards lacked identifiers and descriptions, so users did not know what to expect or why they needed to do the physiotherapy sessions. This has been changed. The cards now include an image, the name and a brief description of the session as well as an estimate of how much time will be spent in the physiotherapy session (Figure 6.14). In addition, each card now has a status. In the beginning, all the cards have the status 'não realizado', as we can see in the left image in Figure 6.14, and when the user performs a session, it changes to 'já realizado', as shown in the right image. Also, the progress bar on the screen increases proportionally as more sessions are completed (right image in Figure 6.14).

We kept the side menu, but unlike the previous version (Figure A.7), it is now always visible. This change was made since the results from the expert evaluation (chapter 4), showed that as the menu was always hidden, users had to remember what was in it and that opening the menu overlapped the content. As a result, now the menu is always visible (Figure 6.14).

The profile button, which is at the top right in Figure 6.14, was changed from the previous version (Figure A.2), as users did not know that the profile button was clickable. Therefore, we gave it a button-like layout to make it clear to users that it is clickable. Notifications were also moved to the top bar and a chat function was introduced.

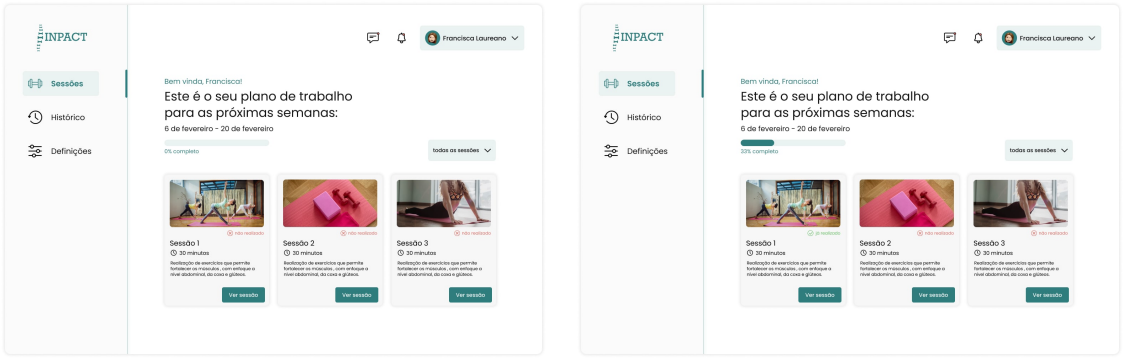

Figure 6.14: High-fidelity prototype: "Home" screens

Session Information

When the user clicks on a card on the home page, he/she is taken to a page that contains additional information about the selected session. As shown in Figure 6.15, the "session information" screen contains a video of each exercise, as well as the name, description, number of repetitions and series. Also, at the bottom of the page, the user can see which items can unlock for the garden. This meets the third, fourth and fifth requirements of Table 4.22.

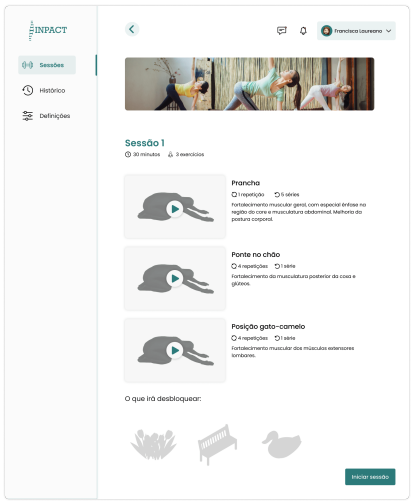

Figure 6.15: High-fidelity prototype: "Session information" screen

Errors

When the user starts the session, they see a carousel with instructions on how to do the exercise correctly (Figure 6.16). It shows how to perform the exercise correctly and incorrectly so that one does not injure oneself while performing the exercise. The user can start the session at any time and is not required to look at the instructions. This screen did not exist in the previous version and meets the first requirement of Table 4.19 and the second of Table 4.22.

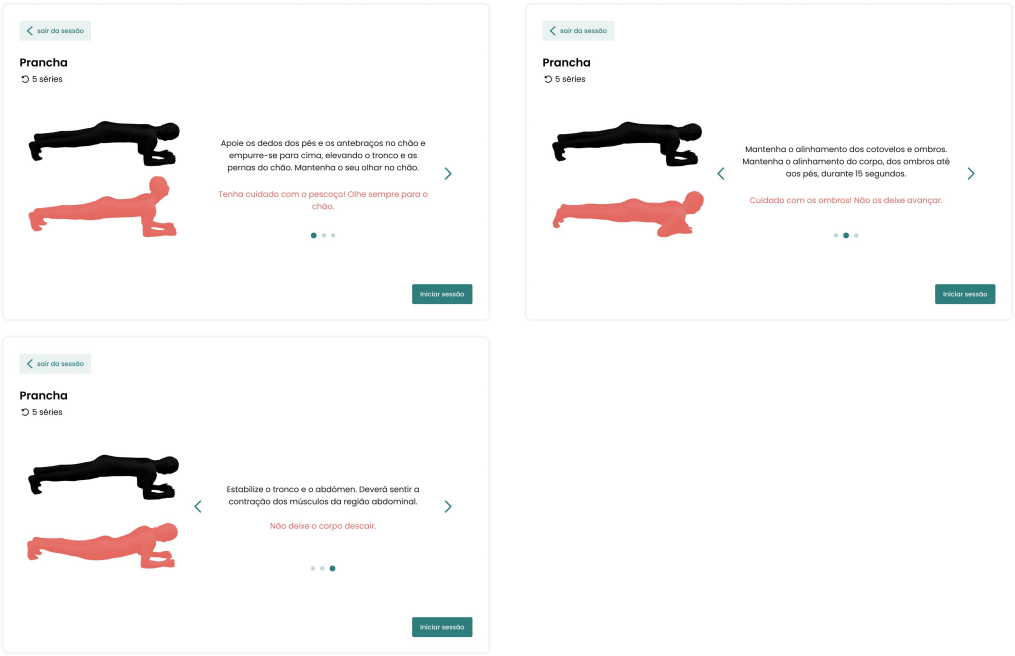

Figure 6.16: High-fidelity prototype: "Error" screens

Session performance

The "session performance" screen is different from the previous version (Figure A.8). In the new version, the user can start the session by saying 'Start' (sixth requirement of Table 4.22), which gives them time to position themselves, as shown in the left image of Figure 6.17. During the session, the user is accompanied by a virtual assistant (present on the bottom left side of the screen (Figure 6.17)), who not only visually displays what is being said, but also speaks (seventh requirement of Table 4.22). This new feature was added because users felt that there was no real accompaniment by the physiotherapist, which was important for them, as shown in chapter 2. So we wanted this assistant to be able to provide that accompaniment. The virtual assistant also provides auditory feedback so that the user does not have to move their head (which can be harmful in certain exercises) to determine, for example, if they have finished the exercise or if it is time to rest.

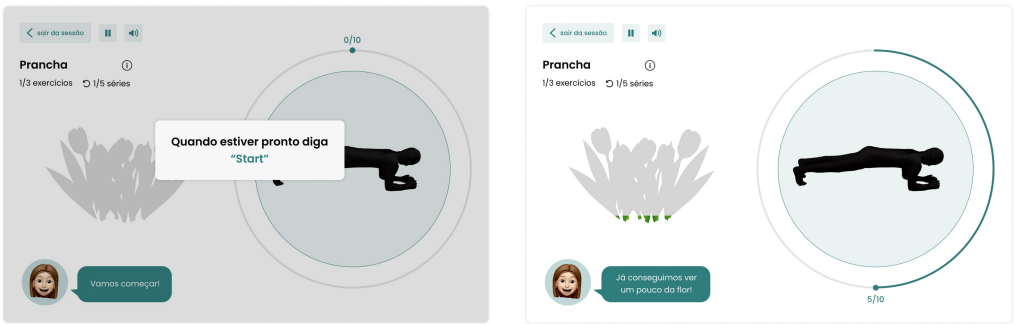

Figure 6.17: High-fidelity prototype: "Session performance" (start session and virtual assistant) screens

A pause button was also added to interrupt the session (Figure 6.18). This way,

the user does not have to leave the session every time he or she needs to take a short break (e.g. to answer the phone or open the door). The user can also see a progress bar on the right side of the screen that counts the number of exercise repetitions or the time the user has to complete depending on the type of exercise (right image of Figure 6.17). When the user is performing the exercise, the progress bar advances and a video demonstrating the exercise is displayed (right image of Figure 6.17). At the end of each series, the user must take a break of at least 10 seconds (right image of Figure 6.18). During this time, the progress bar stops and a 10-second countdown begins. When the countdown is finished, a pop-up window appears asking the user to say 'Start' when he or she is ready to continue the exercise. Finally, on the left side of the screen, as the user performs their exercise, they can gradually see the element that they will unlock by performing the session. This element will change from grey to its final colour.

Figure 6.18: High-fidelity prototype: "Session performance" (pause session and break) screens

Pain and effort evaluation

The pain and effort scales were redesigned, as established in the second and third requirements of Table 4.23. These scales were transformed into a slider where the user can select a value between 0 and 10. When the user selects the value, the slider moves forward and displays the number corresponding to the selected value at the top (Figure 6.19). We constructed the scale in the following way because, according to the findings of student Grego (2022) dissertation, users preferred this method. The user receives a bonus item at the end of the rating for having rated it (third image on Figure 6.19).

Session feedback

As established in the requirements of the application (Table 4.18 and Table 4.20), at the end of the physiotherapy session must appear a "session feedback" screen displaying important information, such as the objectives of the session, what to look out for in the next few days and the items that were unlocked during the session (Figure 6.20).

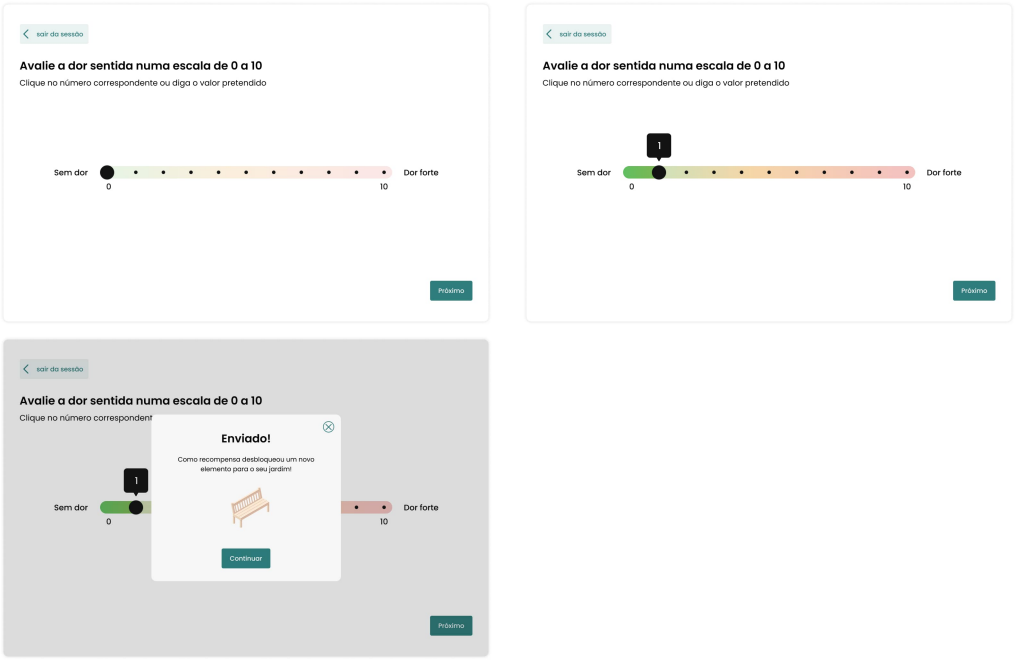

Figure 6.19: High-fidelity prototype: "Pain and effort evaluation" screens

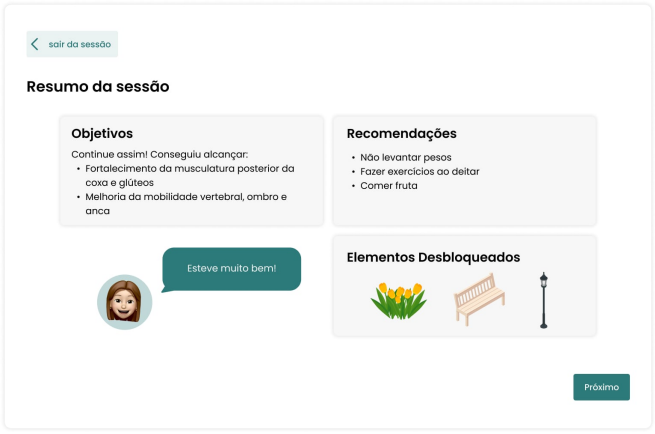

Figure 6.20: High-fidelity prototype: "Session feedback" screen

Voice message

The user can leave a voice message for their physiotherapist at the end of the session (Figure 6.21). In the previous user interface, this screen appeared at the end of each exercise, but the INPACT team decided that it would be more useful to have it only at the end of the session so that the physiotherapist does not receive new messages each time the user completes an exercise. This meets the third requirement of Table 4.21.

Session evaluation

The "session evaluation" screen is similar to the "pain and effort evaluation" screens. However, it has differences that allow the user to distinguish them. The values

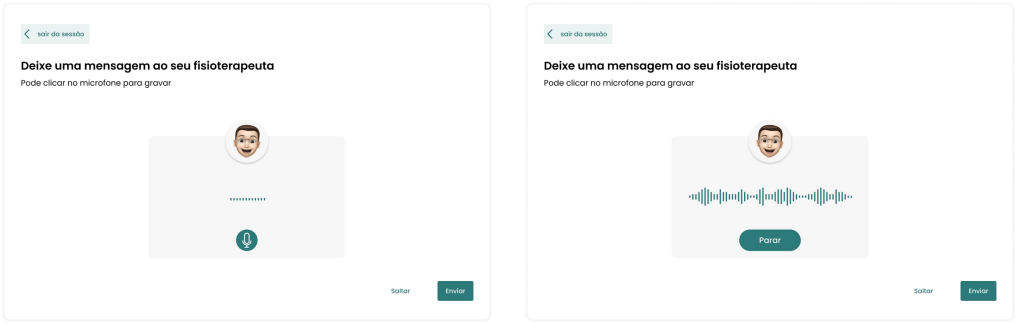

Figure 6.21: High-fidelity prototype: "Voice message" screens

here range from 0 to 7 and the top bar is filled with a different colour, in this case, the main colour (Figure 6.22). If the user evaluates the session he gains a new element for the garden (third image in Figure 6.22). This screen meets the fourth requirement of Table 4.23.

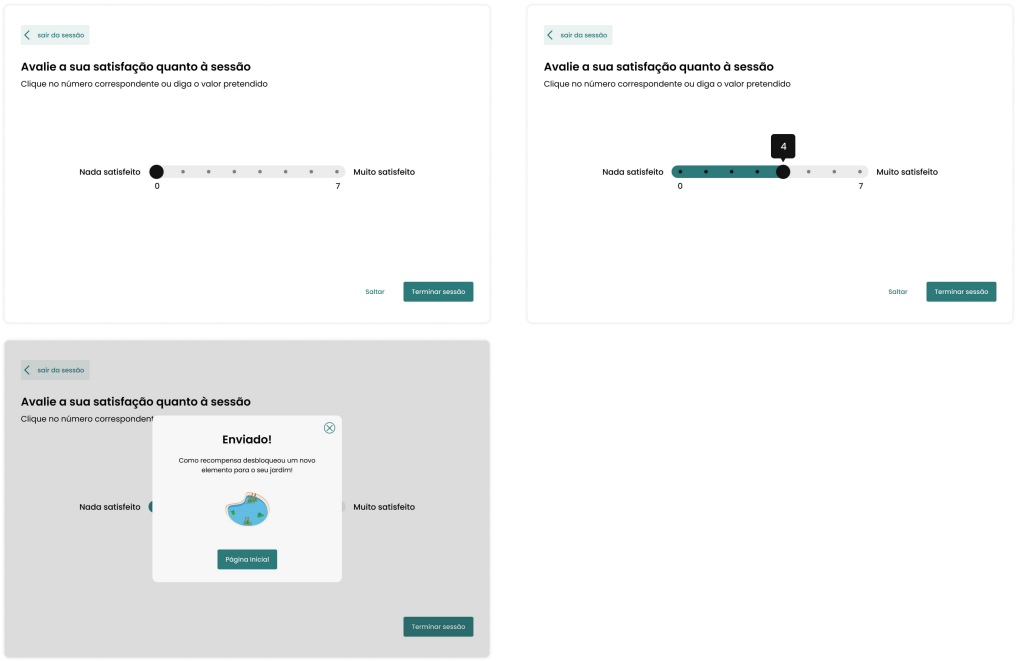

Figure 6.22: High-fidelity prototype: "Session evaluation" screens

Settings

On the "settings" screen, the user can change the voice of their virtual assistant, the scenario, the password and view the tutorial and application setup again (Figure 6.23). As for the scenario, only the garden was created for this proof-of-concept, but if the gamification strategy works well, more scenarios will be developed.

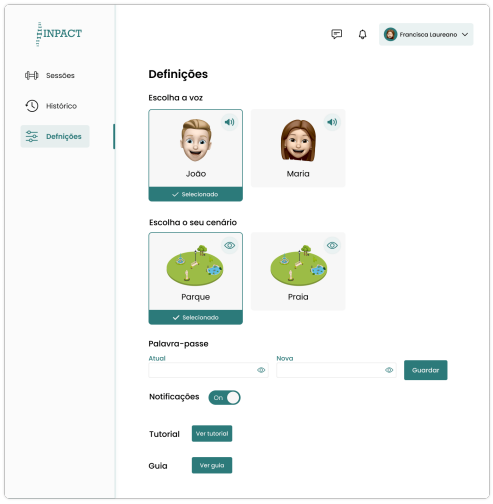

Figure 6.23: High-fidelity prototype: "Settings" screen

History

The "history" screen displays information about each session as well as the progression over a week and a month (Figure 6.24). The user can see the session done that day (first image), the pain and effort felt in each exercise, and all unlocked elements. On the weekly screen (second image), we can see how long it took to complete each session, the items unlocked and the pain and effort felt on each day of the selected week. The monthly screen (third image) shows the same information as the weekly screen but for each week of the selected month. These screens meet the requirements established in Table 4.19.

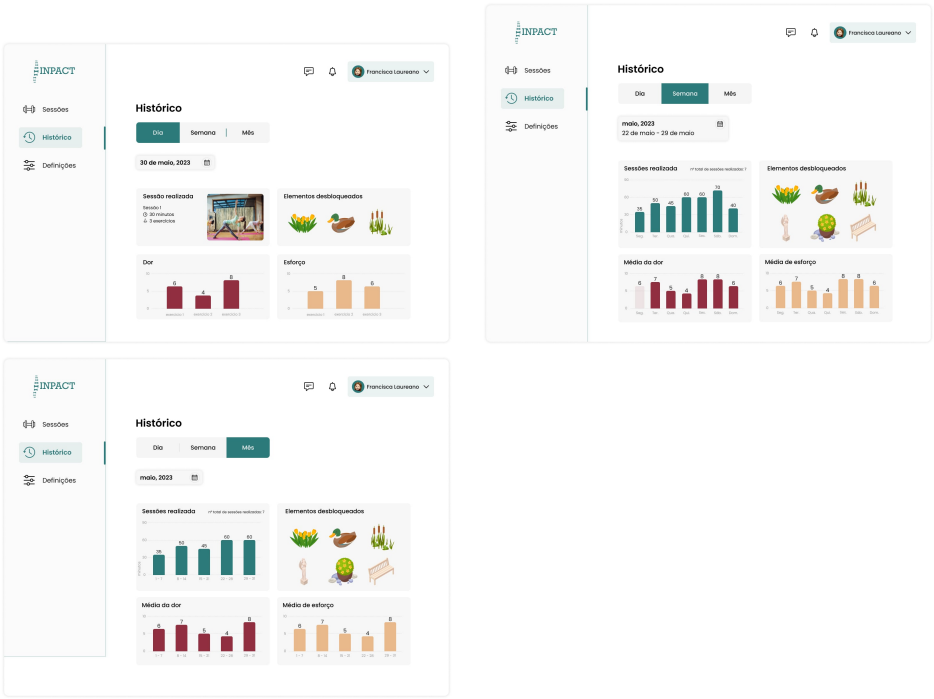

Figure 6.24: High-fidelity prototype: "History" (day, week, month) screens

Garden and notifications

On the "garden" screen, we find the garden with the items already unlocked and/or to be unlocked (Figure 6.25). There is also a progress bar with a heart icon that symbolises the life span of the garden, which changes colour depending on whether it has little, average or much life span, as seen in section 5.1. The right image of Figure 6.25 shows the notifications. The "garden" screen did not exist in the previous version and meets the requirements of Table 4.17. The notifications already existed in the previous version (Figure A.6) and meet the first requirement of Table 4.21 and the eighth and ninth requirements of Table 4.22.

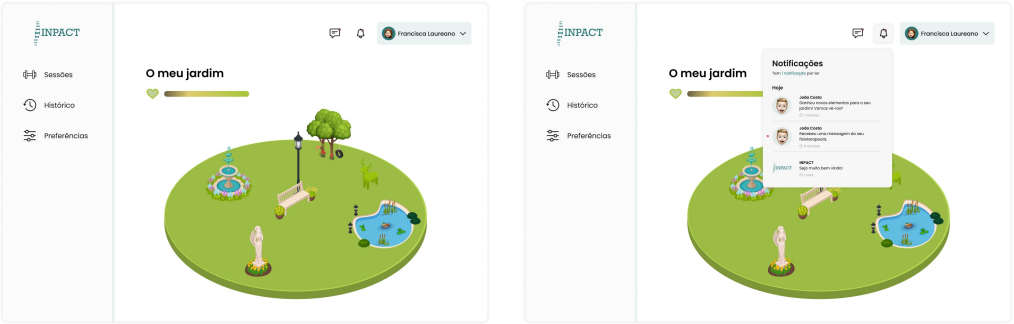

Figure 6.25: High-fidelity prototype: "Garden" and "notifications" screens

Profile

The "profile" screen displays information about the user, as established in the first requirement of Table 4.23. The physical therapist enters all the information. Part of the information entered by the physical therapist can be changed by the user. This includes the profile picture, name and email address (Figure 6.26).

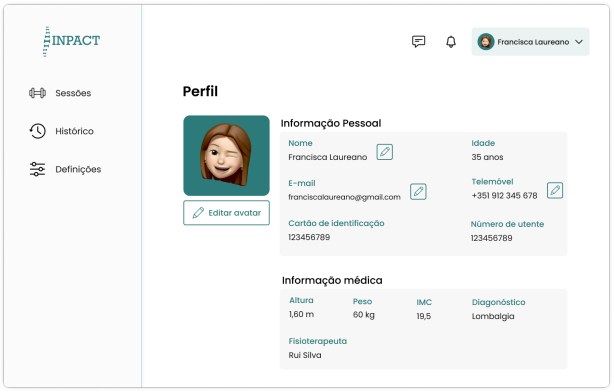

Figure 6.26: High-fidelity prototype: "Profile" screen

Chat

The user can use the chat screen to communicate with his physiotherapist. Figure 6.27 shows the different interactions with the screen. The first shows a message

from the physiotherapist, the second is responding and then sending a message. This screen meets the second requirement of Table 4.21

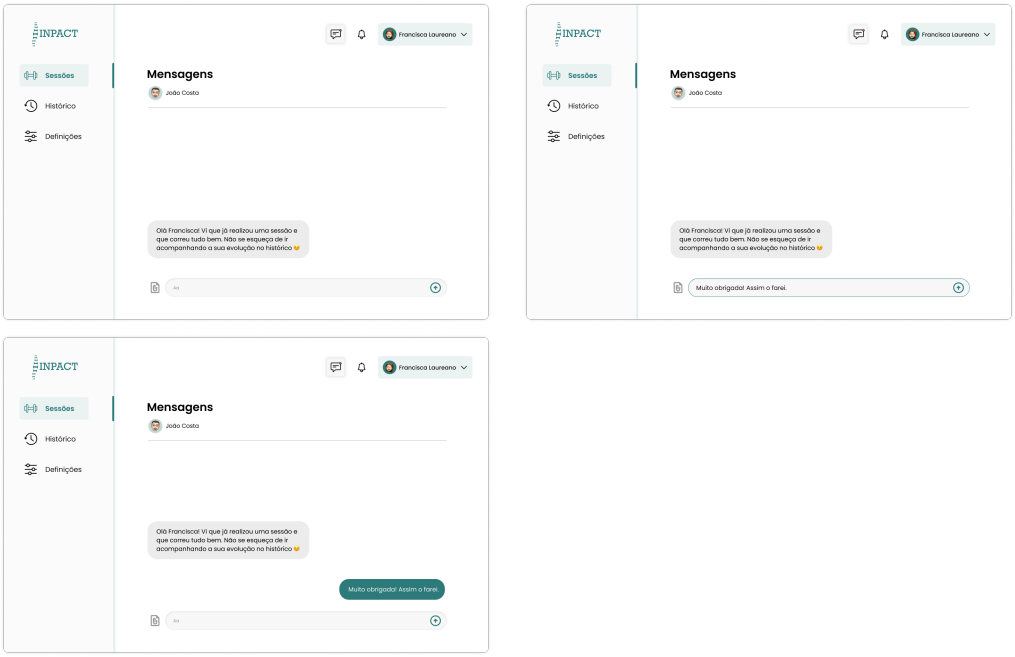

Figure 6.27: High-fidelity prototype: "Chat" screen

In summary, above we presented the high-fidelity prototypes developed. All pages have been changed from the previous user interface, however, in some, the information present has remained similar. After finishing the design of the high-fidelity prototypes we implemented the prototypes, as we will discuss in the next section.

6.3 Application implementation

The implemented INPACT application was created with React.js[3], a JavaScript framework for creating component-based user interfaces. The choice of this framework was made beforehand by the INPACT team, as the previous user interface was already implemented in React.js. As this is an application with different screens and components that are used repeatedly on multiple pages, developing a component-based framework is ideal. The application was implemented to display well on computer and tablet screens. The rest of this section will focus on the code structure, website structure flow and the advanced functionalities of the application. The application is deployed in the following link: https://inpact-utente.vercel.app/; and the code is in a GitHub repository (https://github.com/franciscalaureano/inpact-utente.git). A video demonstration of the application was also made: https://youtu.be/nUjzUy-GyME.

6.4 Code structure

When a React.js repository is created, a folder with several pre-configured files and folders is automatically generated. The 'package.json' file contains information about the project, its dependencies, execution scripts and other settings; the 'src' folder is the main folder where we put the application's code; the 'public' folder contains static files, such as the application's favicon, and the 'node modules' folder contains the project's dependencies. The 'src' folder contains all the written code needed to implement the application, and it is this folder that we will examine through this section.

There are four files and four folders in the 'src' folder. The main component of the application is the file 'App.js'. In this file, all components of the application are routed and rendered. There is also the file 'index.js', the entry point of the application, which configures the React execution environment and renders the main component of the application, in this case, the 'App.js'. Another file is 'generalData.js'. This is where the application's general information is stored, such as the user's name, medical information and physiotherapy plan data. Since we do not have a database connection yet, this was the solution we created to simulate it. So if we need this information on any page of the application, we do not have to rewrite it, we can retrieve it from this file. Finally, at the file level, we have the file 'general.css' which contains the general styles of the application, such as font import, size and colour definition.

Apart from the files already mentioned, the 'src' folder contains four folders with the following names: components, content, fonts and pages. The 'components' folder contains common components that are usually repeated on several pages, such as the sidebar and topbar, which appear on almost every screen. Each component has its own folder within the 'components' folder. Each of these subfolders contains an 'index.js' file that has the JavaScript code for that component. In case the component requires a different variant, there is an additional JavaScript file with the name of the component, a JavaScript file that contains the necessary data for that component, and a CSS file that contains the styles for that component. The JavaScript file with the data and the CSS file always follows the same naming convention: 'componentNameData.js' and 'componentName.css'.

The multimedia contents are stored in the folder 'content'. This has the following subfolders: 'img', 'audio', 'video' and 'bodymovin'. The images are stored in the sub-folder 'img'. Within this sub-folder there are other folders, all with the same name as the component in which the images are used, so that we can find them more easily. The sounds and videos of the application are stored in the folders 'audio' and 'video'. Finally, there is a sub-folder called 'bodymovin' which contains the JSON files of the animations created with Bodymovin[5]. Bodymovin is an extension for the Adobe After Effects programme that allows us to export animations in JSON from the same programme. The ttf files for the fonts used are in the 'fonts' folder.

Finally, the 'pages' folder contains the parent components, from which the pages

[5] `https://exchange.adobe.com/apps/cc/12557/bodymovin`

are created by joining the components in the 'components' folder. There are several sub-folders within the 'pages' folder. Each of these sub-folders contains an index.js file with the main code of each component, a file named 'subfolderNameData.js' with the information for each page, and a CSS file named 'subfolderName.css' with the styles associated with it. Figure 6.28 shows the organisation of the code in greater detail.

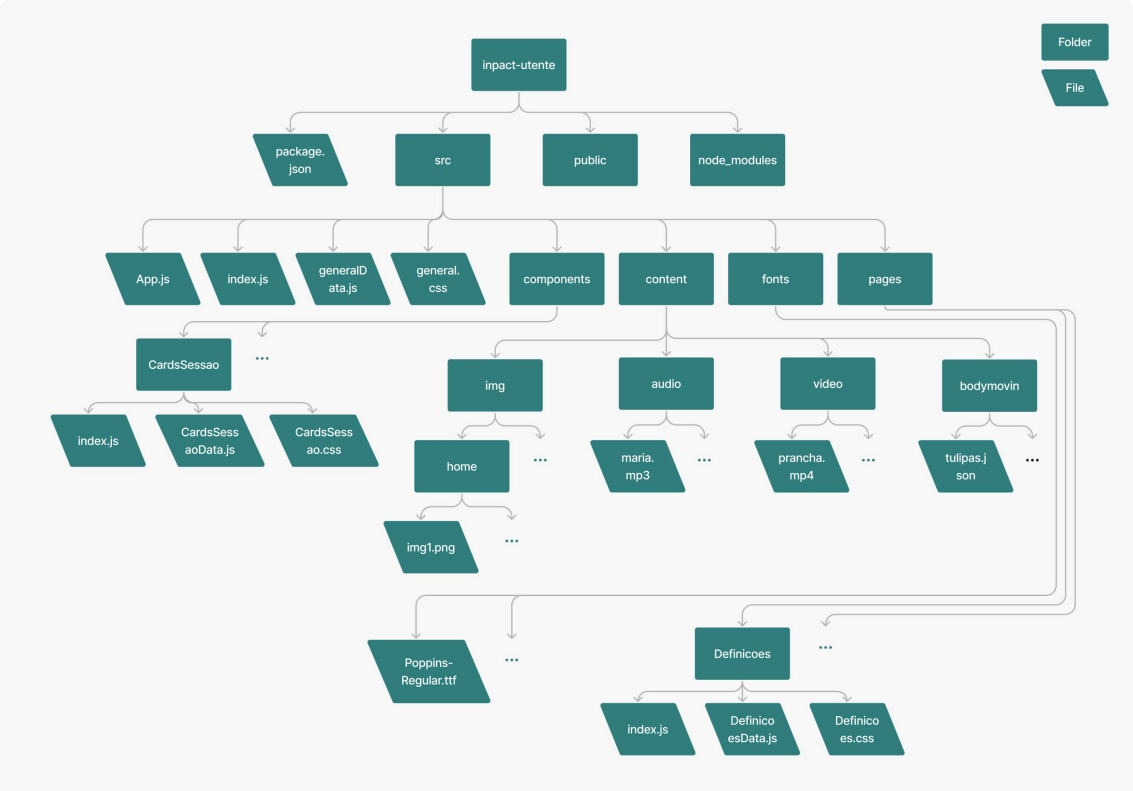

Figure 6.28: Implementation: Code structure

6.5 Advanced functionalities

All pages of the high-fidelity prototype have been implemented, however, the developed application is still a proof-of-concept as it is not linked to a database and is not a finished, market-ready product (other INPACT project members are responsible for implementing this part of the system). However, we wanted to test the new user interface elements that have been developed, such as the gamification, the virtual assistant and all the new features which we have presented throughout section 6.2. For this reason, we decided to implement a full version of the application, that provides the experience, look and feel of what we envision the final version to be, but the information presented is not dynamic.

6.5.1 localStorage

On the home screen, each session has an associated card. Each of the cards has a status. The status can have the value 'não realizado' or 'já realizado' if the user has not yet done the session or has already done it. To provide a realistic user experience, the application displays the message 'não realizado' when the users start the sessions. The status of the card associated changes to 'já realizado' when users perform the first session.

In order for the user to have the experience described above when testing the application, a browser API called localStorage was used in the testing phase. The status of each card is stored in localStorage as a boolean value (true or false), enabling us to customise the text for each state. If the status is true, the text on the card says 'não realizado' and if it is false, it says 'já realizado'.

The progress bar, like the card status, is determined by the values stored in localStorage. It grows in proportion to the number of sessions held. If all values are true, i.e. no sessions have taken place, the bar is not filled and shows '0% completo'. If one of the values is false and the others are true, the bar is 1/3 and shows '33% completo'. If two are true and one is false in the array of the localStorage, it is 2/3 filled and the text '66% complete' appears, and if all three are true, it is all filled and the text '100% complete' appears.

The same applies to other components such as notifications and messages. If the user has not yet completed any sessions, only one notification appears, namely a welcome message. Other notifications appear when the user completes at least one session. In addition, notifications have their own localStorage, which keeps track of the total number of notifications present and the number of notifications tapped on. If none of them has been touched, the status is true; if they have been tapped, the status is false. With this control, we can change the text 'Tens 3 notificações por ler' to the number that corresponds to the actual number of notifications still to be read. Furthermore, when the user has no more unread notifications, i.e. the array elements are all false, the notifications icon switches to the off state, indicating that all messages have been read. As for the message screen, no message from the physiotherapist appears if no sessions have taken place yet, but after a session it does.

The inclusion of this API improves the user experience by simulating the dynamics of the commercial version of the application.

6.5.2 Datepicker

Datepicker is a user interface component that lets users select a date from a calendar. They can navigate between days, weeks, months and years to select the date they want. In React, the datepicker is provided by the library "react-datepicker".

The datepicker has been implemented in the application in the history screen so that users can see their progress. By implementing this function, the user can easily select the dates he/she wants. This implementation is important for the

evaluation of the user interface phase, as this component provides a more realistic user experience.

6.5.3 "Session performance" screen

The session performance screen is one of the most important parts of the INPACT user interface because the application's main purpose is to execute rehabilitation sessions. This component is not only the most vital but also the most complex to implement.

This page has several loops and mechanisms that interact with each other to allow the session to progress. The loops are created by the circular progress bar (circular element on the right side of the images in Figure 6.29). This is a component from the 'react-circular-progressbar' library. This progress bar goes from zero to 100, 10 by 10 at a time. When the progress bar reaches 100, it stops, starts the 10-second countdown (second image) and adds another series to the series counter at the end (element at the top left of the image). After these interactions, a pop-up window appears where the user can start the exercise again (third image). If the user says 'start', the progress bar goes back to zero and everything starts again.

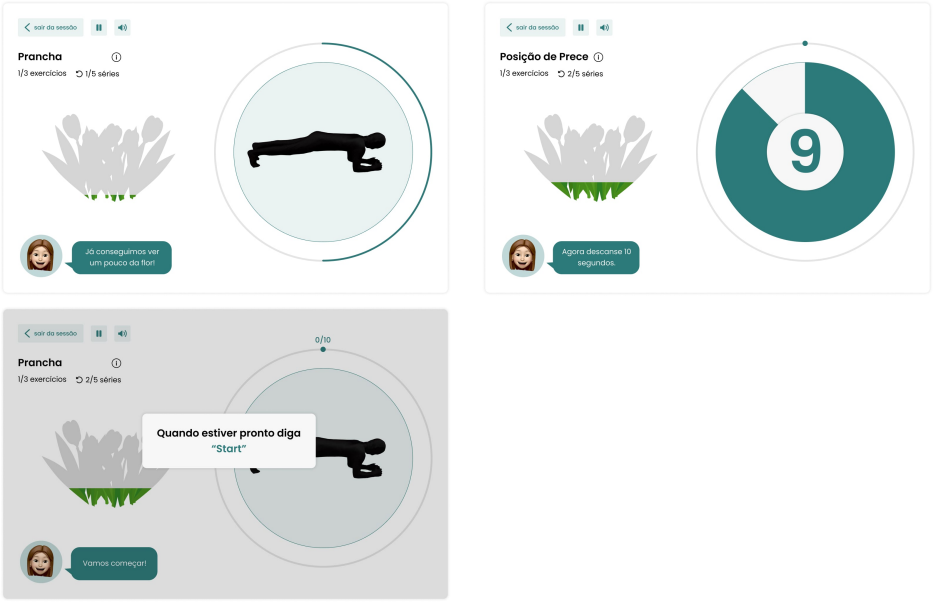

Figure 6.29: Implementation: Session Performance

Another important function on this page is voice control. This is implemented through a component of speech recognition, the 'react-speech-recognition' library. This feature is crucial because it saves the user from having to return to the tablet again and again during a session to start and restart the session's exercise. This allows the person to start the session when they are ready. The pause between exercises is set to 10 seconds. However, some users need more time before continuing with the next series. With voice control, the user restarts the exercise only after saying 'start' again, so the user can take a longer break if needed. In this way, the session can be tailored to each individual user.

6.5.4 "Chat" screen

We did not implement a chat function, as this is beyond our current knowledge and was not the focus of this dissertation. Nevertheless, as the interaction between the person undergoing rehabilitation and her/his physiotherapist is an important feature of the INPACT application, it was important to implement it.

To make it seem like the user is actually exchanging messages with her/his physiotherapist, we developed a function called 'handleMessageSend'. When the user sends a message in the chat, the function 'handleMessageSend' is activated, which inserts a new paragraph on the screen saying what we previously wrote in the function to reply when this action is done, which is "De nada! Fico à espera de voltar a falar consigo brevemente.".

6.6 Summary of the chapter

This chapter started by presenting the graphic identity for the new INPACT application, then the prototypes created (mid and high fidelity) and the implementation process of the proof-of-concept application. The implemented proof-of-concept is going to be used in the interface evaluation, which will be discussed in the next chapter.

Chapter 7

User Interface Evaluation

Usability and user experience tests are essential to check whether the developed solution addresses the requirements and resolve the problems identified through the heuristic evaluation (as previously mentioned in subsection 2.4.2). This chapter covers the usability and user experience tests conducted with users. This includes the materials and methods used in the tests, the procedures, the results of the tests and their analysis.

7.1 Materials and methods

To conduct these tests we used the traditional (moderated) usability testing method (Tullis & Albert, 2013). To determine whether participants with different characteristics, technological proficiency, and experience with physiotherapy were able to understand and easily use the application. The evaluation was carried out with two different groups, one group of volunteers, with or without experience in rehabilitation, and typically more experienced with technology (group A) and another composed of people undergoing rehabilitation referred by clinics collaborating with the INPACT project, typically older and less experienced with technology (group B). Furthermore, we wanted to know whether watching the tutorial impacted participants' performance and understanding of the system, and as a result, should be made mandatory. For this purpose, the participants of each group were divided into two subgroups: those who watched the tutorial before performing the remaining tasks and those who did not.

The evaluation was carried out with the high-fidelity prototype implemented in React.js (section 6.3) running on a 10-inch iPad. The implemented version of the prototype allowed users to see the setup and tutorial. Initially, all cards on the "home" screen were in the "not performed" state and the "history" screen displayed the up-to-date date. Before the physiotherapy session is carried out, the garden is brown (no life) and has no unlock items and no message from the physiotherapist appears in the "chat" screen. To start the physiotherapy session, users navigated through the "session information" and "errors" pages. The screen that appears when a user performs an exercise is fully implemented, but with dummy

data, as the system is not yet able to receive the user's actual performance. Users can rate the pain, the effort and the whole session and record, play and send an audio message to the physiotherapist. Upon returning to the "home" screen, the status of the completed session card changed to "performed" and the progress bar showed '33% completo'. The garden is green and the unlocked items appear on the screen. In the "chat" screen after the session, users could view and send a message to the physiotherapist. Replies triggered a simulated message from the physiotherapist to create the impression of an actual conversation. The developed screens can be seen in subsection 6.2.3. Additionally, a video showcasing the implemented interface is available at https://youtu.be/nUjzUy-GyME.

A script was prepared to guide the assessment (Appendix L) and the evaluation was divided into three sections: Pre-session questionnaire (Appendix M), tasks and post-session questionnaire (both included in the script (Appendix L)). The **pre-session questionnaire** included questions about the participants' profile, background and experience. Participants were also given **13 tasks** with sub-tasks to complete, to assess the common and usual tasks performed in a physical rehabilitation application. The tasks were:

- T1: Review session information;
- T2: Start physiotherapy session;
- T3: Perform session;
- T4: Evaluate pain and effort;
- T5: Provide session feedback;
- T6: Send audio message to physiotherapist;
- T7: Session evaluation;
- T8: View notifications;
- T9: Go to garden;
- T10: Send text message to physiotherapist;
- T11: Review sessions history;
- T12: View daily session summary;
- T13: View monthly session history.

The **post-session questionnaire** contains seven open-ended questions, a System Usability Scale (SUS) questionnaire and Net Promoter Score (NPS) to assess the user experience of the application. The SUS questionnaire contains ten statements about the experience of the application on a likert scale where respondents indicate whether they fully disagree, disagree, neither agree nor disagree, agree or fully agree with each sentence. The NPS is a scale ranging from 0 to 10 indicating how likely a user would recommend the application to others.

7.2 Procedures

Ethical approval had been granted for the project (CE-UBI-Pj-2020-070:ID2177) prior to the start of this dissertation. This section now outlines the procedures followed in preparing and conducting the evaluation of the INPACT user interfaces, from the recruiting of participants up to data collection.

Group A participants were recruited from the author's personal networks through an e-mail describing the project, the purpose of the evaluation, and a link to schedule the evaluation session, in case of availability. Group B participants were recruited from INPACT's partner clinics through the physiotherapist working on the project.

With regards to the settings of the evaluation sessions, both groups carried out the usability tests face-to-face on the same tablet, running the INPACT application. The test sessions with group A took place on a dedicated room where the tablet was placed on a table with a chair in front and a yoga mat behind the chair (Figure 7.1). When prompted to perform the physiotherapy exercises, group A participants moved to the mat to perform the exercises, while the tablet continued running the application. Once finished, participants sat on the chair to perform the remaining tasks of the session.

Figure 7.1: Usability and user experience evaluation: Group A tests setting

The tests with group B took place in the clinics. The clinics could not offer a dedicated room to carry out the evaluation sessions, so the tests took place on the physiotherapy cabinets, at the end of the participant's own physiotherapy session. Tests were then subject to the participant's time availability and cabinet availability. Because the cabinets were less spacious and filled with physiotherapy equipment, group B participants were exposed to the exercise screens of the application, but did not physically perform them. While interacting with the application and performing the tasks, group B participants held the tablet in their hands.

All tests followed the evaluation script (Appendix L). First, the facilitator explained the context of the INPACT project and what was going to happen during the session. Participants were then given an informed consent form (Appendix N) to read and sign and authorise the audio-recording of data. The pre-session

questionnaire was then handed out to the participant to fill out. After completing the questionnaire, the usability test of the INPACT application started. Tasks were introduced to participants one at a time, and when a task was completed the next one was presented, following the order of the evaluation script. Finalised the usability test, the evaluation proceeded to the open-ended questions and finally the Net Promoter Score (NPS) and System Usability Scale (SUS) questionnaires.

All tests were moderated by a member of the INPACT project team. Group A was moderated by the author and the tests with group B were moderated by three members of the team: one person responsible for the pre-session questionnaire, another (the author) for the tasks, the open-ended questions of the post-session questionnaire and NPS and the third for the SUS questionnaire.

The following metrics were collected for the usability tests: taps on the screen, errors, time on task and task completion. To gauge participants' user experience, we audio-recorded participants' answers to the seven open-end questions, the NPS and SUS questionnaire. For the data analysis, the results of the usability and user experience tests were entered into a spreadsheet (Google Sheets[1]). The information was organised into two groups of tables, one organised per usability test task (Table 7.2) and another per group of participants (Appendix O). Both groups of tables contain the usability metrics (taps per screen, errors, time on task and task completion). Whereas the tables organised per task show the overall results of both groups in each task, the table organised per group shows a detailed view of the results of each group for each metric. Additionally, graphics were created to get a visual representation of the results of each metric.

7.3 Participants

	Gender		Age						Has performed physiotherapy	
	Male	Female	18-24	25-29	30-39	40-49	50-64	65 +	Yes	No
Group A	8	16	15	4	0	0	4	1	9	15
Group B	11	12	0	2	0	7	8	6	17	5

	Performing physiotherapy at the moment		Use tablet or mobile phone		Frequency of tablet or mobile phone use		
	Yes	No	Yes	No	never	4-5 times (month)	more than 5 times (week)
Group A	2	22	24	0	0	0	24
Group B	23	0	22	1	1	1	20

Table 7.1: Usability and user experience evaluation: Participants

The evaluation involved 47 participants, divided into two groups. **Group A** (Table 7.1) consisted of 24 participants, eight male and 16 female. 15 of the 24 participants were aged 18 to 24, four were 25 to 29, another four were 50 to 64, and one was over 65 years old. Where nine of the participants have previously performed physiotherapy and two are currently undergoing physiotherapy. All participants reported using their mobile phones regularly for various activities, from most to least frequently, reading and writing messages, making phone calls, checking information such as the news and weather, reading and writing e-mails, making

[1] `https://www.google.com/sheets/about/`

video calls and playing games. In this group, the number of people who watched and did not watch the tutorial was equal, 12 for each.

Group B (Table 7.1) included 23 participants, 11 male and 12 female. With regards to age distribution, two were 25 to 29, seven were 40 to 49, eight were 50 to 64 and six were over 65 years of age. All participants are currently undergoing physiotherapy and 17 participants reported they had done physiotherapy before. Into what concerns technological proficiency, this group reported diverse levels, where one person does not use a mobile phone or tablet, another uses it rarely (four to five times a month) and two use it only to make phone calls and read messages. For the rest of the group, mobile phones or tablets are mostly used to make phone calls, read and write messages and search for information. Only two users said they used phones and tablets to play games. In this group, 13 participants watched the setup and tutorial, 10 people did not.

For an overview of the participants please refer to Table 7.1.

7.4 Results and analysis

This section presents the results of the evaluation. We first analyse task performance metrics of the usability tests to then explore the results of the post-session questionnaire, the System Usability Scale (SUS) and the Net Promoter Score (NPS). Finally, we review the differences between the two groups of participants.

In this section, we refer to Group A (volunteers with or without experience in physical rehabilitation) as PAn and to group B (people underdoing rehabilitation referred by the INPACT partner clinics) as PBn. To distinguish between those participants who watched the tutorial before the usability tasks, group A and group B participants who watched the tutorial are referred to as PATn and PBTn, respectively. 'n' refers to the participant number.

7.4.1 Tasks

The usability tests comprised 13 tasks. Table 7.2 presents an overview of the results. More complete versions of these tables can be found in Appendix O. Next, we analyse the results per task.

T1: Review session information was completed on an average time of 11 seconds (max 31s, min 4s). Two group B participants experienced difficulties performing the task and three errors were recorded: PBT4 first tapped on the history button instead of the 'ver sessão' button (2 errors), and PBT3, when prompted to name the exercises of the session, described the illustration on the top of the page instead of the session exercises (1 error).

T2: Start physiotherapy session was performed on an average time of four seconds (max 28s, min 1s), however, three users (PAT1, PAT4, and PA5) of group

	T1				T2				T3				T4			
	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC
Average	3	0,06	11,24	1	3,12	0,17	3,91	0,94	0,81	0,34	7,24	0,79	4	0,85	17,40	1
Standard deviation	0,42	0,06	6,40	0	0,38	0,38	4,63	0,25	0,45	0,56	4,58	0,42	0	0,356	5,83	0
Total	141	3	528,10	47	55	8	183,73	44	38	16	340,32	37	188	40	817,77	47
Mode	3	0	7,98	1	1	0	-	1	1	0	3,91	1	4	1	-	1

	T5				T6				T7				T8			
	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC
Average	0	0,02	15,29	0,98	1,89	0,11	8,17	0,91	2	0	4,31	1	1,06	0,40	6,44	0,83
Standard deviation	0	0,15	4,28	0,15	0,31	0,31	2,83	0,28	0	0	1,99	0	0,672	0,54	6,29	0,38
Total	0	1	718,83	46	89	5	383,81	43	94	0	202,77	47	50	19	302,53	39
Mode	0	0	-	1	2	0	5,78	1	2	0	3,97	1	1	0	1,08	1

	T9				T10				T11				T12			
	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC	ToS	Errors	ToT (s)	TC
Average	1	0,43	7,21	1	3	0	9,88	1	1,09	0,06	5,35	1	2,06	0,43	8,88	0,81
Standard deviation	0	0,50	3,86	0	0	0	3,85	0	0,28	0,25	3,03	0	1,07	0,88	7,02	0,40
Total	47	20	338,80	47	141	0	464,56	47	51	3	251,56	47	97	20	417,27	38
Mode	1	0	-	1	3	0	12,85	1	1	0	4,63	1	2	0	9,05	1

	T13			
	ToS	Errors	ToT (s)	TC
Average	4	1,13	18,41	4,21
Standard deviation	1,67	1,66	9,76	0,28
Total	188	53	865,07	43
Mode	3	0	43,03	1

Legend: ToS: Taps on Screen; ToT: Time on Task; TC: Task Completion

Table 7.2: Usability evaluation: Results per task

A were not able to complete this task and eight errors were recorded. All errors occurred because participants played the exercise video before tapping on the 'iniciar sessão' button. PAT1, PAT4 and PA5 stated that they thought the 'inicar sessão' button would lead them to a login screen instead of starting the physiotherapy session.

T3: Perform session took an average of seven seconds to be completed (max 25s, min 2s), yet, ten users did not conclude the task. Four users (PAT2, PAT3, PAT5 and PA7) said they would say 'stop' to pause the session, as they had to say 'start' to begin it. Because the functionality was not implemented, this was considered an error. The implementation of this functionality is something to consider for the next version of the application. Two people (PA3 and PBT8) touched the screen elsewhere and not on target. Four participants (PA11, PBT9, PB5 and PB7) said they would not answer the phone, even though they were asked to stop the session. These four people are all 65 years old or older.

T4: Evaluate pain and effort was completed in an average time of 17 seconds (max 33s, min 9s) and 40 errors, by 40 users were recorded (no errors were recorded for PAT4, PAT7, PAT9, PA6, PA9, PTB6 and PTB11). After evaluating the pain and effort, a pop-up appears on the screen saying that the user has unlocked a new element for the garden, however, when asked why a new item had been unlocked, participants stated it was because they had completed the exercise, instead of the pain and effort evaluation. This means the pop-up is something to consider for the next version of the application.

T5: Provide session feedback was not concluded by one user (PBT4), as he re-

sponded "I do not know". The average time of completeness was 15 seconds (max 29s, 4s) and no errors were recorded.

T6: Send audio message to physiotherapist was completed on an average of eight seconds (max. 14s, min. 2s). Four participants (PBT4, PBT5, PBT7 and PBT8) did not complete the task. These participants verbalised the message out loud, however, they did not press the record button and then moved on to the next page.

T7: Session evaluation was completed on an average of four seconds (max 10s, min 1s) and no errors were recorded.

T8: View notifications was finished on an average of six seconds (max 27s, min 1s), where eight people (PBT3, PBT4, PBT9, PBT10, PB3, PB6, PB7 and PB10) were not able to conclude the task and 19 errors were recorded. PBT4 and PB7 participants who did not finish the task reported that the 'bell' icon referred to alerts rather than notifications. Seven errors were performed because users taped the chat button, instead of the notification button. The remaining six errors were caused by touching elsewhere on the screen before noticing the notifications button.

T9: Go to garden was completed on an average of seven seconds (max 15s, min 2s). Everyone completed the task but 20 errors, by 20 users (PAT2, PAT3, PAT12, PA2, PA6-PA8, PA11, PA12, PBT4-PBT6, PBT10, PB2-PB7 and PB9) were recorded. When asked why the garden was green, no participants were able to say it was because they had exercised. Users did not understand this, even though seven of the 20 people had seen the tutorial before. Thus, we conclude that is not straightforward to understand the life of the garden and is something to consider for the next version of the application.

T10: Send text message to physiotherapist was completed on an average of 10 seconds (max 20s, min 4s) and no errors were recorded.

T11: Review sessions history was completed on an average of five seconds (max 15s, min 2s), still, three errors were recorded (PB6, PB7 and PB9), due to users touching elsewhere on the screen before tapping on the 'history' button. Everyone completed the task.

T12: View daily session summary was completed on an average of nine seconds (max 38s, min 3s), nine users (PAT4, PA11, PBT3, PBT9, PBT10, PB3, PB6, PB7 and PB10) did not complete the task and 20 errors were recorded. The nine users could not find the button to change the date. The remaining 11 errors all occurred due to users touching on the week tab to see if they had performed any sessions on the day we asked to consult. Although the latter is not the most efficient way to perform the task, the result achieved is the same.

T13: View monthly session history took an average of 18 seconds to complete (max 43s, min 6s). In terms of time conclusion, four people (PBT3-PBT5 and PBT7) from group B did not finish the task and 53 errors were recorded, with this being the screen with the most errors. 39 errors occurred because all the users accessed the week's progress to see their progression in the first week of the month. This was not the most efficient way to complete the task, but the result is

the same, however, the errors indicate that the task was not explicit enough. Six of the 53 errors occurred because the user touched elsewhere on the screen before realising where to go. The remaining eight errors were recorded by the four users who had not completed the task and were tapping the screen to figure out how to do it.

Overall, participants of both groups A and B were mostly able to complete all tasks, however, some tasks took longer than expected to complete. There were also tasks that users were not able to conclude. The task that took the longest time to complete was T4 and is the longest task because it is the one with the most expected taps on the screen, as shown in Table O.1. T13 had the most errors recorded, but the errors were not an impediment to completing the task. T3 was the one that most participants could not complete, as most indicated they would interrupt the session by saying 'stop'. This was a voice command that was not implemented but would be considered in the next design iteration. In general, as shown in Table 7.2, T4 is the only task that has a deviation from the expected error mode value. This was the task with 40 errors because 40 users could not understand why they gained the extra item for the garden, which was not a significant error. These results were good because all the other values analysed were within the expected mode.

Between groups analysis

Having two distinct test groups allows us to establish comparisons between them. Following we will analyse the overall performance of each group through graphs created for the number of taps (Figure 7.2), errors (Figure 7.3), time on task (Figure 7.4) and task completion (Figure 7.5) for each group (A and B) in each task.

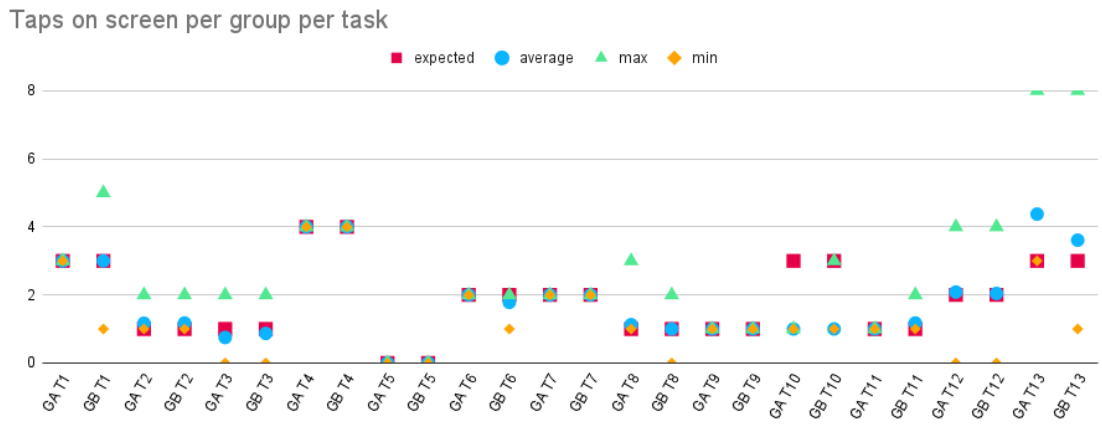

Figure 7.2: Usability evaluation: Taps on screen per group per task

Through the analysis of the results, Figure 7.2 and Figure 7.4 shows that the average number of taps and time on task of the two groups were similar. Group B (85 errors) performed a larger number of errors (in total) than group A (55 errors) (Figure 7.3). There were also more tasks which were not completed in group B (12 people) than in group A (8 people) (Figure 7.5).

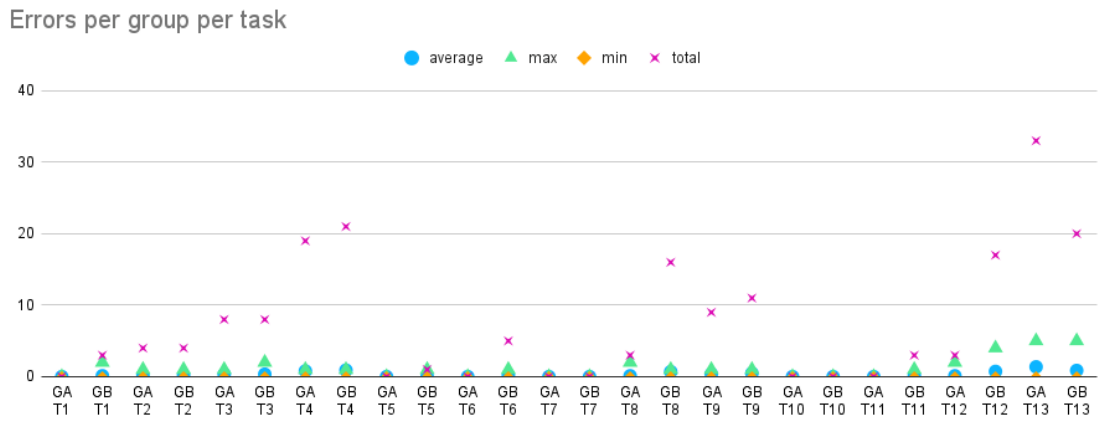

Figure 7.3: Usability evaluation: Errors per group per task

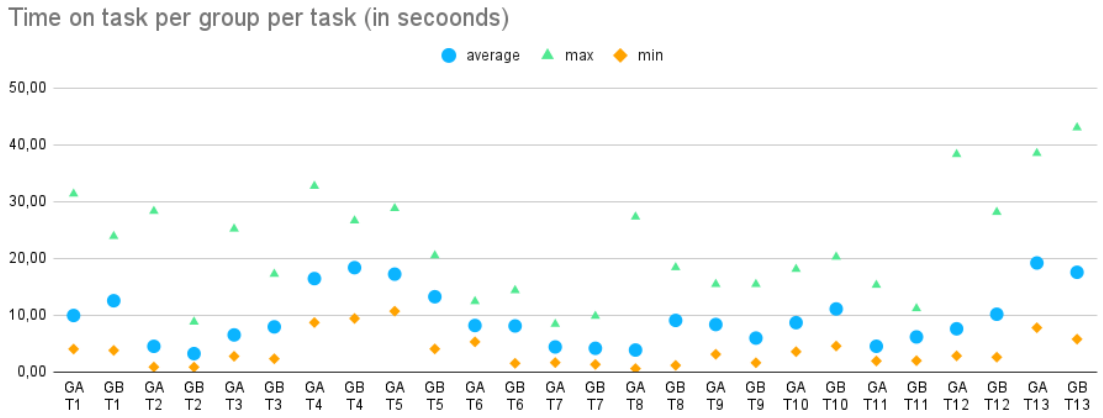

Figure 7.4: Usability evaluation: Time on task in seconds per group per task

Results show that group A had more difficulty identifying the 'iniciar sessão' button to begin their physiotherapy session (T2) than users in group B. This could be explained by group B's greater familiarity with physiotherapy terms and group A's with technology, associating the text 'iniciar sessão' to login. Furthermore, regarding the errors recorded, we can observe that there was a greater discrepancy between the total errors in T6, T8, T12, and T13. In T6, T8 and T12, group B recorded more errors than group A, and the errors were made by people at or above 50. Besides, we identified that it was people aged 50+, who had the most difficulty recognising the notification button (T8), in both groups. The different levels of exposure and experience with technology between the two groups might explain the differences in the results of T6, T8 and T12. Still, among a total of 26 tasks, errors only occurred in 9 of them, and there were only two tasks (T3 and T12) in which both groups struggled.

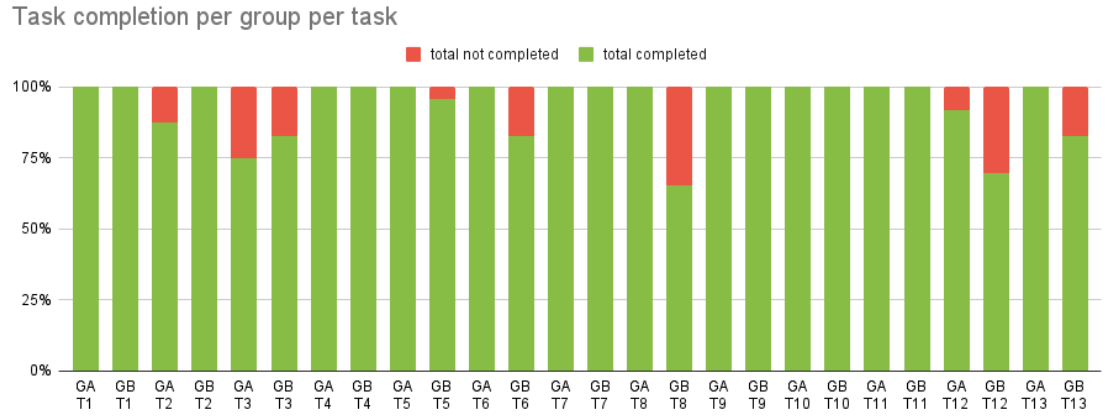

Figure 7.5: Usability evaluation: Task completion per group per task

Tutorial tests results analysis

Of the 12 people in group A who watched the tutorial, three could not figure out why the garden was green. Of the remaining 12 people that did not see the tutorial, six could not figure it out either. Users who have seen the tutorial are more adept at recognising why the garden is green, according to the results. In group B, from the 13 people who watched the tutorial, four of them could not figure out why the garden was green and from the remaining 10 people who did not see the tutorial, seven could not figure it out either. These results demonstrate that as in group A, the tutorial helped most users to understand why the garden was green, which demonstrates the importance of displaying the tutorial during the first interaction with the application. However, the user interface should be straightforward with and without the tutorial. The test results show that the life of the garden is not clear, yet, it is a challenge for both groups. This is something to consider for the next version of the application.

7.4.2 Post-session open-ended questions

This section analyses the seven open-ended questions of the post-session questionnaire results, that aimed to gain an understanding of the participant's experience during the interaction with the application.

When asked whether all the information needed to perform the physiotherapy session remotely was provided, only one user (PB1) said that the information received was insufficient. To that, the user added that: "It should be possible to update one's body weight and to enter the value of the weights used in the sessions".

When asked if there were any problems or difficulties, seven users (PAT11, PA3, PA4, PA7, PA11, PBT12, PB4) answered yes: three (PAT11, PA3 and PA4) said they had difficulties with the weekly history page, two (PA7 and PA11) could not identify the reason for the garden being green and two (PBT12 and PB4) could not locate the notification.

Following, when asked about their favourite screen, most participants chose the screen they see when they are performing the exercise, people especially liked to see the garden element being unlocked and to receive the positive incentive of the virtual assistant. Two screens tied for second place in participants' preferences, the garden and the session information, with nine mentions each. Then, we asked which part they liked least, to which they all replied that they had none.

When asked if users felt motivated to do more physiotherapy sessions with this application, two users (PBT3 and PB2) answered no and another two (PB1 and PB9) stated that they felt they needed to use the application longer to be able to respond. PBT3 justified his decision by saying that it is not in his nature to use technology, while PB2 said that she does not like doing exercises without supervision. The other users said they felt motivated and explained that the application is very practical and provides more flexibility for each individual to do regular physiotherapy.

When asked if the garden's construction was important in motivating them to attend their physiotherapy sessions, six participants (PAT12, PA6, PB1, PB2, PB5 and PB8) responded that this was indifferent to them, although they acknowledge that seeing the garden gradually being completed can be a stimulus for some. The remaining users said that it was important to them because it is a different way of tracking their evolution, as it is a visual stimulus that they see growing. Finally, users were asked if they had any additional comments or suggestions, to each only one said that would add an information button on the garden screen showing the tutorial.

The analysis of the open questions reveals that most users did not experience significant difficulties using the application and felt motivated to use it and complete the garden. The test results for the redesign were vital, but longer tests with concrete conclusions about long-term motivation will be required in the future.

7.4.3 System Usability Scale and Net Promoter Score

This section analyses the results of the System Usability Scale (SUS) questionnaire and the Net Promoter Score (NPS) (Table 7.3; Table 7.4).

	System Usability Scale											Net Promoter Score
	1	2	3	4	5	6	7	8	9	10	Total Score	Total
Average	4,35	1,54	4,59	1,76	4,54	1,35	4,37	1,30	4,39	1,43	87,12	9,11
Standard deviation	0,77	0,55	0,54	1,1	0,55	0,57	0,57	0,51	0,74	0,81	12,32	1,68
Mode	4	2	5	1	5	1	4	1	5	1	97,5	10
Min value	1	1	3	1	3	1	3	1	2	1	52,5	0
Max Value	5	3	5	5	5	3	5	3	5	4	100	10

Table 7.3: User experience evaluation: SUS and NPS from all participants

Brooke (1996) suggests a model for the interpretation of the SUS (Tullis & Albert, 2013).

For SUS:

- <50: Not acceptable

	System Usability Scale		Net Promoter Score	
	Group A	Group B	Group A	Group B
Average	93,54	80,11	9,54	8,64
Mode	90	75	10	10
Min value	80	52,5	8	0
Max Value	100	100	10	10

Table 7.4: User experience evaluation: SUS and NPS per group

- 50–70: Marginal
- >70: Acceptable

The average SUS score (Table 7.3), from 0 to 100, was of 87.1, the mode 97.5, where only five ratings were between 50 and 70 and the rest from 70 upwards. This is a very good result.

Between groups, the average in group A was 93.5, while in group B was 80.1 (Table 7.4). The discrepancy between groups may be due to the fact that users in group B are not so comfortable with technology. In group A all ratings were above 70, while in group B there are five ratings between 50 and 70, and the remaining 16 above 70. Still, together or in separation, results fall within the acceptable range.

Net Promoter Score (NPS) also follows a model, created by Reichheld (2003) to analyse the results (Tullis & Albert, 2013).

For NPS:

- 0-6: Detractors
- 7-8: Passives
- 9-10: Promoters

The NPS from 0 to 10 had an average of 9.1, the mode 10, having had two ratings between zero and six (detractors), eight ratings from seven to eight (passives) and the rest from nine to 10 (promoters). The user who rated the NPS with 0 stated that they would need to use the application more often to rate it. The person who gave it a 6 said that this type of application does not interest her/him. Though we had two detractors the majority (36) of the participants had values within the promoter level.

Between groups, group A averaged 9.4 and group B averaged 8.6 (Table 7.4). Group A had values ranging from eight to 10, whereas group B had one zero, one six, and one seven, with the remaining values ranging from eight to 10.

7.5 Analysis of the redesign in relation to the previous version of the user interface

One of the goals of this dissertation was the redesign of the INPACT user interface. As reported by Fonseca, Santos, Amorim, and Silva (2023), in the usability and the user experience of the previous version of the user interface had been previously evaluated by five participants, aged between 25 and 65 years, all of whom had previously done physical rehabilitation. It is therefore pertinent to review the results of the redesign and establish a comparison where appropriate. Nonetheless, it is important to note that a lot more functionalities have been implemented in the current version of the application and therefore no straight comparisions can be made.

Table 7.5 shows the tasks that, to some extent, can be compared between the evaluations of both versions. Table 7.6 shows the results of time on task and number of errors obtained in the evaluation of the previous version of the user interface.

Task on evaluation with previous version	**Task on evaluation with current version**
T1: See details of the rehabilitation session	similar to T1
T2: Change rehabilitation settings	no correspondence
T3: Perform rehabilitation session	T3
T4: Evaluate the pain, fatigue and the overall session	T4 and T7
T5: Send an audio message to the physiotherapist	T6
T6: Exit the session	no correspondence

Table 7.5: Tasks on evaluation with previous version and their correspondence in the evaluation made on the new version of the user interface

Participants	T1		T2		T3		T4		T5		T6	
	Errors	ToT (s)	Errors	ToT (s)	Errors	ToT(s)	Errors	ToT (s)	Errors	ToT (s)	Errors	ToT (s)
P1	2	41	3	26	3	46	1	11	0	21	0	13
P2	2	31	1	24	1	54	2	25	1	24	0	19
P3	2	54	3	58	0	30	0	10	2	31	0	38
P4	1	18	1	10	1	34	0	9	0	7	1	16
P5	1	25	1	16	0	38	1	12	1	13	0	17
Average	1.6	33.8	1.8	26.8	1	40.4	0.8	13.4	0.8	19.2	0.2	20.6

Legend: ToT: Time on Task

Table 7.6: Usability evaluation: Errors and time on task (in seconds) for each task of the previous user interface

In the previous version of the system, the exercise session screen (T3) was problematic. Three of the five participants performed errors due to misguided information and cropped elements that made it challenging to understand how to proceed in the exercise session. In contrast, in the current version of the user interface, although there were still participants who struggled to complete the session (6 of group A, 4 of group B), errors were due to the new pause button implemented in this version. Besides those challenges, as reported in the post-session interview results, this part of the application was indicated as the participants' favourite, which indicates an improvement.

On T4, of the previous user interface, four errors were made by three users because feedback was missing, which prevented participants to understand whether their selection had been made. There were also buttons on the screen which functionality had not been implemented, which caused confusion. In the evaluation of the current version of the system, these functionalities were assessed through T4 and T7. No errors were recorded by any user in performing strictly the tasks covered in the previous evaluation. The errors recorded in T4 were due to a question asked at the end of the effort assessment, where participants were asked if they knew why they had gained a new item for the garden. Although participants said it was because they had finished their session, which would have made sense, the reason was in fact because they had replied to the effort question.

The voice message recording was assessed in T5 in the previous evaluation and in T6 in the current one. In the previous user interface, three participants made four errors. These errors occurred because users felt the need to press the record button multiple times, due to the lack of feedback. In the current version of the interface, four participants experienced challenges because they did not press the record button, yet that did not prevent them from proceeding with the task. Furthermore, the new user interface allows the user to record, playback, and send the message they recorded, receiving automatic feedback on their performance.

Regarding the System Usability Scale (SUS), the average of the five participants was 72, while in the new user interface, with 47 participants, the average was 87.12. This is significant progress that brings the user interface from the lower to the upper band of the acceptable range, especially if one considers that the mode value for the new user interface was 97.5. Furthermore, the maximum value was 85. While both experiences are situated in the acceptable range, the new user interface has higher scores, when compared.

For Net Promoter Score (NPS) the average was 9.4 (previous user interface) with four participants answering between nine and 10 (promoters) and one eight (passives), while in the new user interface was 9.1, having 36 ratings between nine and ten (promoters), eight between seven and eight (passives) and two between zero and six (detractors). We can conclude that most people would recommend both applications because they consider it a fundamental instrument to be able to bring physiotherapy treatments to everyone everywhere.

The results of the evaluation not only show an improvement in the usability and user experience of the application for the current version, but also the evaluation results are more robust, as they were drawn from a much larger sample size (47 participants versus 5 participants). Furthermore, having conducted the evaluation with two distinct groups, allow us to conclude that the platform can be used by both groups.

7.6 Final evaluation considerations

Overall, the evaluation of the redesign showed positive results, as already analysed. However, there are still issues that need to be addressed.

Starting with task T2 (start physiotherapy session), three users did not finish the task because they thought that the 'iniciar sessão' button was for login. With a previous explanation about the application from the physiotherapist, the users would not have this difficulty. However, adjustments can be made to the button, like changing the name to 'iniciar exercício'.

In T3 (perform session) adjustments have to be made to the method by which the user can pause the session. Four users said they would pause by saying 'pause', which is not a command that was previously implemented but should be in the next iteration.

The notification visualisation task (T8) was not completed by eight people from group B. Group B participants were older and reported having a lower level of technical skill, however, they are a non-negligible part of the target audience of telerehabilitation applications. As two people from group B stated, "The bell icon reminds me of alarms and not notifications". A solution to this problem could be to change the icon symbol and location, because next to the notification icon is the chat, which has a similar appearance. In contrast, users had no problems identifying the chat icon as the place to send a message to the physiotherapist (T10).

Tasks 12 and 13 recorded 20 and 39 errors, respectively. As in task T2, a previous explanation of the interface by the physiotherapist may help the users efficiently perform these tasks, as most errors were due to lack of efficiency, which did not prevent participants from finishing the task.

The errors recorded are easy to be addressed and should be addressed in the next iteration of the system.

7.7 Summary of the chapter

In this chapter, we first presented the methods, materials and procedures for conducting the usability and user experience tests. We then described the two groups of participants, their characteristics and their experiences. Then, the results of each task were analysed according to the established metrics: taps per screen, time on task, errors and task completion. This was followed by an analysis of the post-session questionnaire, the System Usability Scale (SUS) and Net Promoter Score (NPS).

We can conclude that users were satisfied with the application and found it easy to use. Significant improvements have been made compared to the previous version of the user interface. However, there are still some flaws that need to be addressed in the next version of the application, such as those related to the notifications and the life of the garden. **The tests were necessary to analyse the redesign of the system, but there are some features of the application that can only be tested with tests where people interact with the system over a longer period of time, such as long-term motivation.**

Chapter 8

Conclusions and Future Work

This chapter presents the conclusions of the work and outlines what has been done as well as the contributions and limitations of the work. The chapter closes with the opportunities for future work.

Developed as part of the INPACT project, this dissertation aimed to redesign and implement a telerehabilitation application. At the same time, it also aimed to design a strategy that could motivate use. The INPACT project already had a user interface for people undergoing rehabilitation. Therefore, the first step of this dissertation was to conduct a heuristic evaluation of the existing user interface. Next, we developed a gamification strategy that could support motivation and continuous use. Once the strategy was defined, and considering the results of the heuristic evaluation and the requirements of the project, we designed and developed the new gamified prototype of the user interface. Finally, we validated the new user interface with 47 end-users through a usability and user experience evaluation, which yielded good results. It is our understanding that all the goals of the dissertation were successfully achieved. The new design is functional and is perceived as easier to use than the previous user interface. The gamification strategy was also developed. In the future, its effectiveness should be assessed.

8.1 Contributions

Starting with the evaluation of the previous user interface, the need arose to compile a list of heuristics to evaluate the interface. We created a list of heuristics directed to telerehabilitation applications due to the lack of a complete list to evaluate telerehabilitation systems. Four evaluators used the developed list to evaluate the user interface and considered it to be very complete and appropriate to evaluate this type of system.

An issue identified in chapter 2 was the progressive loss of interest that people underdoing physiotherapy felt while following their rehabilitation plan. The search for solutions to this problem led us to gamification, which we implemented in our application. End-users found it interesting to be able to track their progress as they built a garden, allowing them to receive not only a physical but

also a virtual reward for completing the plan.

Furthermore, in chapter 2, we found that contact between the physiotherapist and the person undergoing physiotherapy should be integrated into remote rehabilitation systems. We have integrated a chat functionality into the developed application that allows contact between the user and the physiotherapist. This was mentioned as important in the tests conducted with the people undergoing physiotherapy in the clinics (chapter 7) and was identified as one of the reasons why people would use the INPACT application.

8.2 Limitations and future work

The new user interface was tested with a large number of volunteers, which was excellent, especially when compared to previous tests which were carried out with only five participants. However, the tests with group A and group B could not be conducted under similar circumstances. While group A had ideal test settings with enough space to perform the physiotherapy exercises, in group B this was not possible because the clinic could not provide us with a dedicated room. In addition, the tests in the clinic had to be performed during the users' physiotherapy sessions, which meant that some users rushed to complete the evaluation. There was even one case where the user did not finish the test due to time constraints, resulting in an incomplete evaluation session. The fact that the groups have different test settings limits the ability to compare results between the two groups.

Another limitation concerns the gamification strategy. Because gamification is linked with motivation and motivation can only be assessed over an extended period of time, is it not possible to determine whether the implemented motivational strategy is effective. Future work should address this.

The INPACT application has been redesigned to better address the issues associated with remote rehabilitation. The usability and user experience tests (chapter 7) allowed us to draw conclusions regarding the new design of the developed application. In general, users found the application easy to use and felt motivated to use it in the future. However, problems with the user interface were identified and need to be addressed. During the evaluation phase (chapter 7), we observed that the user struggled the most with two tasks, T8: view notifications and T13: view monthly session history. These screens need to be redesigned to improve the usability and user experience of the application. However, for the most part, these errors were not limiting, and people were able to complete the tasks. Furthermore, these errors should be simple enough to fix and should be included in the next redesign iteration.

The application developed is a proof-of-concept and not a final commercial product. The information is not dynamic, the chat functionality that allows users to communicate with their physiotherapists is not fully implemented and the information inserted and changed is not stored. In the future, the application developed should be integrated with a database and machine learning that is being

developed by other team members. In a future version of the application, more analogies, besides the garden, should be created (e.g. a beach), as different scenarios might be more appealing to users who might not be interested in building a garden.

When the application is fully integrated, a pilot test should be done where people can take it home and test it for a longer period of time. This way it will be possible to assess the system as a whole and to confirm whether the motivational strategy produces the desired results.

In developing the work of this dissertation a number of contributions were made. We are in the process of writing a scientific article with the results, which we aim to submit and publish in the near future.

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Appendices

Appendix A

INPACT's previous user interface

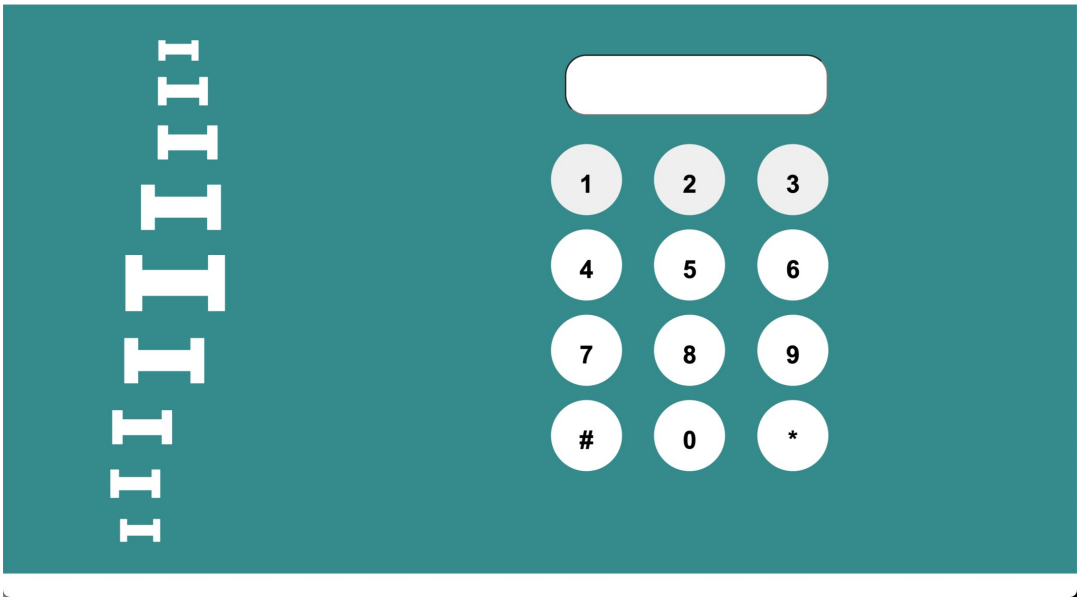


Figure A.1: Previous user interface: "Login" screen

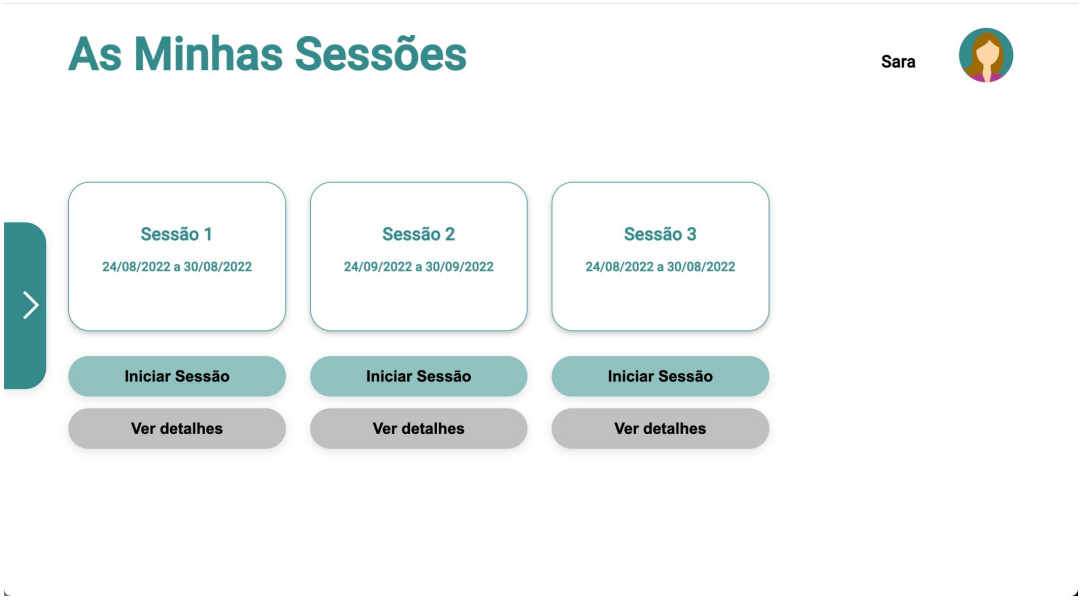


Figure A.2: Previous user interface: "My session" screen

Figure A.3: Previous user interface: "Session details" screen

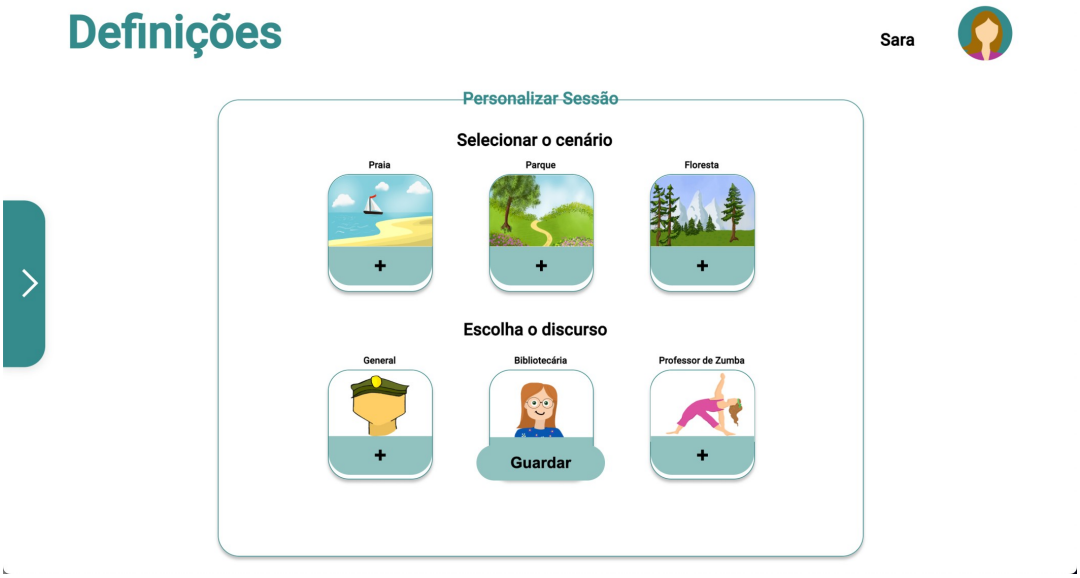


Figure A.4: Previous user interface: "Settings" screen

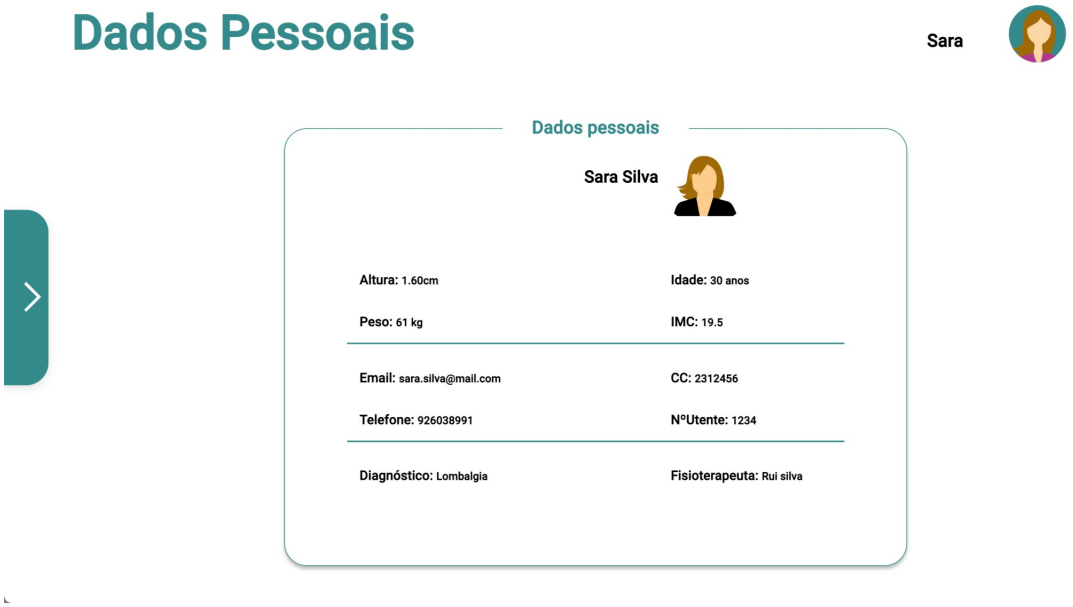


Figure A.5: Previous user interface: "Profile" screen

Figure A.6: Previous user interface: "Notifications" screen

Figure A.7: Previous user interface: "Menu" screen

Figure A.8: Previous user interface: "Session performance" screen one

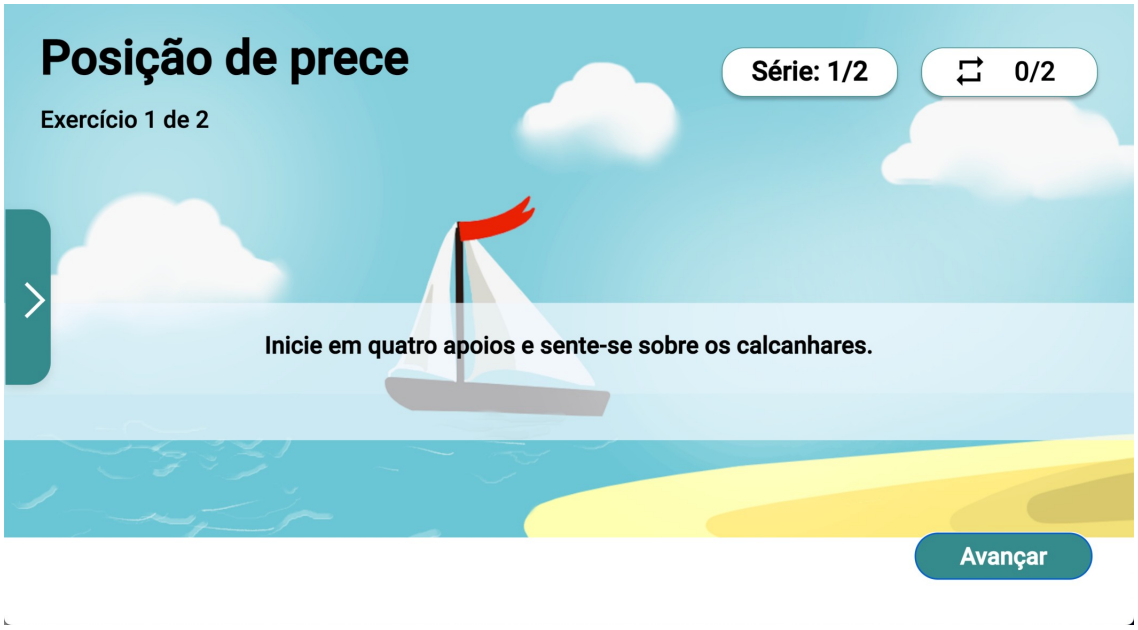


Figure A.9: Previous user interface: "Session performance" screen two

Figure A.10: Previous user interface: "Session performance" screen three

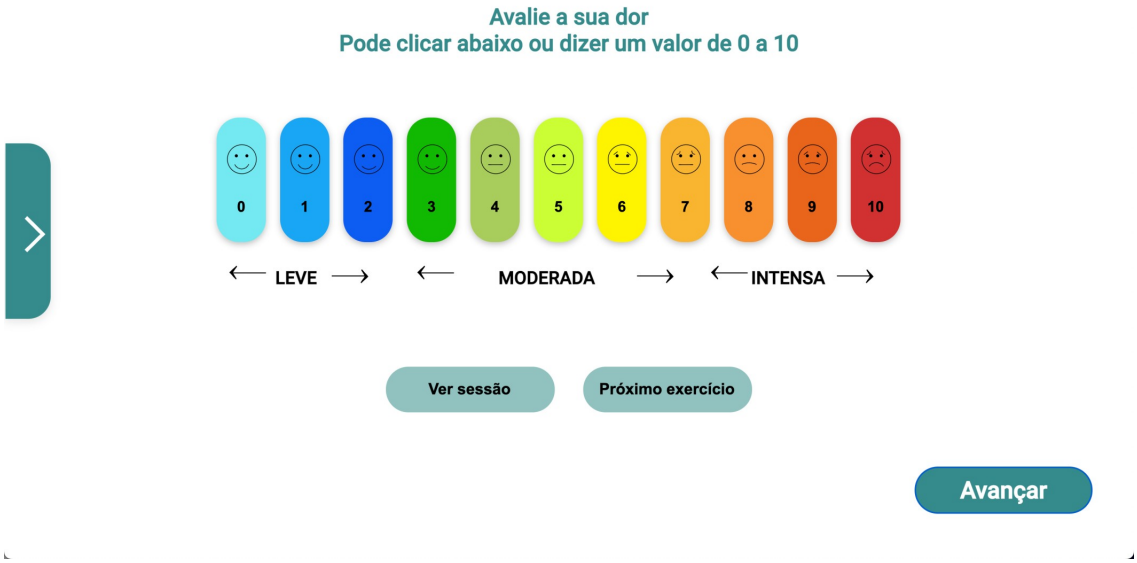


Figure A.11: Previous user interface: "Exercise evaluation" screen one

Figure A.12: Previous user interface: "Exercise evaluation" screen two

Figure A.13: Previous user interface: "Exercise evaluation" screen three

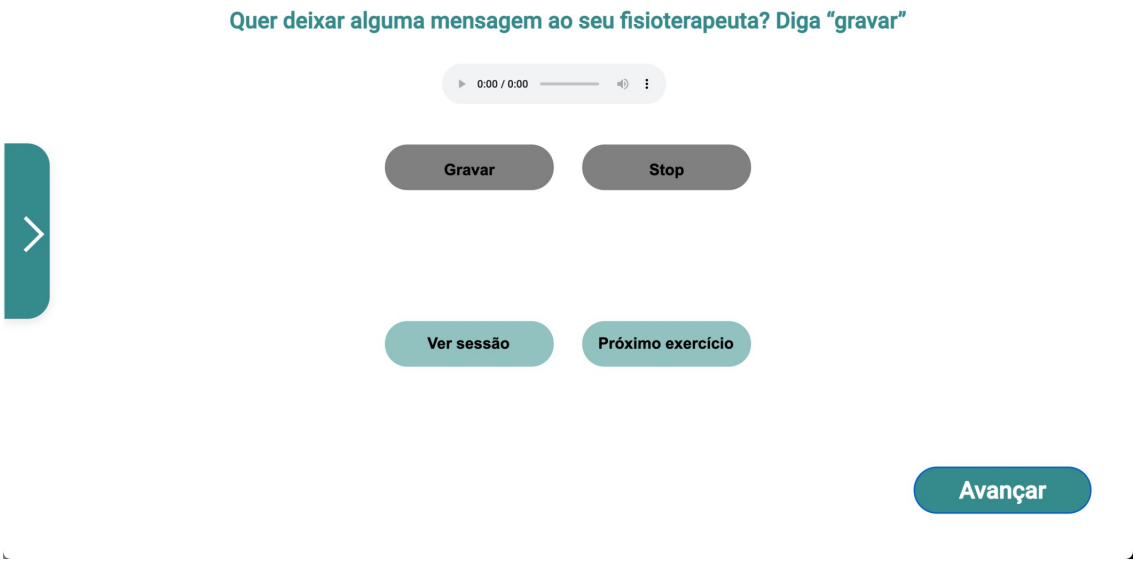


Figure A.14: Previous user interface: "Message to the physiotherapist" screen

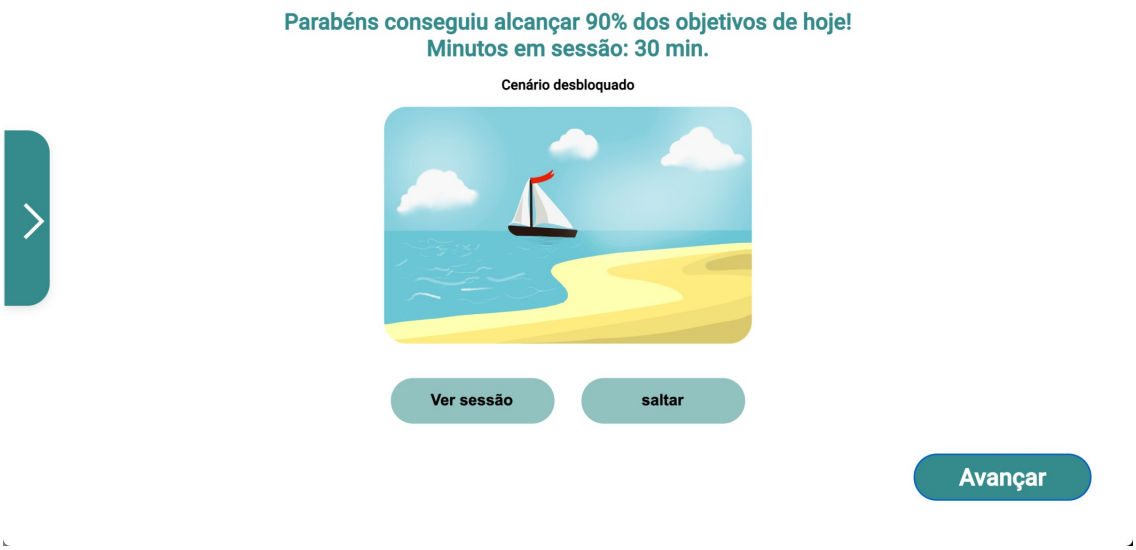


Figure A.15: Previous user interface: "Leave the session" screen one

Figure A.16: Previous user interface: "Leave the session" screen two

Figure A.17: Previous user interface: "Session history" screen

Appendix B

Persuasive System Design (PSD) model

The following information has been taken entirely from (Oinas-Kukkonen & Harjumaa, 2009).

Primary task support (Table B.1)

Principle	Definition
Reduction	"A system that reduces complex behavior into simple tasks helps users perform the target behavior, and it may increase the benefit/cost ratio of a behavior."
Tunneling	"Using the system to guide users through a process or experience provides opportunities to persuade along the way."
Tailoring	"Information provided by the system will be more persuasive if it is tailored to the potential needs, interests, personality, usage context, or other factors relevant to a user group."
Personalization	"A system personalized services has a greater capability for persuasion."
Self-monitoring	"A system that keeps track of one's own performance or status supports the user in achieving goals."
Simulation	"Systems that provide simulations can persuade by enabling users to observe immediately the link between cause and effect."
Rehearsal	"A system providing means with which to rehearse a behavior can enable people to change their attitudes or behavior in the real world."

Table B.1: Persuasive System Design primary task support principles

Dialogue support (Table B.2)

Principle	Definition
Praise	"By offering praise, a system can make users more open to persuasion."
Rewards	"Systems that reward target behaviors may have great persuasive powers."
Reminders	"If a system reminds users of their target behavior, the users will more likely achieve their goals."
Suggestion	"Systems offering fitting suggestions will have greater persuasive powers."
Similarity	"People are more readily persuaded through systems that remind them of themselves in meaningful way."
Liking	"A system that is visually attractive for its users is likely to be more persuasive."
Social role	"If a system adopts a social role, users will more likely use it for persuasive purposes."

Table B.2: Persuasive System Design dialogue support principles

System credibility support (TableB.3)

Principle	Definition
Trustworthiness	"A system that is viewed as trustworthy will have increased powers of persuasion."
Expertise	"A system that is viewed as incorporating expertise will have increased powers of persuasion."
Surface Credibility	"Systeem should have competente look and feel"
Real-world feel	"A system that highlights people or organization behind its content or services will have more credibility."
Authority	"A system that leverages roles of authority will have enhanced powers of persuasion.
Third-party endorsements	Third-party endorsements, especially from well-known and respected sources, boost perceptions on system credibility."
Verifiability	"Credibility perceptions will be enhanced if a system makes it easy to verify the accuracy of site content via outside sources."

Table B.3: Persuasive System Design system credibility support principles

Social support (Table B.4)

Principle	Definition
Social learning	"A person will be more motivated to perform a target behavior if (s)he can use a system to observe others performing the behavior."
Social comparison	"System users will have a greater motivation to perform the target behavior if they can compare their performance with the performance of others."
Normative influence	"A system can leverage normative influence or peer pressure to increase the likelihood that a person will adopt a target behavior."
Social facilitation	"System users are more likely to perform target behavior if they discern via the system that others are performing the behavior along with them."
Cooperation	"A system can motivate users to adopt a target attitude or behavior by leveraging human beings' natural drive to cooperate."
Competition	"A system can motivate users to adopt a target attitude or behavior by leveraging human beings' natural drive to compete."
Recognition	"By offering public recognition for an individual or group, a system can increase the likelihood that a person/group will adopt a target behavior."

Table B.4: Persuasive System Design social support principles

Appendix C

Game design principles

The following information is taken entirely from (Herne et al., 2020).

Princípios	**Definição**
Arousal	The Oxford Dictionary of English [33] defines to arouse as: "evoke or awaken (a feeling, emotion, or response)."
Attention	The Oxford Dictionary of English [33] defines attention as: "notice taken of someone or something; the regarding of someone or something as interesting or important."
Interest	The Oxford Dictionary of English [33] defines interest as: "excite the curiosity or attention of (someone)."
Immersion	The Oxford Dictionary of English [33] defines to immerse as: "involve oneself deeply in a particular activity."
Involvement	The Oxford Dictionary of English [33] defines to involve as: "be or become occupied or engrossed in something."
Presence	The feeling of "being there" within a game world [22].
Psychological Absorption	Psychological absorption means complete engagement with an experience that is currently occurring [24].
Motivation	The Oxford Dictionary of English [33] defines to motivate as: "provide (someone) with a reason for doing something; cause (someone) to have interest in or enthusiasm for something."
Effort	The Oxford Dictionary of English [33] defines effort as: "a vigorous or determined attempt."
Delight	The Oxford Dictionary of English [33] defines to delight as: "please (someone) greatly."
Enjoyment	The Oxford Dictionary of English [33] defines to enjoy as: "take delight or pleasure in (an activity or occasion)."
Coolness	The Oxford Dictionary of English [33] defines coolness as: "the quality of being fashionably attractive or impressive."
Awareness	The Oxford Dictionary of English [33] defines awareness as "knowledge or perception of a situation."
Feedback	Lohse et al. [11] defined feedback as: "any information about how a skill was performed and/or the effectiveness with which the skill was performed."
Clear Instructions	Clear instructions are instructions that make it clear how to use Neuromender Upper Limb in an unambiguous and easy to understand manner.
Improvisation	The Oxford Dictionary of English [33] defines improvised as: "performed spontaneously or without preparation."

Princípios	**Definição**
Usability	The Oxford Dictionary of English [33] defines usability as: "the degree to which something is able or fit to be used."
Interactivity	The Oxford Dictionary of English [33] defines interactivity as: "the ability of a computer to respond to a user's input." In this case, this means the ability of Neuromender Upper Limb to respond to a variety of your input.
Choice	The Oxford Dictionary of English [33] defines choice as: "the right or ability to choose." In this case, this means the ability to choose which actions to undertake in Neuromender Upper Limb Tool.
Perceived Control Flow	This refers to whether you believe you have control over the tool and its outcomes. Flow is caused by a balance between player challenge and skill, avoiding player frustration and boredom [18]. This means you will feel the game is not easy enough for you to become bored and not hard enough to cause you to become frustrated.
Challenge	The Oxford Dictionary of English [33] defines challenge as: "a task or situation that tests someone's abilities."
Novelty	The Oxford Dictionary of English [33] defines novelty as: "the quality of being new, original or unusual."
Purpose	The Oxford Dictionary of English [33] defines purpose as: "the reason for which something is done or created or for which something exists." The three questions below refer to the purpose you feel Neuromender Upper Limb may or may not have.
Fun	The Oxford Dictionary of English [33] defines fun as: "amusing, entertaining, or enjoyable."
Reward	The Oxford Dictionary of English [33] defines reward as: "a thing given in recognition of [..] effort or achievement."
Socialisation	The Oxford Dictionary of English [33] defines socialisation as: "the activity of mixing socially with others." In this case, it means engaging in social actions through Neuromender Upper Limb.
Identification	The Oxford Dictionary of English [33] defines identification as: "the action or process of identifying someone or something." In this case, this means identifying with someone or something in Neuromender Upper Limb.
Emotional Connection	This refers to an emotional connection to Neuromender Upper Limb or someone or something within it.

Princípios	**Definição**
Story	The Oxford Dictionary of English [33] defines story as: "a plot or storyline." The Oxford Dictionary of English [33] defines plot as: "the main events of a play, novel, film, or similar work, devised and presented by the writer as an interrelated sequence."
Safe Environment	A safe environment means the initiation of use of Neuromender Upper Limb in what you would consider to be safe circumstances.
Low vs. High Fidelity Graphs	Low fidelity graphics refers to graphics that have less detail and realism (i.e. in Neuromender Upper Limb's case, the low level of detail in the wingman and the environment through which he flies). Inversely, high fidelity graphics refer to graphics that have a high level of detail and look more realistic.
First vs. Third Person View	A first-person view is where the player (you) sees the game world (the Neuromender Upper Limb environment) through the eyes of the controlled character (in this case: the wingman). A third-person view is where the player sees the controlled character (the wingman) from behind, as is such in Neuromender Upper Limb currently.
Feedback Sounds	Feedback sounds are sounds that are played in response to an action (such as in the case of Neuromender Upper Limb, when the Wingman flies through a wing) to indicate that something has happened in the game or that the game has recognised your input.
Feedback Music	Feedback music is music that is played in response to an action to indicate that something has happened in the game or that the game has recognised your input. This can take the form of fanfare in response to successfully completing something in a game or music that indicates some event has occurred in game.
Ambient Sounds	Ambient sounds are sounds that give auditory atmosphere to a game, such as by establishing an outdoor location by having the player hear wind (such as in Neuromender Upper Limb) or establishing a laboratory with computer sounds.
Ambient Music	Ambient music is music that is played in a game to establish atmosphere, such as incidental music in a television program or film. The piano music that plays as the wingman flies through the course of rings is ambient music.

Table C.1: Game design principles

Appendix D

System usability scale

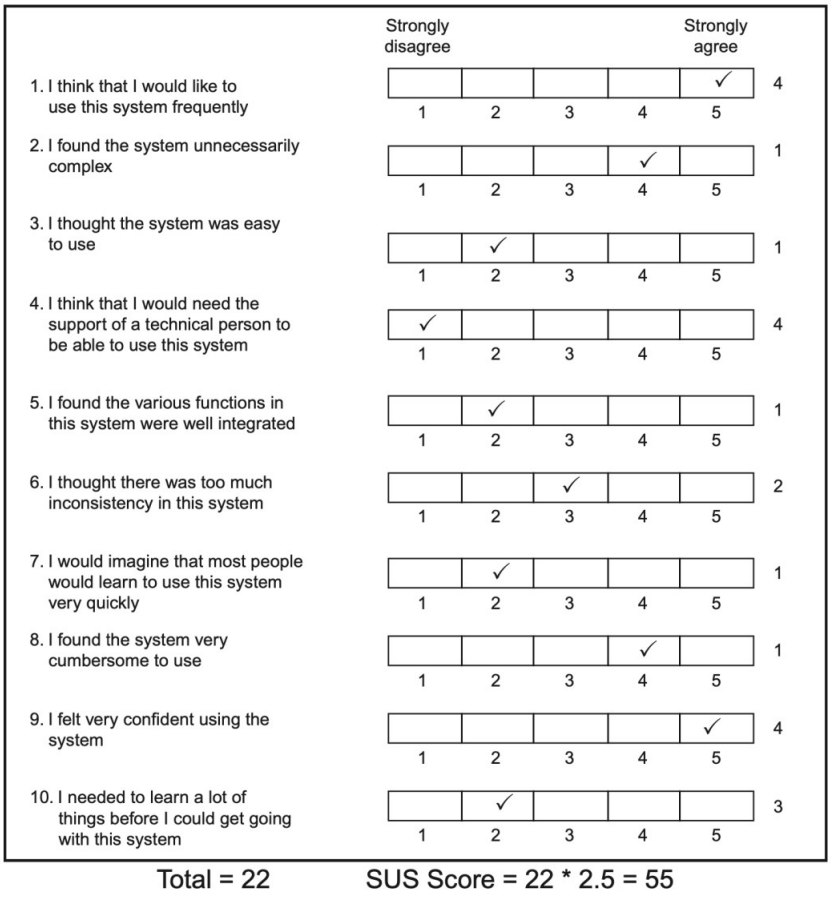


Figure D.1: System usability scale example (Gutiérrez-Carreón et al., 2015)

Appendix E

Heuristic evaluation principles

Heuristics	Name	Description
H1	Visibility of system status	The design should always keep users informed about what is going on, through appropriate feedback (e.g. textual, visual, or through sound or music) within a reasonable amount of time.
H2	Match between system and the real world	The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon. Follow real-world conventions, making information appear in a natural and logical order.
H3	User control and freedom	Users often perform actions by mistake. To avoid mistakes, users need to be provided with clear instructions. It is also important to make sure that the user has the ability to choose which action to undertake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process.
H4	Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.
H5	Error prevention	Good error messages are important, but the best designs carefully prevent problems from occurring in the first place. Either eliminate error-prone conditions, or check for them and present users with a confirmation option before they commit to the action.

Heuristics	**Name**	**Description**
H6	Recognition rather than recall	Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design (e.g. field labels or menu items) should be visible or easily retrievable when needed.
H7	Flexibility and efficiency of use	Shortcuts — hidden from novice users — may speed up the interaction for the expert user such that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
H8	Aesthetic and minimalist design	Interfaces should not contain information that is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility. The system should have a competent look and feel.
H9	Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.
H10	Help and documentation	It's best if the system doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks. To highlight the people or organization behind the content or services, might have more credibility. Additionally a system that leverages roles of authority will have enhanced powers of persuasion.
H11	Reduction	A system that reduces complex behavior into simple tasks helps users perform the target behavior, and it may increase the benefit/cost ratio of a behavior.
H12	Tunneling	Using the system to guide users through a process or experience provides opportunities to persuade along the way.

Heuristics	**Name**	**Description**
H13	Tailoring	Information provided by the system will be more persuasive if it is tailored to the potential needs, interests, personality, usage context, or other factors relevant to a user group that could catch their interest, curiosity and attention.
H14	Personalization	A system personalized services that is also attractive, amusing, entertaining, or enjoyable has a greater capacity to persuade.
H15	Self-monitoring	A system that keeps track of one's own performance or status supports the user in achieving goals.
H16	Simulation	Systems that provide simulations and a clear purpose can persuade by enabling users to observe immediately the link between cause and effect.
H17	Rehearsal	A system providing means with which to rehearse a behavior can enable people to change their attitudes or behavior in the real world.
H18	Praise	By offering praise, a system can make users more open to persuasion.
H19	Rewards	Systems that reward target behaviors may have great persuasive powers.
H20	Reminders	If a system reminds users of their target behavior, the users will more likely achieve their goals.
H21	Suggestion	Systems offering fitting suggestions will have greater persuasive powers.
H22	Similarity	People are most readily persuaded through systems that remind them of themselves or allow them to identify with someone or something in a meaningful way.
H23	Social role	If a system adopts a social role, users will more likely use it for persuasive purposes.
H24	Trustworthiness	A system that is viewed as incorporating expertise and trustworthiness will have increased powers of persuasion.
H25	Social learning	A person will be more motivated to perform a target behavior if (s)he can use a system to observe the rehabilitation professional performing the behavior.

Heuristics	Name	Description
H26	Social comparison	System users will have a greater motivation to perform the target behavior if they can compare their performance with the performance of the rehabilitation professional.
H27	Normative influence	A system can leverage normative influence from the rehabilitation professional to increase the likelihood that a person will adopt a target behavior.
H28	Social facilitation	System users are more likely to perform target behavior if they discern via the system that the rehabilitation professional is performing the behavior along with them.
H29	Cooperation	A system can motivate users to adopt a target attitude or behavior by leveraging human beings' natural drive to co-operate.
H30	Recognition	By offering public recognition for an individual or group, a system can increase the likelihood that a person/group will adopt a target behavior.
H31	Novelty	A system that has the quality of being new, original or unusual.
H32	Story	A system with a narrative, plot or storyline that allows users to be or become occupied or engrossed in something
H33	Ambient Sounds and Music	Ambient sounds and music establish and give the game an auditory atmosphere.

Table E.1: Heuristic evaluation principles

Appendix F

Heuristic evaluation procedures

Heuristic evaluation procedures for evaluators

Thank you for agreeing to take part in this study, your help is greatly valued.
As this is a Heuristic Evaluation, if you would like to review the procedures, please refer to: https://www.nngroup.com/articles/how-to-conduct-a-heuristic-evaluation/ .

The aim of this evaluation is to inspect the INPACT Project's person undergoing rehabilitation interface with reference to the list of 33 heuristics. Please read the following guidelines carefully before you begin:

- In addition to this document, you should take into account the following two files:
  - "List of Heuristics" that contains the list of heuristics to guide the evaluation;
  - "Evaluation Report" that contains the tables to record the results of your evaluation;

- When performing a Heuristic Evaluation, each evaluator goes through the interface at least twice: the first to get a feel of the flow of the user interface and make a preliminary evaluation; the second, when the evaluator thoroughly inspects the user interface, to identify and record the specific problems found on the user interface and violations of heuristics.

- When inspecting the user interface for the second time, while you may inspect it freely, please make sure to go through the following areas:
  - Login Page
  - Sessions Page
  - See a notification
  - See session details
  - Go to settings
  - Do a session
  - Evaluate the exercise
  - Leave a message for the physiotherapist
  - View a session's history
  - Profile page
  - Leave the session

- As you go through the user interface, each problem identified in the user interface should be clearly described in text but also through an image documenting the problem and the screen in which it occurs. To this end, we have prepared a template of a table in which you should record:
  - a short description of the problem,
  - a clear statement and description of the problem,
  - an illustrative screenshot, the violated heuristic(s),
  - a possible solution for it, and
  - the degree of severity of the problem and priority of correction.

Figure F.1: Heuristic evaluation: Procedures (first page)

Each problem should be described in a separate table

- Make sure to list all of the problems that you identify, by adding as many tables into the document as necessary.
- Usually each individual evaluation lasts between one and two hours. (Please indicate the amount of time spent evaluating the user interface – 1st (preliminary evaluation) and 2nd (in-depth evaluation) round – in the evaluation report)

Figure F.2: Heuristic evaluation: Procedures (second page)

Appendix G

Heuristic evaluation report

Evaluation Instructions

Read the following instructions carefully

1- Before starting the evaluation please answer this short questionnaire: https://forms.gle/FSnXtB1ss2VsLurK9

2- Explore the user interface (https://inpact.vercel.app/ - Utente) and do the first round of evaluation (preliminary overview), note down the time and fill the corresponding row in the time table of the evaluation report.

3- Do the second round of evaluation (in-depth evaluation), taking into account the list of areas requested in the Heuristics Evaluation Procedure document. Note down the time and fill the corresponding row in the time table of the evaluation report.

4- While carrying out the in-depth assessment, identify the problems encountered and then describe them in the corresponding table in the evaluation report. For each problem create a new table.

5- Once you have entered all the problems encountered, fill in the following form: https://forms.gle/QxDmPTbvVBN8jkgA9

Figure G.1: Heuristic evaluation: Evaluation report (first page)

Evaluation Report

Time Spent	Minutes
preliminary overview	
in-depth evaluation	

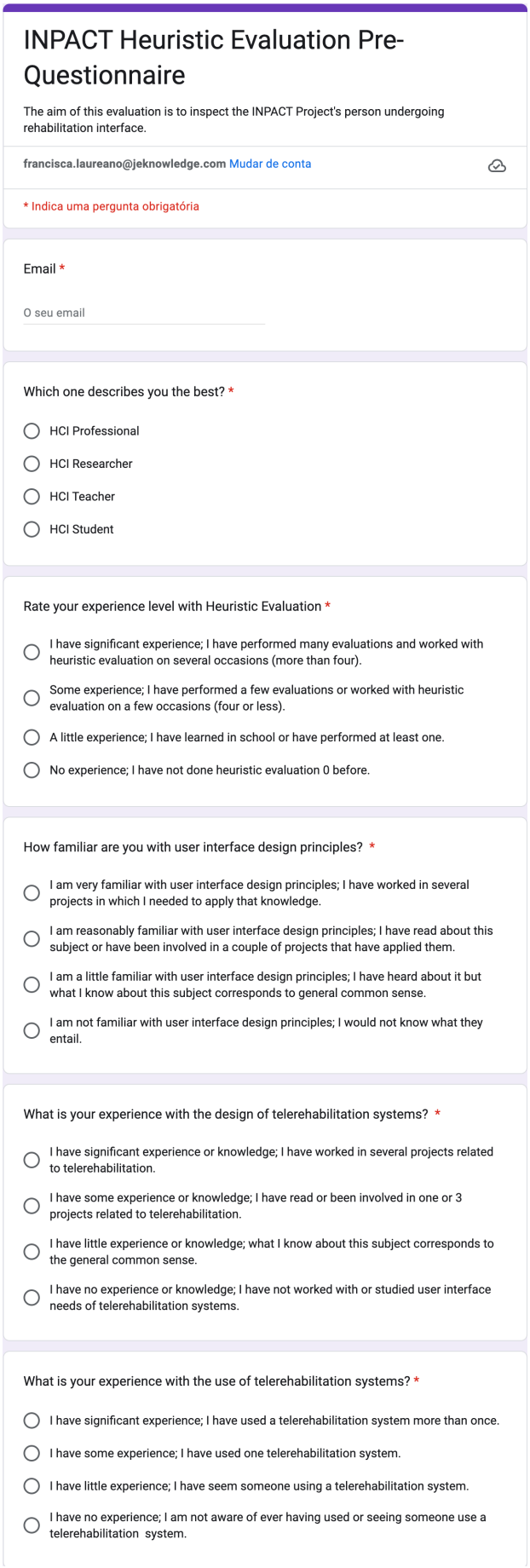
Problem Description and Screenshot	**Violated Heuristic(s)**	
Short description: **Detailed description and illustrative screenshot:**		
Solution Proposal	**Priority***	**Severity ***

*You can state the degree of priority and severity using the following scale: Very low, low, medium, high, very high

Figure G.2: Heuristic evaluation: Evaluation report (second page)

Appendix H

Heuristic pre-evaluation questionnaire



INPACT Heuristic Evaluation Pre-Questionnaire

The aim of this evaluation is to inspect the INPACT Project's person undergoing rehabilitation interface.

francisca.laureano@jeknowledge.com Mudar de conta

* Indica uma pergunta obrigatória

Email *

O seu email

Which one describes you the best? *

- HCI Professional
- HCI Researcher
- HCI Teacher
- HCI Student

Rate your experience level with Heuristic Evaluation *

- I have significant experience; I have performed many evaluations and worked with heuristic evaluation on several occasions (more than four).
- Some experience; I have performed a few evaluations or worked with heuristic evaluation on a few occasions (four or less).
- A little experience; I have learned in school or have performed at least one.
- No experience; I have not done heuristic evaluation 0 before.

How familiar are you with user interface design principles? *

- I am very familiar with user interface design principles; I have worked in several projects in which I needed to apply that knowledge.
- I am reasonably familiar with user interface design principles; I have read about this subject or have been involved in a couple of projects that have applied them.
- I am a little familiar with user interface design principles; I have heard about it but what I know about this subject corresponds to general common sense.
- I am not familiar with user interface design principles; I would not know what they entail.

What is your experience with the design of telerehabilitation systems? *

- I have significant experience or knowledge; I have worked in several projects related to telerehabilitation.
- I have some experience or knowledge; I have read or been involved in one or 3 projects related to telerehabilitation.
- I have little experience or knowledge; what I know about this subject corresponds to the general common sense.
- I have no experience or knowledge; I have not worked with or studied user interface needs of telerehabilitation systems.

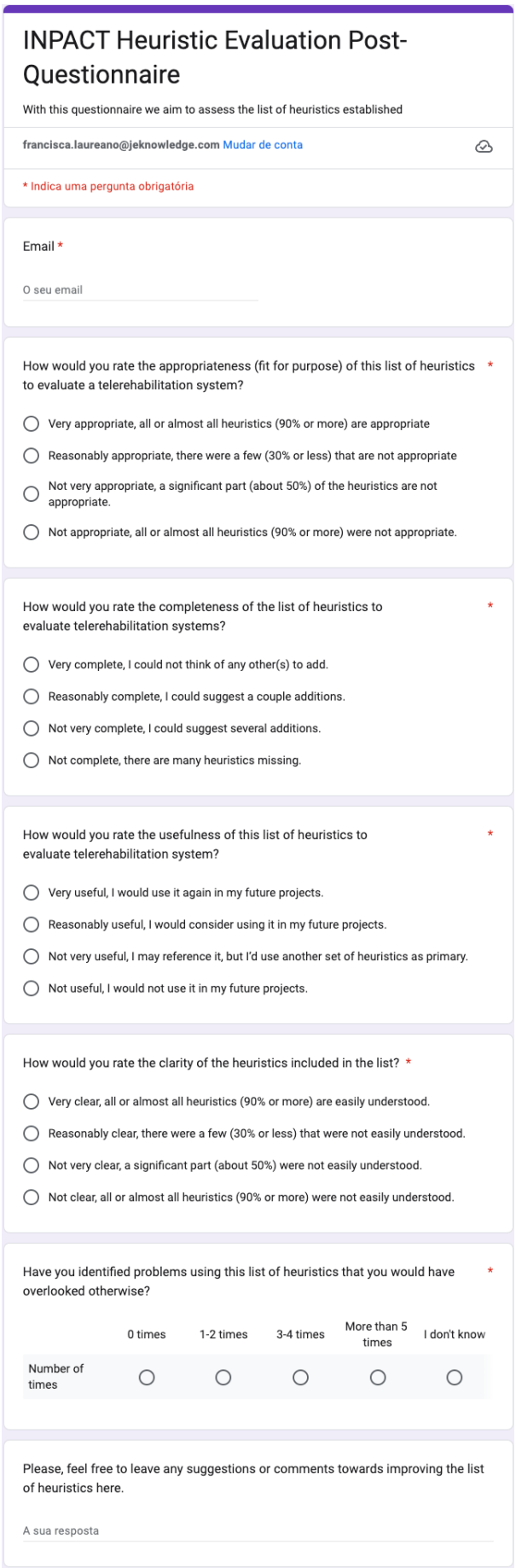
What is your experience with the use of telerehabilitation systems? *

- I have significant experience; I have used a telerehabilitation system more than once.
- I have some experience; I have used one telerehabilitation system.
- I have little experience; I have seem someone using a telerehabilitation system.
- I have no experience; I am not aware of ever having used or seeing someone use a telerehabilitation system.

Figure H.1: Heuristic evaluation: Pre-evaluation questionnaire

Appendix I

Heuristic post-evaluation questionnaire



INPACT Heuristic Evaluation Post-Questionnaire

With this questionnaire we aim to assess the list of heuristics established

francisca.laureano@jeknowledge.com Mudar de conta

* Indica uma pergunta obrigatória

Email *

O seu email

How would you rate the appropriateness (fit for purpose) of this list of heuristics to evaluate a telerehabilitation system? *

- Very appropriate, all or almost all heuristics (90% or more) are appropriate
- Reasonably appropriate, there were a few (30% or less) that are not appropriate
- Not very appropriate, a significant part (about 50%) of the heuristics are not appropriate.
- Not appropriate, all or almost all heuristics (90% or more) were not appropriate.

How would you rate the completeness of the list of heuristics to evaluate telerehabilitation systems? *

- Very complete, I could not think of any other(s) to add.
- Reasonably complete, I could suggest a couple additions.
- Not very complete, I could suggest several additions.
- Not complete, there are many heuristics missing.

How would you rate the usefulness of this list of heuristics to evaluate telerehabilitation system? *

- Very useful, I would use it again in my future projects.
- Reasonably useful, I would consider using it in my future projects.
- Not very useful, I may reference it, but I'd use another set of heuristics as primary.
- Not useful, I would not use it in my future projects.

How would you rate the clarity of the heuristics included in the list? *

- Very clear, all or almost all heuristics (90% or more) are easily understood.
- Reasonably clear, there were a few (30% or less) that were not easily understood.
- Not very clear, a significant part (about 50%) were not easily understood.
- Not clear, all or almost all heuristics (90% or more) were not easily understood.

Have you identified problems using this list of heuristics that you would have overlooked otherwise? *

	0 times	1-2 times	3-4 times	More than 5 times	I don't know
Number of times	○	○	○	○	○

Please, feel free to leave any suggestions or comments towards improving the list of heuristics here.

A sua resposta

Figure I.1: Heuristic evaluation: Post-evaluation questionnaire

Appendix J

Heuristic evaluation results

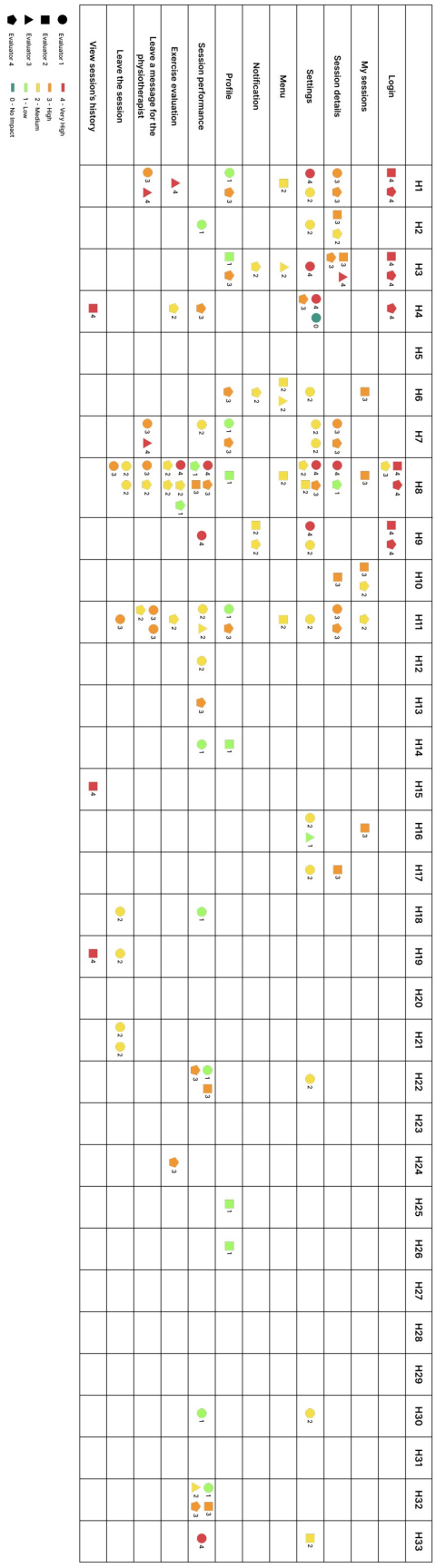


Figure J.1: Heuristic evaluation: Number of violated heuristic per screen

Appendix K

Wireframes

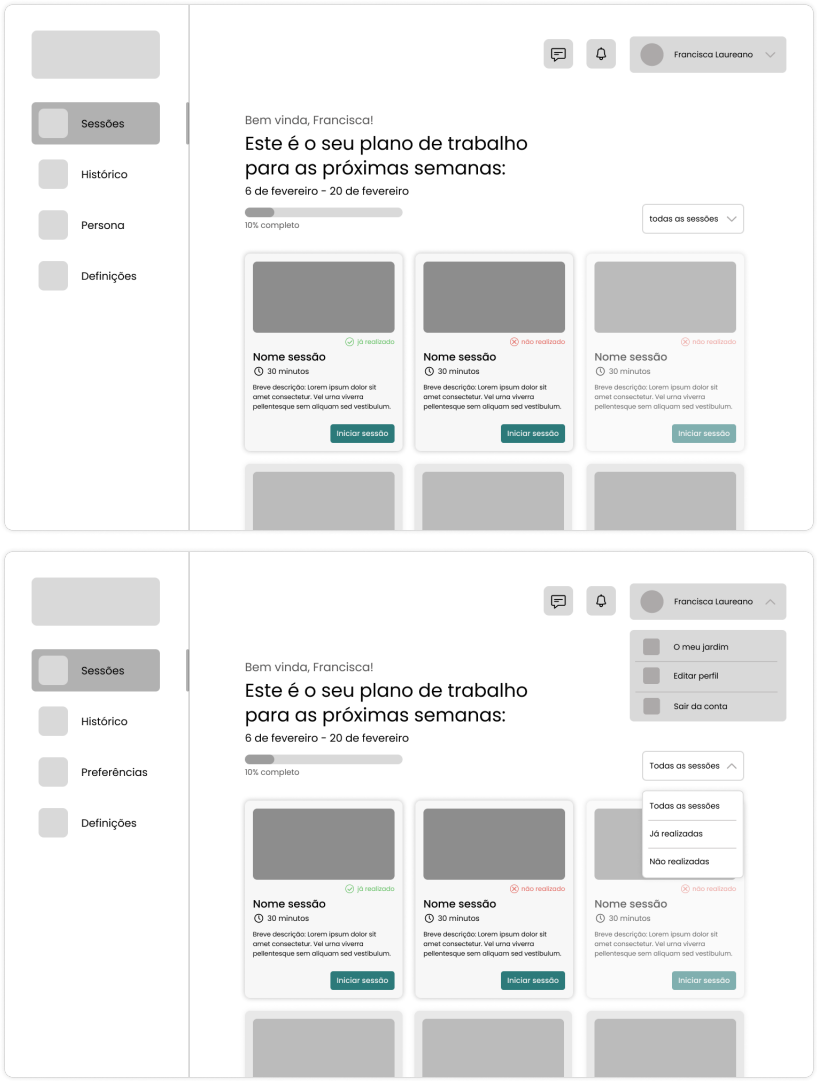


Figure K.1: Wireframes: "Home" screen

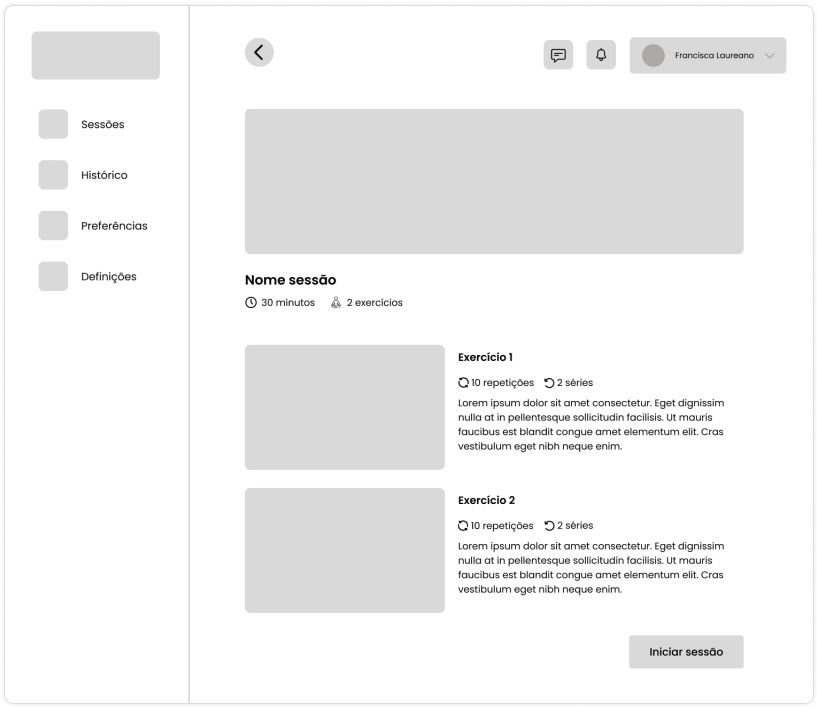


Figure K.2: Wireframes: "Session information" screen

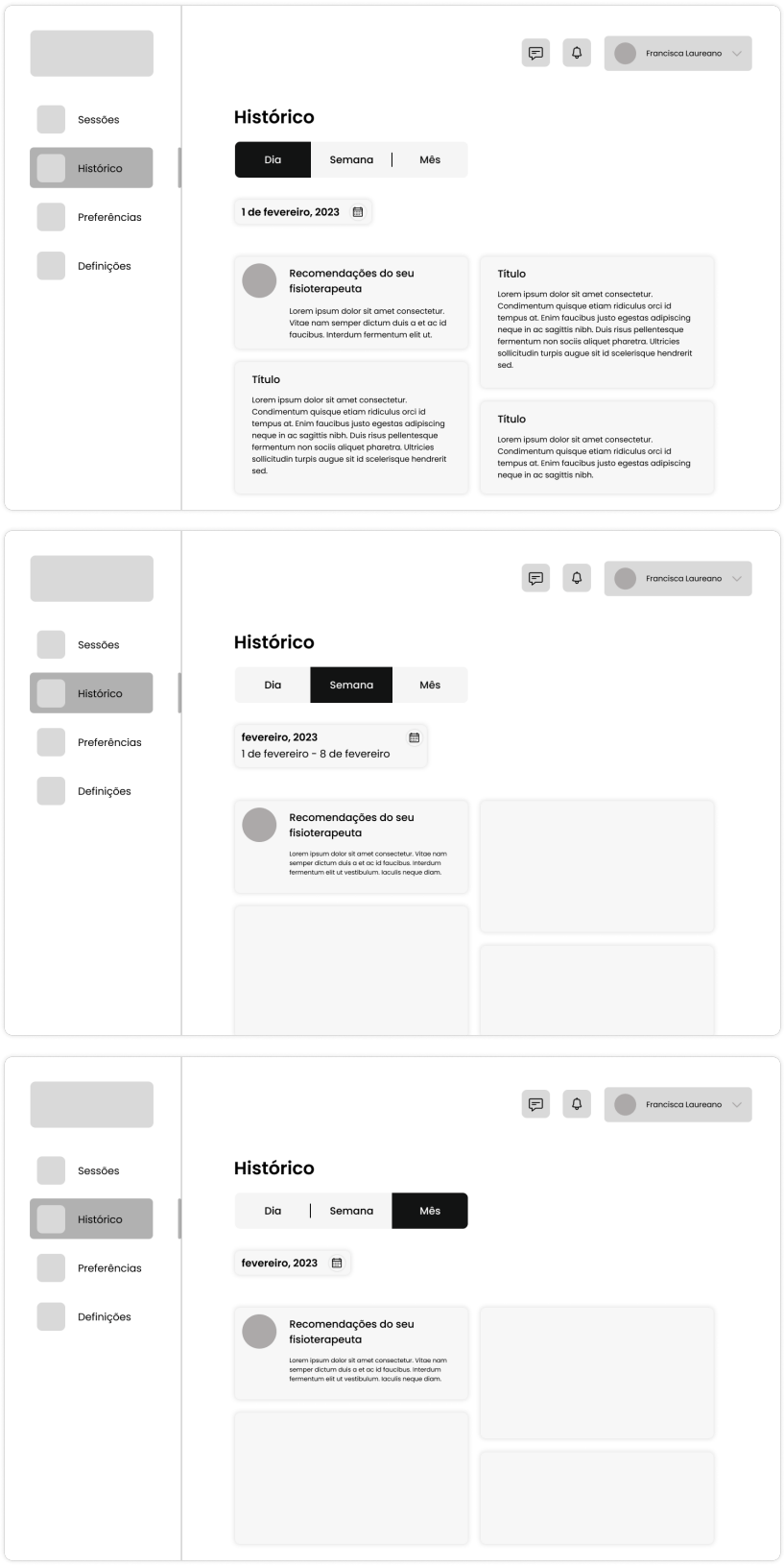


Figure K.3: Wireframes: "History" screen

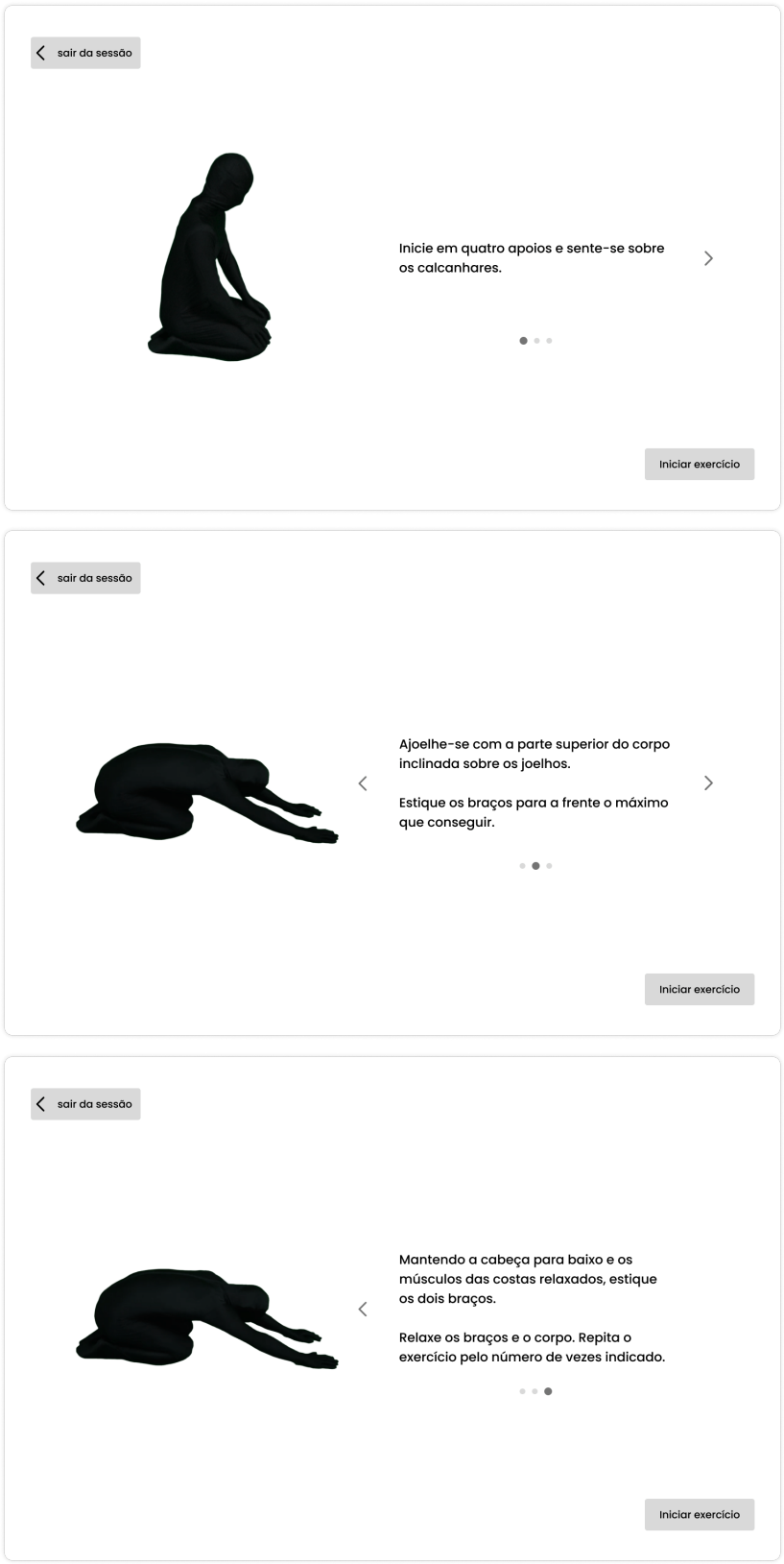


Figure K.4: Wireframes: "Errors" screen

Figure K.5: Wireframes: "Session performance" screen

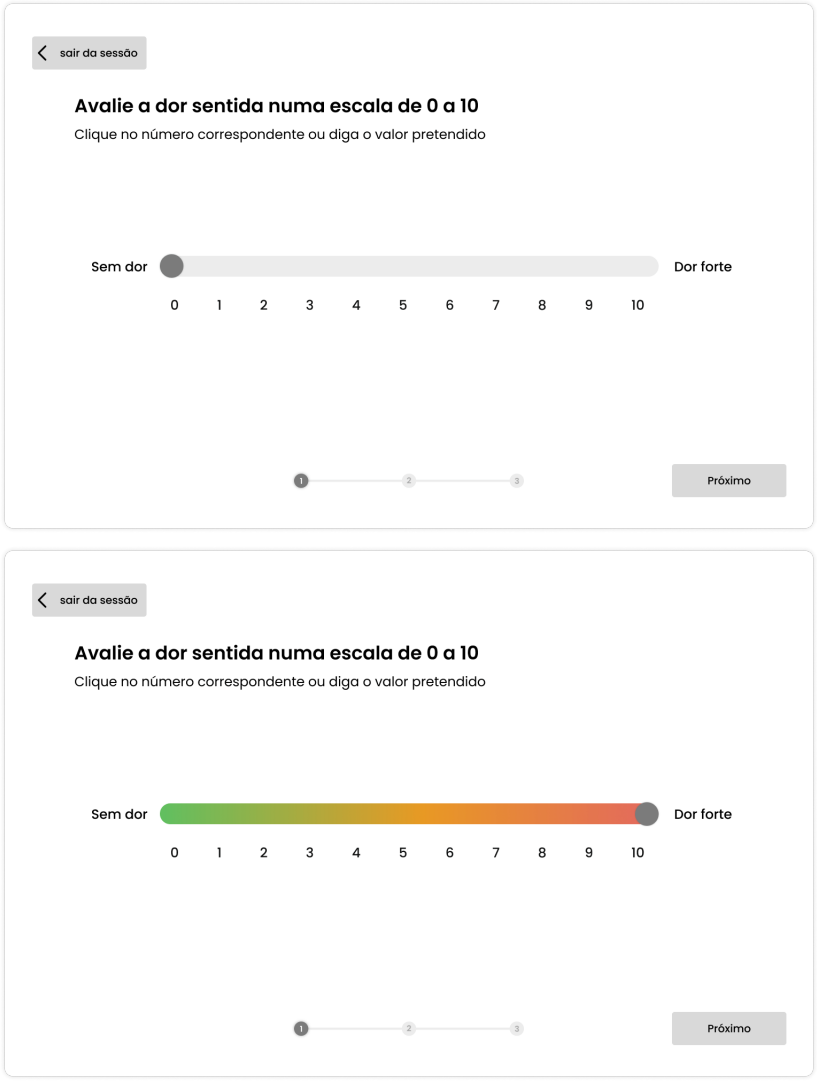


Figure K.6: Wireframes: "Pain and effort evaluation" screen

Appendix L

User interface evaluation script

Introdução

Olá, sou a Francisca. Estou neste momento a trabalhar para o projeto INPACT. O projecto tem como objetivo desenvolver uma solução inovadora que permita monitorizar sessões de fisioterapia em casa. Deste modo, o sistema possibilita o acompanhamento do desempenho do utente, dando feedback em tempo real, dispensando o utente de estar constantemente a deslocar-se a uma clínica para realizar as suas sessões de fisioterapia.

No contexto do projeto, eu estive responsável pelo re-design da a plicação dos utentes, que agora precisamos de testar. Para percebermos se estamos num bom caminho para criar a melhor solução possível para futuros utentes de fisioterapia, precisamos da sua valiosa colaboração.

Irei dar-lhe algumas tarefas para fazer na aplicação e enquanto as faz, peço-lhe que vá verbalizando os seus pensamentos e me dê todo o feedback que lhe parecer relevante. Devemos demorar cerca de 30 minutos.

Antes de começarmos gostaria de perguntar se não se importa que grave o áudio da nossa sessão. Esta recolha serve apenas para me facilitar a análise mais detalhada dos resultados posteriormente. Aproveito para reforçar que todos os dados recolhidos servem apenas para avaliar o protótipo em questão, não o estamos a avaliar a si.

Tem alguma questão? Se quiser parar a sessão a qualquer momento, pode fazê-lo. Só terá de me dizer e interrompemos o teste imediatamente.

Sem mais demoras pedia então que lesse, com atenção, este formulário de consentimento e o assinasse, caso concorde, por favor.

Consentimento

Perguntas Pré Sessão

Antes de passarmos à aplicação, vou pedir-lhe que preencha este breve formulário para o ficarmos a conhecer melhor.

Testes de Usabilidade

Exploração Inicial

Agora vamos passar à parte divertida! Pedia-lhe que viesse para esta zona, entre o tapete verde e o tablet. Consegue ler bem o que está no ecrã do tablet?

Figure L.1: User interface evaluation: Script (first page)

Ao longo da interação com a aplicação do INPACT vou dar-lhe 3 tarefas que pretendemos que realize. Se tiver alguma questão durante a sessão, não hesite em fazê-la. Enquanto faz as tarefas eu vou estar a tirar notas. Sempre que terminar uma tarefa, indico-lhe a próxima.

Antes de começarmos esta parte queria relembrar que nós não estamos a testar os seus conhecimentos. O que pretendemos é testar o design da nova aplicação. Se houver algo que considere confuso ou pouco claro é útil para nós saber, por isso, não hesite em dizer-nos honestamente o que está a pensar.

Esta é a aplicação do INPACT.

Pedia-lhe que explorasse brevemente a aplicação à vontade. Quando quiser parar, pode parar, senão eu ao fim de 2 minutos aviso-o.

Tarefas:

Imagine que o seu fisioterapeuta lhe propôs que usasse a plataforma INPACT para realizar as suas sessões domiciliárias e você decide começar hoje a utilizar a aplicação.

Tarefa 0 - Setup e tutorial

A aplicação disponibiliza um setup do sistema e tutorial da aplicação. Pedia que consultasse visse essas informações com atenção até ao fim.

Tarefa 1 - Realizar a sua sessão diária

[Sem tutorial e setup] - Por isso, vai à procura da primeira sessão que tem para realizar.
[Com tutorial e setup] - Agora procure a primeira sessão que tem para realizar e…

- Diga-me que exercícios tem essa sessão
- Quantas repetições tem o primeiro exercício?

Ok, agora vamos realizar a sua sessão. Assim que estiver pronto pode iniciar a sua sessão!
[durante a sessão]

- Diga-me em que série vai.
- Imagine que o seu telefone começava a tocar, pare a sessão para o atender.

Boa! O primeiro exercício está feito. Agora avalie a dor e o esforço sentido ao longo da execução do mesmo.

Sabe porque ganhou esse elemento?

Vamos agora imaginar que a sessão já chegou ao fim e você completou todos os exercícios da sessão.

- Que objetivos alcançou?
- Diga-me a que deve ter em atenção nos próximos dias.
- Envie uma mensagem de áudio ao seu fisioterapeuta a dizer “Olá, correu tudo bem!”
- Agora avalie a sessão.

Figure L.2: User interface evaluation: Script (second page)

- Durante a realização da sessão havia um elemento grande do lado esquerdo do ecrã. Sabe a que se refere?

Tarefa 2 - Ver notificações recebidas

Boa! Conseguiu completar a sua sessão de hoje.
- Parece que tem notificações. Consulte-as
- Diga-me o que diz a mais recente.
- Então vamos ver o jardim.

Que jardim tão bonito!
- Está muito verde! Sabe porquê?
- Sabe quais os elementos que já ganhou para o seu jardim?
- E sabe quais os elementos que ainda pode ganhar?

Parece que ainda ficou com notificações por ler.
- Consulte-as
- Veja a mensagem do fisioterapeuta
- ~~A~~gradeça ao seu fisioterapeuta, enviando-lhe uma mensagem a dizer 'obrigado'

Tarefa 3 - Visualização do seu histórico

Agora que já não tem mais notificações por ler, vamos ver o seu histórico como o seu fisioterapeuta recomendou.
- A sessão que realizou hoje já aparece no seu histórico?
- Diga-me se realizou alguma sessão dia 9 de junho.
- Aceda à progressão ao longo do mês de maio [deveria ir ver o mês] e diga-me qual o tempo total que despendeu para as suas sessões na primeira semana do mês.
- E qual a média de esforço da segunda semana do mês?

Perguntas Finais

Muito bem! Chegamos ao fim desta etapa da avaliação.

Tenho agora umas questões relativas à aplicação que lhe ia pedir para responder, se não houver problema.

1. Considerando a sua experiência de utilização da aplicação, sentiu que lhe foram disponibilizadas todas as informações que necesitava para a realização das sessões de fisioterapia ou faltou alguma informação que acrescentaria valor? Se sim, justifique por favor.

2. Durante a utilização da aplicação houve alguma coisa que não percebeu ou teve dificuldade em compreender? Se sim, o quê, e explique-me, por favor.

Figure L.3: User interface evaluation: Script (third page)

3. Qual foi a parte da aplicação que gostou mais? Explique-me porquê, por favor.
4. Qual foi a parte da aplicação que gostou menos? Explique-me porquê, por favor.

5. Sentiu-se motivado/a para realizar mais sessões de fisioterapia remota através desta aplicação? Porquê?

6. Acha que a construção do jardim é importante para o/a motivar a realizar as suas sessões de fisioterapia?

7. Numa escala de 0 a 10, qual a probabilidade de recomendar esta plataforma a outra pessoa?

8. Tem algum outro comentário ou sugestão que pretenda deixar?

Agora pedia-lhe que respondesse às seguintes questões numa escala de 1 a 5. Marque a sua resposta com uma "x" e assinale apenas uma resposta por linha.

Semantic Usability Scale (SUS)

Conclusão

Chegámos ao fim dos testes. Muito obrigada por ter disponibilizado do seu tempo para nos ajudar!

Figure L.4: User interface evaluation: Script (fourth page)

Appendix M

User interface evaluation pre-session questionnaire

Questionário

1. **Género:**
   - ☐ Feminino
   - ☐ Masculino
   - ☐ Prefiro não responder
   - ☐ Outro: _____

2. **Idade:**
   - ☐ 18 - 24
   - ☐ 25 - 29
   - ☐ 30 - 39
   - ☐ 40 - 49
   - ☐ 50 - 64
   - ☐ 65 ou mais

3. **Já recorreu a serviços de fisioterapia?**
   - ☐ Sim
   - ☐ Não

   3.1. Se sim, em que circunstâncias?

   _____

   3.2. E com que frequência? Assinale com um "x" a resposta.

	Não sei	1 vez	2 a 3 vezes	4 a 5 vezes	Mais de 5 vezes
Semana					
Mês					
Ano					

4. **Neste momento está a fazer sessões de fisioterapia?**
   - ☐ Sim
   - ☐ Não

Figure M.1: User interface evaluation: Pre-session questionnaire (first page)

4.1. Se sim, quantas vezes por semana? Assinale com um "x" a resposta

	1 vez	2 a 3 vezes	4 a 5 vezes	mais de 5 vezes
semana				

5. No seu dia a dia utiliza tablet ou telemóvel?

☐ Sim
☐ Não

5.1. Se sim, com que frequência? Assinale com um "x" a resposta.

	Não uso	1 vez	2 a 3 vezes	4 a 5 vezes	Mais de 5 vezes
Semana					
Mês					
Ano					

5.2. Que tipo de tarefas realiza no seu tablet/telemóvel? Assinale com "x" a(s) resposta(s).

	Nunca	Raramente	Às vezes	Quase sempre	Sempre
Chamadas telefónicas					
Ler e escrever mensagens					
Ler e escrever e-mails					
Consultar informação (notícias, metereologia,..)					
Videochamadas					
Videojogos					

Figure M.2: User interface evaluation: Pre-session questionnaire (second page)

6. Tem alguma limitação ao nível da visão?

☐ Sim
☐ Não

6.1. Se sim, qual e até que ponto é impeditiva de uma vida normal?

_____

7. Tem alguma limitação física?

☐ Sim
☐ Não

7.1. Se sim, qual?

_____

Figure M.3: User interface evaluation: Pre-session questionnaire (third page)

Appendix N

User interface evaluation informed consent

Declaração de Consentimento Informado

a) Solicitamos a sua colaboração num estudo que tem como objetivo a recolha de dados sobre a experiência do **utente** numa sessão de fisioterapia para tratamento de Lombalgia e Cervicalgia.
   i) Os dados serão essenciais para a avaliação da aplicação do **utente** da Plataforma INPACT[1], uma Plataforma de Reabilitação com interface de utilizador que sugere/orienta exercícios, capaz de monitorizar o desempenho do utilizador e fornecer uma monitorização em tempo real.

b) Este estudo é constituído por:
   i) Questionário, com a duração aproximada de 6 minutos, que contempla questões sociodemográficas e profissionais.
   ii) Observação da interação com a aplicação, com duração aproximada de 20 minutos. Com o consentimento do **utente** poderá ser realizado um registo audiovisual.
   iii) Entrevista, com duração aproximada de 7 minutos, com questões específicas sobre a experiência do **utente** durante a interação com a aplicação.

c) A sua participação neste estudo é voluntária e pode ser interrompida a qualquer momento, sem necessidade de justificação. Além disso, não lhe trará qualquer despesa ou risco.
d) Todos os dados relativos à identificação dos participantes neste estudo são confidenciais. Os seus dados poderão ser usados, de forma completamente anónima, em trabalhos académicos, apresentações públicas, congressos científicos e publicações, no âmbito do projeto INPACT, em estrita obediência ao Regulamento Geral de Proteção de Dados e da sua Lei de Execução Nacional.
e) Para participar, precisa de ler e concordar com as condições da Declaração relativa ao tratamento dos dados pessoais e privacidade nos termos do art.º 13.º do RGPD (disponível nos anexos deste documento).
f) Se tiver alguma questão para nos colocar antes, ou após o preenchimento do questionário, por favor contacte através dos endereços laureano@student.dei.uc.pt ou paulasilva@dei.uc.pt

☐ Compreendi a explicação que me foi fornecida acerca deste projeto de investigação.
☐ Tomei conhecimento de que, de acordo com as recomendações da Declaração de Helsínquia[2], a informação que me foi prestada versou os objetivos, métodos e fins do presente estudo.
☐ Tomei também conhecimento de que poderei, a qualquer momento, recusar ou terminar a minha participação neste estudo, sem que isso possa trazer-me qualquer prejuízo.
☐ Compreendi que os resultados do estudo podem ser publicados em revistas científicas e apresentados em conferências, sem que haja qualquer quebra da confidencialidade ou do seu anonimato.

[1] INtelligent Platform for Autonomous Collaborative Telerehabilitation
[2] Declaração de Helsínquia ou Helsinque é um conjunto de princípios éticos que regem a pesquisa com seres humanos

Figure N.1: User interface evaluation: Informed consent (first page)

☐ Li a declaração relativa à informação sobre o tratamento dos dados pessoais e privacidade nos termos do art.º 13.º do Regulamento Geral de Proteção de Dados.
☐ Autorizo a minha participação, de forma voluntária, neste projeto de investigação.

Autorizo a recolha de ☐ Áudio ☐ Vídeo ☐ Notas

Código de identificação: _____

Recebi uma cópia deste formulário de consentimento informado. O formulário original será armazenado pela equipa de investigação.

Assinatura do participante:
_____

Assinatura pela equipa de
Investigação:_____

Data: _____

Em caso de impossibilidade de assinatura, marcar com impressão digital.

Figure N.2: User interface evaluation: Informed consent (second page)

Appendix O

User interface evaluation results

Tasks - Taps on screen													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
Expected	3	1	1	4	0	2	2	1	1	3	1	2	3
PAT1	3	2	1	4	0	2	2	1	1	3	1	2	4
PAT2	3	1	0	4	0	2	2	1	1	3	1	2	3
PAT3	3	1	0	4	0	2	2	1	1	3	1	2	3
PAT4	3	1	1	4	0	2	2	1	1	3	1	2	3
PAT5	3	1	0	4	0	2	2	2	1	3	1	2	6
PAT6	3	1	1	4	0	2	2	1	1	3	1	2	3
PAT7	3	1	1	4	0	2	2	1	1	3	1	2	7
PAT8	3	1	1	4	0	2	2	1	1	3	1	2	3
PAT9	3	1	1	4	0	2	2	1	1	3	1	2	3
PAT10	3	1	1	4	0	2	2	1	1	3	1	2	3
PAT11	3	1	1	4	0	2	2	1	1	3	1	2	8
PAT12	3	1	1	4	0	2	2	1	1	3	1	4	3
PA1	3	1	1	4	0	2	2	1	1	3	1	2	6
PA2	3	1	1	4	0	2	2	1	1	3	1	2	3
PA3	3	2	1	4	0	2	2	1	1	3	1	4	5
PA4	3	1	1	4	0	2	2	1	1	3	1	2	6
PA5	3	1	1	4	0	2	2	1	1	3	1	2	5
PA6	3	1	1	4	0	2	2	1	1	3	1	2	3
PA7	3	1	0	4	0	2	2	1	1	3	1	2	3
PA8	3	1	1	4	0	2	2	1	1	3	1	2	8
PA9	3	2	0	4	0	2	2	1	1	3	1	2	3
PA10	3	2	0	4	0	2	2	3	1	3	1	2	8
PA11	3	1	0	4	0	2	2	1	1	3	1	0	3
PA12	3	1	2	4	0	2	2	1	1	3	1	2	3
Average	3	1,17	0,75	4	0	2	2	1,13	1	3	1	2,08	4,38
Standard deviation	0	0,38	0,53	0	0	0	0	0,45	0	0	0	0,72	1,88
Total	72	28	18	96	0	48	48	27	24	72	24	50	105
Mode	3	1	1	4	0	2	2	1	1	3	1	2	3
Min value	3	1	0	4	0	2	2	1	1	3	1	0	3
Max value	3	2	2	4	0	2	2	3	1	3	1	4	8

Table O.1: Usability evaluation: Taps on screen (group A)

Tasks - Taps on screen													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
Expected	3	1	1	4	0	2	2	1	1	3	1	2	3
PBT1	3	1	1	4	0	2	2	1	1	3	1	2	3
PBT2	3	1	1	4	0	2	2	1	1	3	1	2	3
PBT3	1	1	1	4	0	2	2	0	1	3	1	4	3
PBT4	5	1	1	4	0	1	2	0	1	3	1	2	5
PBT5	3	2	1	4	0	1	2	2	1	3	1	2	5
PBT6	3	2	1	4	0	2	2	2	1	3	1	4	5
PBT7	3	2	1	4	0	1	2	2	1	3	1	2	4
PBT8	3	1	1	4	0	1	2	1	1	3	1	2	3
PBT9	3	1	0	4	0	2	2	0	1	3	1	0	1
PBT10	3	1	1	4	0	2	2	0	1	3	1	0	3
PBT11	3	1	1	4	0	2	2	2	1	3	1	2	3
PBT12	3	1	1	4	0	1	2	1	1	3	1	4	3
PBT13	3	1	1	4	0	2	2	2	1	3	1	2	3
PB1	3	1	1	4	0	2	2	2	1	3	1	2	8
PB2	3	2	1	4	0	2	2	1	1	3	1	3	3
PB3	3	1	1	4	0	2	2	0	1	3	1	2	3
PB4	3	1	1	4	0	2	2	1	1	3	1	4	3
PB5	3	1	0	4	0	2	2	1	1	3	1	4	5
PB6	3	1	1	4	0	2	2	0	1	3	2	0	4
PB7	3	1	0	4	0	2	2	0	1	3	2	0	4
PB8	3	1	1	4	0	2	2	2	1	3	2	2	3
PB9	3	1	1	4	0	2	2	2	1	3	2	2	3
PB10	3	1	1	4	0	2	2	0	1	3	1	0	3
Average	3	1,17	0,87	4	0	1,78	2	1	1	3	1,17	2,04	3,61
Standard deviation	0,60	0,39	0,34	0	0	0,42	0	0,85	0	0	0,39	1,36	1,34
Total	69	27	20	92	0	41	46	23	23	69	27	47	83
Mode	3	1	1	4	0	2	2	0	1	3	1	2	3
Min value	1	1	0	4	0	1	2	0	1	3	1	0	1
Max value	5	2	1	4	0	2	2	2	1	3	2	4	8

Table O.2: Usability evaluation: Taps on screen (group B)

Tasks - Errors													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
PAT1	0	1	0	1	0	0	0	0	0	0	0	0	1
PAT2	0	0	1	1	0	0	0	0	1	0	0	0	0
PAT3	0	0	1	1	0	0	0	0	1	0	0	0	0
PAT4	0	0	0	0	0	0	0	0	0	0	0	1	0
PAT5	0	0	1	1	0	0	0	1	0	0	0	0	3
PAT6	0	0	0	1	0	0	0	0	0	0	0	0	0
PAT7	0	0	0	0	0	0	0	0	0	0	0	0	4
PAT8	0	0	0	1	0	0	0	0	0	0	0	0	0
PAT9	0	0	0	0	0	0	0	0	0	0	0	0	0
PAT10	0	0	0	1	0	0	0	0	0	0	0	0	0
PAT11	0	0	0	1	0	0	0	0	0	0	0	0	5
PAT12	0	0	0	1	0	0	0	0	1	0	0	2	0
PA1	0	0	0	1	0	0	0	0	0	0	0	0	3
PA2	0	0	0	1	0	0	0	0	1	0	0	0	0
PA3	0	1	1	1	0	0	0	0	0	0	0	0	2
PA4	0	0	0	1	0	0	0	0	0	0	0	0	3
PA5	0	0	0	1	0	0	0	0	0	0	0	0	2
PA6	0	0	0	0	0	0	0	0	1	0	0	0	0
PA7	0	0	1	1	0	0	0	0	1	0	0	0	0
PA8	0	0	0	1	0	0	0	0	1	0	0	0	5
PA9	0	1	1	0	0	0	0	0	0	0	0	0	0
PA10	0	1	0	1	0	0	0	2	0	0	0	0	5
PA11	0	0	1	1	0	0	0	0	1	0	0	0	0
PA12	0	0	1	1	0	0	0	0	1	0	0	0	0
Average	0	0,17	0,33	0,79	0	0	0	0,13	0,38	0	0	0,13	1,38
Standard deviation	0	0,38	0,48	0,41	0	0	0	0,45	0,49	0	0	0,45	1,88
Total	0	4	8	19	0	0	0	3	9	0	0	3	33
Mode	0	0	0	1	0	0	0	0	0	0	0	0	0
Min value	0	0	0	0	0	0	0	0	0	0	0	0	0
Max value	0	1	1	1	0	0	0	2	1	0	0	2	5

Table O.3: Usability evaluation: Errors (group A)

Tasks - Errors													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
PBT1	0	0	0	1	0	0	0	0	0	0	0	0	0
PBT2	0	0	0	1	0	0	0	0	0	0	0	0	0
PBT3	1	0	0	1	0	0	0	1	0	0	0	4	0
PBT4	2	0	0	1	1	1	0	1	1	0	0	0	2
PBT5	0	1	0	1	0	1	0	1	1	0	0	0	2
PBT6	0	1	0	0	0	0	0	1	1	0	0	2	2
PBT7	0	1	0	1	0	1	0	1	0	0	0	0	4
PBT8	0	0	1	1	0	1	0	0	0	0	0	0	0
PBT9	0	0	2	1	0	0	0	1	0	0	0	0	0
PBT10	0	0	0	1	0	0	0	1	1	0	0	0	1
PBT11	0	0	0	0	0	0	0	1	0	0	0	0	0
PBT12	0	0	0	1	0	1	0	0	0	0	0	2	0
PBT13	0	0	0	1	0	0	0	1	0	0	0	0	0
PB1	0	0	0	1	0	0	0	1	0	0	0	0	5
PB2	0	1	0	1	0	0	0	0	1	0	0	1	0
PB3	0	0	0	1	0	0	0	1	1	0	0	2	0
PB4	0	0	0	1	0	0	0	0	1	0	0	2	0
PB5	0	0	1	1	0	0	0	0	1	0	0	2	2
PB6	0	0	1	1	0	0	0	1	1	0	1	1	1
PB7	0	0	2	1	0	0	0	1	1	0	1	1	1
PB8	0	0	0	1	0	0	0	1	0	0	0	0	0
PB9	0	0	0	1	0	0	0	1	1	0	1	0	0
PB10	0	0	1	1	0	0	0	1	0	0	0	0	0
Average	0,13	0,17	0,35	0,91	0,04	0,22	0	0,70	0,48	0	0,13	0,74	0,87
Standard deviation	0,46	0,39	0,65	0,29	0,21	0,42	0	0,47	0,51	0	0,34	1,10	1,39
Total	3	4	8	21	1	5	0	16	11	0	3	17	20
Mode	0	0	0	1	0	0	0	1	0	0	0	0	0
Min value	0	0	0	0	0	0	0	0	0	0	0	0	0
Max value	2	1	2	1	1	1	0	1	1	0	1	4	5

Table O.4: Usability evaluation: Errors (group B)

Tasks - Time on task (in seconds)													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
PAT1	19,05	28,33	9,22	29,86	28,82	10,31	7,42	7,30	6,93	17,02	4,71	7,58	19,96
PAT2	31,37	4,77	6,26	16,25	16,48	7,33	4,19	3,94	15,48	11,35	5,85	3,91	12,82
PAT3	14,40	3,55	5,32	14,29	23,60	6,99	5,95	3,74	13,61	13,04	4,16	4,19	10,17
PAT4	19,86	4,27	9,80	22,64	21,05	11,10	8,45	3,34	14,83	11,73	4,89	22,08	16,52
PAT5	9,06	2,43	3,91	16,39	17,40	7,98	4,32	5,67	8,40	8,36	2,86	4,97	22,34
PAT6	5,04	1,94	6,03	8,72	19,90	11,02	2,8	1,56	7,47	6,65	3,92	8,30	10,1
PAT7	10,35	0,95	3,27	10,54	13,71	5,33	4,59	0,62	5,58	6,36	2,31	4,62	21,25
PAT8	8,62	2,39	3,91	11,64	16,31	10,45	3,36	1,56	6,13	6,96	3,06	4,16	15,98
PAT9	4,06	2,11	5,19	14,71	17,58	6,30	3,97	1,29	6,58	6,24	2,15	5,65	12,41
PAT10	5,59	1,53	3,84	12,66	12,02	7,00	3,97	1,08	4,93	8,13	2,12	5,56	7,81
PAT11	5,44	1,49	2,79	16,38	10,72	5,39	4,68	0,92	4,71	4,86	11,02	4,68	38,51
PAT12	5,37	0,90	3,00	22,44	21,51	6,90	7,45	1,13	5,31	7,47	5,38	12,54	19,84
PA1	7,98	2,16	10,55	11,78	18,52	5,78	5,23	3,86	8,18	8,84	8,34	4,22	17,52
PA2	8,64	1,97	13,49	16,98	19,93	10,16	4,27	2,10	3,83	9,26	3,96	6,45	9,79
PA3	10,59	18,62	6,17	17,75	13,08	5,78	5,99	1,93	15,47	7,57	4,63	38,33	31,74
PA4	7,07	2,10	4,22	8,80	14,73	6,52	3,74	1,34	3,51	8,17	2,65	3,46	14,14
PA5	7,40	2,05	4,71	14,92	17,01	6,35	1,68	1,08	8,34	4,14	2,73	4,55	18,88
PA6	5,00	1,79	3,60	12,84	13,47	6,20	3,32	1,52	13,79	3,6	1,96	6,39	12,49
PA7	5,75	2,12	5,12	10,18	15,64	10,12	2,41	2,01	3,14	4,78	2,40	4,18	9,65
PA8	5,11	3,01	5,46	20,36	15,01	7,96	3,61	1,32	13,35	11,16	4,27	5,95	28,19
PA9	5,90	3,56	3,96	21,23	14,51	9,92	4,6	1,33	11,51	7,69	2,89	5,02	20,44
PA10	7,89	3,10	5,14	32,75	17,55	10,08	3,45	27,32	3,46	7,85	4,10	2,86	38,3
PA11	21,64	6,45	25,22	12,99	19,69	9,48	4,37	13,10	11,87	18,12	15,32	3,24	33,22
PA12	7,96	7,32	6,97	17,89	15,52	12,45	2,51	4,17	4,62	9,48	3,47	10,10	18,91
Average	9,96	4,54	6,55	16,46	17,24	8,20	4,43	3,88	8,38	8,70125	4,55	7,62	19,21
Standard deviation	6,69	6,21	4,77	6,07	4,01	2,15	1,65	5,69	4,22	3,62	3,09	7,68	8,95
Total	239,14	108,91	157,15	394,99	413,76	196,90	106,33	93,23	201,03	208,83	109,15	182,99	460,98
Mode	-	-	3,91	-	-	5,78	3,97	1,56	-	-	-	-	-
Min value	4,06	0,90	2,79	8,72	10,72	5,33	1,68	0,62	3,14	3,6	1,96	2,86	7,81
Max value	31,37	28,33	25,22	32,75	28,82	12,45	8,45	27,32	15,48	18,12	15,32	38,33	38,51

Table O.5: Usability evaluation: Time on task (in seconds) (group A)

Tasks - Time on task (in seconds)													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
PBT1	3,82	1,16	4,62	9,44	16,58	9,66	2,37	3,66	3,85	6,51	3,42	5,92	5,85
PBT2	15,72	1,10	2,96	11,62	11,80	6,27	1,96	1,19	2,95	5,89	2,01	2,63	5,8
PBT3	21,78	3,16	15,14	25,56	14,15	13,83	6,24	10,07	6,48	11,75	3,88	28,16	6,22
PBT4	23,91	5,38	14,16	20,68	4,08	1,55	3,6	9,54	9,40	17,04	7,89	6,68	15,47
PBT5	17,61	4,38	13,74	10,78	20,51	6,53	1,35	11,59	10,87	13,87	5,36	9,38	12,34
PBT6	19,53	1,88	6,28	18,51	15,40	8,20	5,55	2,74	4,80	10,56	6,89	18,89	27,39
PBT7	4,55	2,76	5,80	13,32	9,94	3,55	3,22	15,11	6,34	14,87	6,52	7,68	10,15
PBT8	10,61	2,56	5,74	10,33	11,30	2,47	2,7	5,50	4,73	9,13	10,80	5,48	8,63
PBT9	19,53	3,45	7,96	22,59	16,01	12,89	9,86	14,45	15,47	20,28	11,20	3,84	34,12
PBT10	10,04	1,61	5,20	24,62	10,05	9,45	6,46	7,64	4,42	11,44	7,45	13,50	24,63
PBT11	6,05	2,79	3,26	21,97	15,06	7,63	4,54	17,79	5,47	10,42	6,41	4,61	22,81
PBT12	14,22	4,19	8,34	23,89	14,43	2,90	9,34	17,61	5,68	13,57	4,00	15,14	13,04
PBT13	10,07	2,42	2,35	13,76	9,26	9,21	2,54	3,48	3,94	4,59	2,56	6,90	8,13
PB1	5,24	0,88	13,74	11,05	10,94	7,13	1,61	2,01	3,65	8,63	3,45	7,27	15,4
PB2	9,42	4,42	3,58	20,75	11,37	9,30	2,13	3,88	7,38	6,12	4,63	13,83	13,57
PB3	7,98	4,15	6,22	22,19	10,44	12,40	4,12	15,45	5,61	13,66	5,82	9,60	19,83
PB4	12,09	0,92	5,20	26,66	12,89	7,01	4,67	18,42	1,65	11,05	5,09	16,84	14,6
PB5	7,22	2,45	11,00	21,56	13,44	9,95	3,17	4,46	2,14	10,2	6,03	14,17	17,46
PB6	16,45	3,83	9,93	18,30	14,74	14,39	2,73	6,18	7,34	12,85	10,84	9,05	43,03
PB7	19,64	4,74	17,27	19,04	15,04	6,89	5,4	12,83	5,43	12,85	10,84	9,05	43,03
PB8	9,41	1,62	3,34	12,56	11,02	6,66	1,86	3,85	9,93	6,84	3,17	4,00	13,23
PB9	7,88	6,12	8,29	19,52	17,79	9,52	6,42	17,01	5,49	10,08	8,53	16,85	12,25
PB10	16,19	8,85	9,05	24,08	18,83	9,52	4,6	4,84	4,75	13,53	5,62	4,81	17,11
Average	12,56	3,25	7,96	18,38	13,26	8,13	4,19	9,10	5,99	11,12	6,19	10,19	17,57
Standard deviation	5,92	1,91	4,36	5,53	3,62	3,45	2,32	5,86	3,09	3,77	2,78	6,14	10,68
Total	288,96	74,82	183,17	422,78	305,07	186,91	96,44	209,30	137,77	255,73	142,41	234,28	404,09
Mode	19,53	-	13,74	-	-	9,52	-	-	-	12,85	10,84	9,05	43,03
Min value	3,82	0,88	2,35	9,44	4,08	1,55	1,35	1,19	1,65	4,59	2,01	2,63	5,8
Max value	23,91	8,85	17,27	26,66	20,51	14,39	9,86	18,42	15,47	20,28	11,20	28,16	43,03

Table O.6: Usability evaluation: Time on task (in seconds) (group B)

Tasks - Task completion													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
PA1	1	0	1	1	1	1	1	1	1	1	1	1	1
PA2	1	1	0	1	1	1	1	1	1	1	1	1	1
PA3	1	1	0	1	1	1	1	1	1	1	1	1	1
PA4	1	0	1	1	1	1	1	1	1	1	1	0	1
PA5	1	1	0	1	1	1	1	1	1	1	1	1	1
PA6	1	1	1	1	1	1	1	1	1	1	1	1	1
PA7	1	1	1	1	1	1	1	1	1	1	1	1	1
PA8	1	1	1	1	1	1	1	1	1	1	1	1	1
PA9	1	1	1	1	1	1	1	1	1	1	1	1	1
PA10	1	1	1	1	1	1	1	1	1	1	1	1	1
PA11	1	1	1	1	1	1	1	1	1	1	1	1	1
PA12	1	1	1	1	1	1	1	1	1	1	1	1	1
PA13	1	1	1	1	1	1	1	1	1	1	1	1	1
PA14	1	1	1	1	1	1	1	1	1	1	1	1	1
PA15	1	1	0	1	1	1	1	1	1	1	1	1	1
PA16	1	1	1	1	1	1	1	1	1	1	1	1	1
PA17	1	0	1	1	1	1	1	1	1	1	1	1	1
PA18	1	1	1	1	1	1	1	1	1	1	1	1	1
PA19	1	1	0	1	1	1	1	1	1	1	1	1	1
PA20	1	1	1	1	1	1	1	1	1	1	1	1	1
PA21	1	1	1	1	1	1	1	1	1	1	1	1	1
PA22	1	1	1	1	1	1	1	1	1	1	1	1	1
PA23	1	1	0	1	1	1	1	1	1	1	1	0	1
PA24	1	1	1	1	1	1	1	1	1	1	1	1	1
Average	1	0,88	0,75	1	1	1	1	1	1	1	1	0,92	1
Standard deviation	0	0,34	0,44	0	0	0	0	0	0	0	0	0,28	0
Total	24	21	18	24	24	24	24	24	24	24	24	22	24
Mode	-	-	1	-	-	1	1	1	-	-	-	-	-
Min value	1	0	0	1	1	1	1	1	1	1	1	0	1
Max value	1	1	1	1	1	1	1	1	1	1	1	1	1

Table O.7: Usability evaluation: Task completion (group A)

Tasks - Task completion													
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
PBT1	1	1	1	1	1	1	1	1	1	1	1	1	1
PBT2	1	1	1	1	1	1	1	1	1	1	1	1	1
PBT3	1	1	1	1	1	1	1	0	1	1	1	0	0
PBT4	1	1	1	1	0	0	1	0	1	1	1	1	0
PBT5	1	1	1	1	1	0	1	1	1	1	1	1	0
PBT6	1	1	1	1	1	1	1	1	1	1	1	1	1
PBT7	1	1	1	1	1	0	1	1	1	1	1	1	0
PBT8	1	1	0	1	1	0	1	1	1	1	1	1	1
PBT9	1	1	0	1	1	1	1	0	1	1	1	0	1
PBT10	1	1	1	1	1	1	1	0	1	1	1	0	1
PBT11	1	1	1	1	1	1	1	1	1	1	1	1	1
PBT12	1	1	1	1	1	1	1	1	1	1	1	1	1
PBT13	1	1	1	1	1	1	1	1	1	1	1	1	1
PB1	1	1	1	1	1	1	1	1	1	1	1	1	1
PB2	1	1	1	1	1	1	1	1	1	1	1	1	1
PB3	1	1	1	1	1	1	1	0	1	1	1	0	1
PB4	1	1	1	1	1	1	1	1	1	1	1	1	1
PB5	1	1	0	1	1	1	1	1	1	1	1	1	1
PB6	1	1	1	1	1	1	1	0	1	1	1	0	1
PB7	1	1	0	1	1	1	1	0	1	1	1	0	1
PB8	1	1	1	1	1	1	1	1	1	1	1	1	1
PB9	1	1	1	1	1	1	1	1	1	1	1	1	1
PB10	1	1	1	1	1	1	1	0	1	1	1	0	1
Average	1	1	0,83	1	0,96	0,83	1	0,65	1	1	1	0,70	0,83
Standard deviation	0	0	0,39	0	0,21	0,39	0	0,49	0	0	0	0,47	0,39
Total	23	23	19	23	22	19	23	15	23	23	23	16	19
Mode	1	1	1	1	1	1	1	1	1	1	1	1	1
Total 0	0	0	4	0	1	4	0	8	0	0	0	7	4
Total 1	23	23	19	23	22	19	23	15	23	23	23	16	19

Table O.8: Usability evaluation: Task completion (group B)