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UNIVERSIDADE Ð COIMBRA

Petra Grego Rato

Self-report mobile user interface design patterns for older adults with rheumatic conditions

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

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DEPARTAMENTO DE ENGENHARIA INFORMÁTICA

Petra Rato Grego

Padrões de Design de Interface Utilizador Dirigidas ao Autorrelato de Pessoas com Doenças Reumáticas

Dissertação no âmbito do Mestrado em Design e Multimédia, orientada por Paula Alexandra Silva e Francisco Nunes e apresentada ao Departamento de Engenharia Informática da Faculdade de Ciências e Tecnologia da Universidade de Coimbra.

Julho 2022

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Abstract

This work explored how to design self-report mobile apps for people with rheumatic conditions. By recognising the impact of rheumatic conditions on fine motor skills, we wanted to better understand usability issues within current self-report apps and to propose a set of design patterns that could better accommodate for the characteristics of users with rheumatic conditions. The research approach followed was divided into three phases: mobile app search and identification of UI components to test, usability test experiments of UI components, and design patterns definition. The first phase consisted of a systematic mobile app review for rheumatic conditions, which found that the most commonly used UI components were: horizontal sliders, vertical sliders, column selectors, in-line selectors, and selectors incorporated in body graphics. The UI components found were then filtered, to include only those that respected Android or iOS guidelines and those that appeared more often in the reviewed apps. The list of UI components that resulted from this process was then discussed with a group of designers to select the UI components to test. These components were then implemented in a mobile tool used to support the usability experiments that involved a total of 20 people with rheumatic conditions. Metrics such as the subjective preference between UI component alternatives, task completion time, and number of gesture interactions, were statistically analysed to determine the best button height and in-between button sizes, the best characteristics of horizontal and vertical sliders, the best screen positions of the UI components, and the most adequate button width for buttons for body graphics. Based on these results, the third phase of this research consisted of the creation of three UI design patterns for people with rheumatic conditions: (i) RECOMMENDED SLIDER CHARACTERISTICS FOR SLIDERS *, (ii) RECOMMENDED SELECTORS * and (iii) RECOMMENDED SELECTOR SIZE FOR A BODY GRAPHIC *. These design patterns contribute to addressing the current gap in app design by providing guidance to designers developing self-report mobile apps for people with rheumatic conditions.

Keywords

Rheumatic conditions, mHealth, Chronic care, Self-care, Self-Report, UI components, Design patterns.

Resumo

Este trabalho explorou como desenhar aplicações móveis de autorrelato para pessoas com doenças do reumático. Ao reconhecer o impacto das doenças do reumático nas habilidades motoras finas, quísemos entender melhor os problemas de usabilidade nas aplicações de autorrelato atuais e propor um conjunto de padrões de design que pudessem acomodar melhor as características dos utilizadores com estas doenças. A abordagem de investigação seguida foi dividida em três fases: pesquisa de aplicações móveis e identificação de componentes de interface de utilizador (IU) para teste, experiências de usabilidade de componentes de IU e definição de padrões de design. A primeira fase consistiu na revisão sistemática de aplicações móveis para doenças do reumático e conluiu que os componentes de interface do utilizador mais usados nas aplicações eram: sliders horizontais, sliders verticais, seletores em coluna, seletores em linha e seletores incorporados em gráficos do corpo humano. Esses componentes de IU foram filtrados para incluir apenas aqueles que respeitavam as diretrizes do Android ou iOS e aqueles que apareciam com mais frequência nas aplicações revistas. A lista de componentes de interface do utilizador resultante desse processo foi discutida com um grupo de designers de modo a selecionar os componentes de IU a serem testados. Os componentes de IU finais foram então implementados numa ferramenta móvel usada para apoiar as experiências de usabilidade que envolveram um total de 20 pessoas com doenças do reumático. Métricas como a preferência subjetiva entre alternativas de componentes de IU, tempo de conclusão da tarefa e número de interações de gestos foram analisadas estatisticamente para determinar a melhor altura e espaçamento entre botões, as melhores características de sliders horizontais e verticais, as melhores posições no ecrã dos componentes de IU, e a largura de botões mais adequada para botões para gráficos do corpo humano. Com base nesses resultados, a terceira fase desta investigação consistiu na criação de três padrões de design de interface do utilizador para pessoas com doenças do reumático: (i) CARACTERÍSTICAS RECOMENDADA PARA SLIDERS *, (ii) SELETORES RECOMENDADOS * e (iii) TAMANHO DE SELETOR RECOMENDADO PARA UM GRÁFICO DE CORPO HUMANO *. Os padrões de design criados esperam abordar a lacuna atual no design de aplicações, fornecendo orientação aos designers que desenvolvem aplicações móveis de autorrelato para pessoas com doenças do reumático.

Palavras-Chave

Doenças do reumático, mHealth, Cuidados crónicos, Autocuidado, Autorrelato, Componentes IU, Padrões de design.

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Acronyms

AICOS Assistive Information and Communication Solutions.

CSV Comma-Separated Values.

DMARDs Disease-Modifying Antirheumatic Drugs.

ePRO Electronic Patient-Reported Outcomes.

EULAR European League Against Rheumatism.

HCI Human-Computer Interaction.

HIG Human Interface Guidelines.

ICT Information and Communication Technology.

NSAIDs Nonsteroidal Anti-inflammatory Drugs.

OA Osteoarthritis.

PROMs Patient-Reported Outcome Measures.

PROs Patient-Report Outcomes.

PsA Psoriatic Arthritis.

RA Rheumatoid Arthritis.

UCD User-Centered Design.

UI User Interface.

W3C World Wide Web Consortium's.

WCAG Web Content Accessibility Guidelines.

WU Web Usability.

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Chapter 1

Introduction

According to the European League Against Rheumatism (EULAR), there are 120 million Europeans living with rheumatic conditions (EULAR, 2011), and these numbers are expected to rise as the population ages (Najm et al., 2019). Many rheumatic conditions do not currently have a cure, so people must engage in self-care for a long period of time (Mollard and Michaud, 2019). The self-care of people with rheumatic conditions usually entails keeping track of one's health, dealing with symptoms, managing medication prescriptions, coping with impairments, and getting appropriate medical advice (Welsing et al., 2004).

The use of mobile apps for self-reporting symptoms, also known as Electronic Patient-Reported Outcomes (ePRO), is viewed as key to supporting rheumatology care with valuable patient feedback (Mollard and Michaud, 2021). However, ePRO solutions are rarely subjected to usability testing, which is particularly problematic for older patients with limited Information and Communication Technology (ICT) knowledge or expertise (Solomon and Rudin, 2020). Unless these limitations are resolved, ePROs' potential is considerably diminished.

This dissertation aims to improve self-report apps for people with rheumatic conditions by reviewing User Interface (UI) components incorporated in existent mobile apps and testing them with people with rheumatic conditions. The results of the UI components tests, conducted through usability experiments, will provide for the development of evidence-based design patterns. The design patterns shall enable the synthesis of our findings with a view to providing guidance to designers developing smartphone user interfaces for people with rheumatic conditions.

1.1 Research focus and motivation

This dissertation focuses on three of the most common rheumatic conditions, namely Rheumatoid Arthritis (RA), Osteoarthritis (OA), and Psoriatic Arthritis (PsA). The three conditions are different, but they share several symptoms, such as pain, joint inflammation, stiffness, and swelling. The treatments for rheumatic conditions aim to reduce pain, maintain physical function, and delay the resulting disability. All conditions impact the quality of life of people with these conditions since they live with dysfunction and disability, which has mental health consequences.

People with rheumatic conditions are a special group for mobile health technologies since they are more likely than other mainstream users to experience pain and dysfunction in their hands. Hand discomfort and impairment impose restrictions, such as having difficulties in data input or with coarse precision, on how mobile devices can be used (Mollard and Michaud, 2019). Another issue to consider is the patient's knowledge of mobile apps which can also impact their app usage (Kruse et al., 2017). This work is novel because, while the potential of self-report applications is recognised, the evaluation of such applications is still in the early stages.

This dissertation intends to study existing self-report apps, their characteristics, functionalities, and commonly used UI components, for people with rheumatic conditions, with the aim of better understanding how the latter ones can be adapted and improved to be used in a more appropriate way by people with rheumatic conditions.

1.2 The COTIDIANA Project

This dissertation emerges in the context of COTIDIANA, an European project, led by Fraunhofer Portugal Assistive Information and Communication Solutions (AICOS), and whose goal is to create a mobile solution that enables holistic and efficient rheumatic patient monitoring, for clinical care and drug trials. Patients will be provided with a mobile app that enables them to self-report experiences, symptoms, quality of life, and that monitor smartphone usage passively to characterise patients' condition state. Clinicians and clinical researchers will be provided with a web app that enables them to visualise the data collected by the patients.

In tandem with this goal, the mobile app for patients of COTIDIANA will include features such as self-report prompts/ePRO, medication reminders, data visualisation, and objective tracking methods. The work developed in the context of this dissertation will support the development of the COTIDIANA mobile app by providing evidence-based design patterns for self-report that can be considered in the design of the planned mobile app.

1.3 Objectives and Contribution

The main goals of this dissertation are to uncover UI components used in existing self-report mobile apps and to create evidence-based design patterns for self-report apps for people with rheumatic conditions. In addressing this goal, this work will engage in a systematic review of self-report mobile apps for people with rheumatic conditions to determine the most commonly used

UI components. These will then be tested with participants through usability experiments. The results and analysis of these usability tests will inform the creation of three evidence-based design patterns for people with rheumatic conditions, which can then be used by designers to develop self-report mobile apps for people with rheumatic conditions.

The main contributions of this dissertation are the understanding of existing self-report apps, their characteristics, features, and the more commonly used UI components used in them. The final contribution of this dissertation is three evidence-based design patterns for people with rheumatic conditions.

1.4 Dissertation Outline

This dissertation is organised in six chapters. The current **Chapter 1** introduced this work mentioning the research focus and motivation of the dissertation, the project in which this dissertation is inserted, and the goals and contributions of the research. This chapter also includes this section where the structure of the document is presented.

Chapter 2 presents the Literature Review and the State of the Art. It explores the rheumatic conditions studied in this dissertation, introducing their symptoms, and treatments. Other topics include self-monitoring and the role of technology in supporting patients with rheumatic conditions. The chapter also briefly presents mobile apps for people with rheumatic conditions existent in the market. Finally, chapter 2 discusses design patterns, highlighting their history, structure, and importance in the field of Human-Computer Interaction (HCI).

Chapter 3 introduces the Methodology followed in this work, justifying the two design approaches that influenced the work: User-Centred Design and Designs Patterns. It is also the chapter that presents and explains the work plan and the different stages of development planned for this research.

Chapter 4 is dedicated to the app review. It presents the app review protocol, the data collected, the codes used in the thematic analysis, and the results of the app review. The results are separated into characteristics, features and UI components present in the apps included; the selection of UI components for testing; the pre-selection of these UI components; and the validation of the pre-selected UI components through an expert review.

Chapter 5 introduces the test conditions, procedures, and participants. It is also the chapter where the data analysis and the different tests are further detailed and the findings of each test are individually presented.

Chapter 6 presents the user interface design patterns that build on the findings from the previous research phases. The chapter starts by presenting the goals of the patterns and their structure. Finally, it documents all the design patterns resulting from our research.

Chapter 7 discusses the main findings from this research and reflects on the strengths and limitations of the work.

Chapter 8 concludes this research and suggests a set of possible directions for future work.

Chapter 2

Literature review and state of the art

2.1 Rheumatic Conditions

According to the European League Against Rheumatism (EULAR), rheumatic conditions affect 120 million Europeans (EULAR, 2011). These people are a unique population for mobile apps as they are more likely than mainstream users to experience pain and dysfunction in their hands. Consequently, their usage of mobile devices is hampered by hand pain and impairment (Mollard and Michaud, 2019).

This chapter reviews symptoms, and treatments among other characteristics of Rheumatoid Arthritis (RA), Osteoarthritis (OA) and Psoriatic Arthritis (PsA), highlighting the differences and similarities between them. Then, the chapter presents the typical self-care and self-monitoring performed by people with rheumatic conditions. Lastly, an overview of apps for people with rheumatic conditions is presented.

2.1.1 Rheumatoid Arthritis

Rheumatoid arthritis is a chronic systemic inflammatory autoimmune disease, defined by bouts of disease flares or long-term chronic inflammation (Sparks, 2019). A chronic condition, or chronic disease, is a long-lasting disorder that, although it may be controllable with care interventions, cannot be cured. Thus, the goal of care is to promote independence and quality of life for as long as possible (Pohl and Benseler, 2013). A systemic inflammatory autoimmune disease is characterised by changes in the adaptive immunity, such as autoantibodies, and a dysregulation of the innate immune system (Pohl and Benseler, 2013). RA is more common in women and typically appears between the ages of 30 and 50 years. When the condition appears, patients usually experience significant pain, joint degeneration and functional deterioration, leading to a significant economic impact on both the individual and society (Kvien and Uhlig, 2005).

Symptoms and consequences

RA happens when the body's defence system, the immune system, attacks the joints and causes them to become swollen and painful. RA is observed in any patient with joint stiffness, pain or swelling that persists for more than a few weeks (Sparks, 2019). The hands, wrists and feet are the most common locations of RA, however, it can also affect larger joints like the knee or the hip (Sparks, 2019). The main symptoms of concern for RA are pain, stiffness, inflammation, and depression (Pollard et al., 2005).

Pain and fatigue are essentially symptomatic consequences which occur early on and may persist throughout (Pollard et al., 2005). Pain remains the primary concern for most patients with RA. At first joint pain is frequently symmetrical and can be in two to four joints (oligoarticular) or only in one joint (monoarticular) (Sparks, 2019). Although controlling pain is one sign of effective treatment, most RA patients continue to have substantial pain despite therapy, making it a significant negative consequence of the disease (Pollard et al., 2005).

Patients regard fatigue as a determinant factor in their quality of life and disability (Pollard et al., 2005). Fatigue is perceived as unpleasant, unusual, abnormal, or excessive whole-body tiredness, disproportionate to or unrelated to activity or exertion and present for more than one month (Repping-Wuts et al., 2009). Qualitative research states that RA patients believe reducing fatigue should be an important therapy goal and the absence of fatigue is one of the components of remission (Pollard et al., 2005). Although the exact cause of fatigue in RA has yet to be determined, multiple studies have indicated that fatigue is significantly linked to pain and depression (Pollard et al., 2005).

Joint stiffness is another main concern of people living with RA and is often related to patient symptoms of pain and stiffness and is not always caused by inflammatory arthritis (Sparks, 2019). Although morning stiffness that improves with use throughout the day is not unique to RA, it is a distinct characteristic of the condition.

Disability develops early and gradually due to pain, inflammation and joint damage (Pollard et al., 2005). Disability has been linked to high pain levels and became one of the main reasons for the deterioration in the quality of life (Pollard et al., 2005). RA patients also have higher infection rates, respiratory disease, osteoporosis, cardiovascular disease, cancer and earlier death than the general population (Sparks, 2019).

Treatments

The treatment of RA consists of pharmacological treatment, self-care, behaviour change and physical or occupational therapy, to reduce the impact that the disease has on the patient and halt the progression of the disease (Kingsley et al., 2011). Pharmacologic treatment of RA should tightly control inflammation with the goal of achieving low disease activity or remission even though only a tiny percentage of patients can attain long-term remission without the need for long-term medication intake (Sparks, 2019).

Majithia and Geraci (2007) state that drug treatment generally involves a 3-pronged approach: nonsteroidal anti-inflammatory drugs, disease-modifying antirheumatic drugs and consideration of biologic response modifiers/biologics. Nonsteroidal Anti-inflammatory Drugs (NSAIDs) are generally used on an as-needed basis for pain but do not alter the disease course (Sparks, 2019). Disease-Modifying Antirheumatic Drugs (DMARDs), like steroids, relieve symptoms and may slow joint damage (Sparks, 2019). To maintain joint function and delay disability, patients should learn more about the illness, visit their rheumatologist and do physical or occupational therapy in order to relieve pain and stiffness (Majithia and Geraci, 2007).

According to (Kingsley et al., 2011), to assess treatment impact, formal outcome measures have been developed. Traditionally, outcome measures focus on clinical aspects such as disease activity and joint damage, but there has been an increased focus on outcome measures, such as quality of life. These enable illness evaluation from the patients' perspectives, assessing care quality, and comparing treatment effectiveness and cost-effectiveness (Sparks, 2019). Despite the existence of treatment, RA continues to have deleterious consequences on pain, fatigue, physical function, depression and associated psychological features and disability (Pollard et al., 2005).

2.1.2 Osteoarthritis

Osteoarthritis is the most common rheumatic condition worldwide, affecting an estimated 10% of men and 18% of women over 60 years of age (Glyn-Jones et al., 2015). The condition is characterised by loss or failure of the joint's functional and/or biochemical integrity limiting the ability of patients to participate in main daily activities and increasing the risk for disability. The characteristic of OA is loss of cartilage, joint stiffness, inflammatory pain and dysfunction (Kean et al., 2004), which lead to chronic disease and disability as people get older, lowering their quality of life (Sarzi-Puttini et al., 2005). The prevalence of OA is increasing mainly due to increasing life spans (Sarzi-Puttini et al., 2005).

Symptoms and consequences

Osteoarthritis can be viewed as the clinical and pathologic outcome of various disorders resulting in synovial joint structural and functional failure (Hunter et al., 2008). OA is defined as a loss of a joint's functional integrity and is common in the knee and hip, being the primary source of chronic disability in older people (Kean et al., 2004).

OA causes joint stiffness and dysfunction. However, the main problem for most patients is pain, which leads to loss of function and social disharmony, resulting in impaired performance in the workforce or in the home (Kean et al., 2004). The pain associated with OA is frequently reported as being aggravated by activity and eased by rest periods (Kean et al., 2004). Physical load related to heavy manual work and permanent damage of the joints proves to be a risk factor predicting the development of OA (Toivanen et al., 2010). The more advanced OA is, the more it can cause pain at rest and during the night, leading to sleep loss and pain exacerbation. In advanced cases, pain may awake the patient from sleep because of the loss of protective muscular joint splinting (Sarzi-Puttini et al., 2005).

Short-lasting morning stiffness is a common complaint in patients with OA, and articular gelling, a transient stiffness that lasts only a few flexion-extension cycles, is extremely common in older adults, especially in the lower extremity joints (Sarzi-Puttini et al., 2005). Limited motion develops as the disease progresses because of joint-surface incongruity, muscle spasm and contracture, capsular contracture, and mechanical block due to osteophytes or loose bodies (Sarzi-Puttini et al., 2005).

Sarzi-Puttini et al. (2005) describe crepitus as a crackling or grating sound that occurs when a joint is manipulated, caused by cartilage loss and irregularities in the joint surface. Adding that joint enlargement may be caused by secondary synovitis, an increase in synovial fluid or marginal proliferative changes in cartilage or bone (osteophytes). Late stages of the diseases are associated with gross deformity and subluxation due to cartilage loss, subchondral bone collapse, bone cysts and gross bony overgrowth (Sarzi-Puttini et al., 2005).

Patients also report reduced movement, deformity, swelling in the absence of systemic features such as fever, crepitus, discomfort associated with increased age, and, when pain persists, pain-related psychologic distress (Hunter et al., 2008). OA has been linked to psychological factors such as learned helplessness, coping and mood, often unrelated to the intensity of physical symptoms (Cook et al., 2007).

Treatments

The main treatment goals in OA are to control pain, improve function and reduce impairment. The status and requirements of patients often change over time, thus making it essential to review and adjust treatment regularly rather than rigidly continuing a single intervention (Sarzi-Puttini et al., 2005).

Traditionally, osteoarthritis treatment consists of pain management and joint replacement for end-stage disease (Glyn-Jones et al., 2015). This approach does not address the morbidity associated with early disease and the limits of arthroplasty surgery, such as the risk of adverse outcomes and the prosthetics' limited lifespan.

Joint replacement is an effective treatment for the symptomatic end-stage disease, although functional outcomes can be poor and the lifespan of prostheses is limited (Glyn-Jones et al., 2015). Consequently, the focus shifts to disease prevention and the treatment of early osteoarthritis. Disease prevention is challenging since conventional imaging techniques only detect advanced disease and the relation between pain and structural degeneration is not always clear

(Glyn-Jones et al., 2015).

2.1.3 Psoriatic Arthritis

PsA is generally defined as inflammatory arthritis associated with psoriasis (Mease and Goffe, 2005). Psoriasis is a chronic, non-infectious disease that can involve the skin, nails, joints and is a disfiguring, disabling and painful disease (Michalek et al., 2017). Environmental, genetic, and immunologic variables have all been linked to the disease (Duarte et al., 2012). The peak of PsA incidence occurs between 30 and 50 years of age being more common in men. It is clinically characterised by oedema, pain, tenderness, and stiffness of the joints, ligaments, and tendons (dactylitis and enthesitis) (Duarte et al., 2012). The disease's multifaceted appearance influences patients' physical and psychological well-being. Chronic pain, restrictions in physical functioning and work capacities, acute weariness and emotional and social impairment are symptoms experienced by those with PsA.

Symptoms and consequences

Physical disability is due mainly to the musculoskeletal component since PsA patients have arthritis, dactylitis, enthesitis, and sometimes results in pain, discomfort and reduced mobility (axial involvement). This aspect of the disease may lead to erosion and structural damage over time, resulting in permanent impairment. However, skin disease can also cause pain and discomfort through itching, irritation, redness, skin soreness or bleeding from psoriatic lesions (Gudu and Gossec, 2018).

PsA may afflict any synovial joint and the most common forms of PsA involve the joints of the hands and feet (Boehncke et al., 2014). According to McKenna et al. (2004), PsA can present as asymmetrical oligoarthritis (in which few joints are affected), symmetrical polyarthritis (indistinguishable from rheumatoid arthritis) and predominant spondylitis (with spinal involvement).

PsA is characterised by swollen and tender joints, dactylitis (inflammation of an entire digit), enthesitis (inflammation at sites of tendon insertion to bone) and axial involvement (inflammation in the sacroiliac joints or spine). Inflammation may lead to progressive joint deterioration (Boehncke et al., 2014). Arthritis is marked by periods of flare-ups and remissions, but inflammation remains if the disease is not managed. The appearance of arthritis might precede, succeed or be concomitant with skin lesions. Generally, there is no correlation between the type or severity of skin lesions and the presence, type, or extent of joint affection (Duarte et al., 2012). PsA differs from other forms of inflammatory arthritis in that excessive bone is sometimes produced at joint margins (Boehncke et al., 2014).

Various skin lesions are caused by PsA, including localised, diffuse, guttate or pustular lesions. Among patients with psoriasis, nail dystrophy, scalp lesions, intergluteal/perianal lesions and the percentage of body surface area affected with psoriasis appear to be associated with an increased risk for PsA (Boehncke et al., 2014).

PsA is among the most significant comorbidities associated with psoriasis, resulting in pain and deformities limiting function and reducing the quality of life (Boehncke et al., 2014). Additionally, patients with PsA are also more likely to develop metabolic syndrome and cardiovascular disease; thus, their cardiovascular risk factors should be checked regularly.

Furthermore, PsA patients may experience depression and anxiety as a result of both patient and disease-related factors, such as unemployment status, actively inflamed joints, disability, pain and fatigue (Gudu and Gossec, 2018). The other main aspect that contributes to depression is the embarrassment and shame due to appearance.

Treatments

PsA is characterised as inflammatory arthritis of uncertain pathogenesis, affecting approximately one in four patients with psoriasis. The onset of psoriasis usually occurs before joint-related symptoms (Boehncke et al., 2014). Dermatologists and rheumatologists collaborate to recognise early signs, reduce symptoms, delay disease progression and improve quality of life in many cases (Boehncke et al., 2014).

The dermatologist's role in early diagnosis and treatment is essential for preventing pain, functional disabilities and the joint deterioration that accompanies progressive forms of PsA (Boehncke et al., 2014). Psoriasis occurring as part of PsA requires a different therapeutic approach than psoriasis alone. Hence diagnosing PsA is an integral part of dermatologists' clinical decision-making process when examining patients with psoriasis.

Each visit is an opportunity for a dermatologist to assess for joint pain that may suggest the presence of psoriatic arthritis. However, other arthropathies, such as osteoarthritis, reactive arthritis, RA and ankylosing spondylitis must be ruled out before psoriatic arthritis may be diagnosed (Mease and Goffe, 2005). Dermatologists and rheumatologists collaborate to reduce symptoms, delay disease progression and improve quality of life in many cases (Boehncke et al., 2014).

Imaging helps in differential diagnosis, prognosis, monitoring disease progression and therapy decision-making. Imaging can be helpful for the diagnosis of axial disease and for establishing the severity of peripheral arthritis (Boehncke et al., 2014). However, there is no specific diagnostic test for psoriatic arthritis. The diagnosis is based primarily on medical history, physical examination and radiographic features. The physical examination includes assessing the number, location and distribution of joints involved, along with psoriatic skin lesions (Mease and Goffe, 2005).

The treatment of mild symptoms is usually done with NSAIDs and physical therapy (Boehncke et al., 2014). Because treatments that improve psoriatic lesions do not necessarily improve joint symptoms and vice versa, determining whether a patient has psoriatic arthritis is critical in guiding treatment (Mease and Goffe, 2005).

The presence of PsA is strongly associated with a decline in quality of life, especially regarding an individual's physical health. Patients with PsA commonly report function limitations, emotional problems and bodily pain in quality of life assessments (Mease and Goffe, 2005).

Review of disease symptoms and characteristics

Having listed the symptoms and treatments of some of the most common rheumatic conditions, this section presents a summary of the similarities and differences between conditions (Table 2.1).

Although all three rheumatic conditions affect the joints of a person, they have different causes. RA and PsA are inflammatory types of arthritis caused by the immune system and are more common in the hand, wrists and feet. OA is degenerative, caused by wear and tear over time, and affects mainly the knees and the hips. Pain and swelling are two of the common symptoms of these conditions. On the other hand, stiffness is often related to RA and OA. Dysfunction and disability are one of the main reasons for mental health problems in all three conditions.

Dimention		Conditions		
		Rheumatoid Arthritis (RA)	Osteoarthritis (OA)	Psoriatic Arthritis (PsA)
Joints Affected	Hands, Wrists and Feet	x		x
	Knees and Hips		x	
Symptoms	Pain	x	x	x
	Swelling	x	x	
	Inflammation	x		x
	Stifness	x	x	
	Swollen Fingers and Toes			x
	Skin Rash (Psoriasis)			x
Gait & Physical Activity	Gait Impairment	x	x	
	Deformation		x	
	Dysfunction	x	x	x
	Disability	x	x	x
Mental Health	Depression	x		x
	Fatigue	x		
	Sleep Problems		x	
	Anxiety			x

Table 2.1: Review of disease symptoms and characteristics.

2.2 Care and Self-monitoring

The care of rheumatic conditions has been evolving to achieve greater levels of personalization, with patients being more empowered and more involved in healthcare planning and development (Voshaar et al., 2015). An example of this involvement is patient self-monitoring, whereby patients undertake self-measure-ment of vital signs, symptoms, behavior or psychological well-being through Patient-Reported Outcome Measures (PROMs) that contribute to clinical care decisions (Wilde and Garvin, 2007).

Self-monitoring may gradually replace traditional appointments in some patients with rheumatic conditions such as RA, OA and PsA (Riel et al., 2016). However, there are other reasons why self-monitoring in patients with rheumatic diseases has gained more interest (Welsing et al., 2004). The Treat-to-Target Task Force recommends that rheumatologists assess patients with moderate or high disease activity monthly and patients with controlled and low disease activity every three to six months (Smolen et al., 2010). However, in practice, these frequencies are not always met for various reasons. This strategy causes time constraints on rheumatologists and increases their workload, making it impossible to fully comply with frequent assessments (Renskers et al., 2020).

Another reason is connected to the ageing population. Although rheumatic conditions affect people of all ages, they have a high prevalence among older adults (Sangha, 2000). Disease activity can only be reliably assessed during outpatient consultations. What happens to disease activity between consultations is unknown. Fluctuations and peeks in disease activity are easily missed or remain unnoticed, which can have severe repercussions in terms of joint damage (Welsing et al., 2004). Self-monitoring might provide better insight into these fluctuations of disease activity in-between outpatient clinical consultations. Furthermore, some patients see their rheumatologist while their disease activity is under control, resulting in unnecessary outpatient consultations (Renskers et al., 2020).

Moreover, it can lead to more consistent reporting in the long term and improve the number, time and efficiency of consultations (Riel et al., 2016). Patients who need further medical attention can be identified and receive additional medical attention.

2.3 Issues in technology use

2.3.1 General barriers of rheumatic conditions

Patients with rheumatic conditions are a special group for mobile health technologies since they present characteristics that influence their interaction with technology (Mollard and Michaud, 2019). Therefore, attention to design aspects of apps is critical to improving usability, adherence and clinical outcomes. In fact, there are a number of barriers that must be considered to provide apps that accommodate users and their needs.

The symptoms that people with rheumatic conditions experience affect their hand dexterity, consequently influencing their interactions with technology (Mollard and Michaud, 2019). People with dexterity problems may not be able to move the hand as quickly, may lack flexibility of movement, be unable to touch a button or involuntarily touch it, or can have so much pain that their hand movement is prevented. Therefore, attention to design aspects of apps, such as button size, spacing, and design components, is critical to improving usability, adherence and clinical outcomes (Mollard and Michaud, 2019). There are barriers that must be considered to provide apps that accommodate the users and their needs.

Hand pain and disability

People with rheumatic conditions are more likely to experience pain and disability in their hands compared with the general population or other people affected by chronic illnesses (Mollard and Michaud, 2019). Hand pain and limited hand movement present restraints for the actual operation of mobile devices, such as the precision required by small buttons. In the UI in Fig. 2.1 (left) it would be difficult to press the buttons of the articulation without inadvertently touching the button on the side. The same for the example of the right for *Arthritis Diary* app. (Grainger and Al, 2020) affirm that patients do not consider these limitations a barrier to data input on a smartphone, acknowledging that smartphone screens are small, requiring a simple mechanism for data input. Therefore, there is a need to take these challenges into consideration when designing for these users.

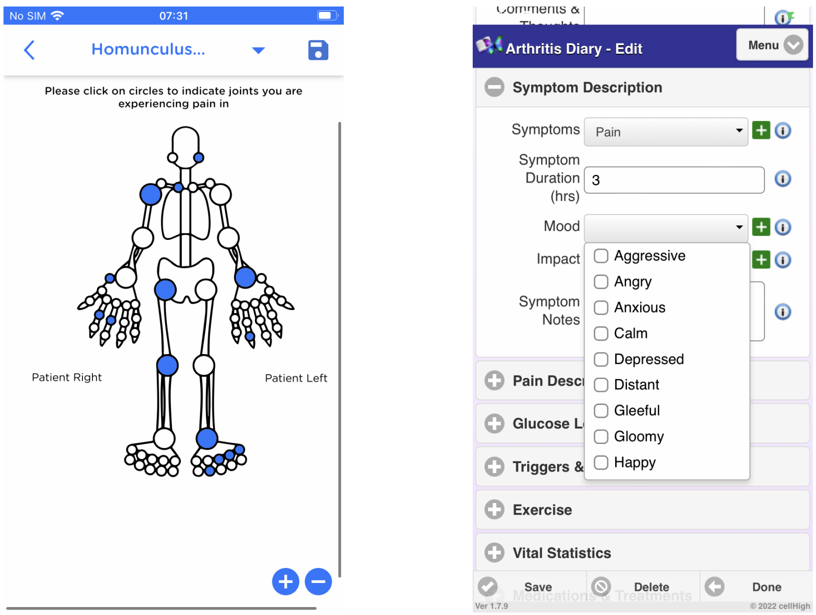


Figure 2.1: Apps' UI that difficult interaction: Arthritis+Patient (left) and Arthritis Diary (right).

Accessibility and technical ability

Another challenge that can be experienced when interacting with mobile phones can be the technical ability of the patient. The accessibility of apps and their ease of use are essential for their implementation and sustainability (Najm et al., 2019). The inclusion of visual display and functionalities (screen, buttons, text boxes, literacy), the use of the principle of universal design and the ability, to use the technology, despite prior experience with mobile devices or technical abilities, determine the quality of the app and success with the end-users (Najm et al., 2019).

Mobile apps are more widely adopted by teenagers, young adults and adults, than by older adults, and the challenges with mobile app uptake and continuous use seem to rise with age (Mollard and Michaud, 2019). Furthermore, one factor related to age and app adoption is individuals' willingness to incorporate technology into their daily lives. Many older adults are interested in using mobile apps (Mollard and Michaud, 2019). However, studies suggest that they prefer only to use technology to understand the benefits of using the app immediately and shortly after the initial use. If benefits are not obvious and frustration is felt with initial use, older adults tend to cease using the app altogether (Mollard and Michaud, 2019).

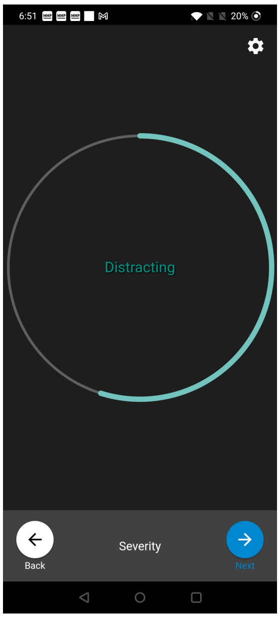
Another challenge relates to the technical ability of the patient. App accessibility and their ease of use are essential for their implementation and sustainability (Najm et al., 2019). The inclusion of the visual display and functionalities (screen, buttons, text boxes, literacy), the use of the principle of universal design, and the ability to use regardless of prior experience with mobile devices or technical abilities determine the quality of the app and success with the end-users (Najm et al., 2019). In the UI in Fig. 2.2 (left) it would be difficult to understand the scale used as it presents no feedback of the input, however, the example of the right provides a more comprehensive scale with numbers and figures.

2.3.2 Accessibility Guidelines

W3C

The World Wide Web Consortium's (W3C) (W3C, 2021a) developed the Web Content Accessibility Guidelines (WCAG), to cover a wide range of recommendations for making Web content more accessible. Following these guidelines will make content more accessible to a broader range of people with disabilities.

In people with rheumatic conditions that have dexterity problems, it is important that users can operate their devices and that these barriers are taken into consideration when the platform's design is conceived. The Input Modalities presented by W3C make it easier for users to operate functionality through various inputs beyond the keyboard. The Input Modalities Guidelines stress that all functionalities should be accessible via a finger interacting with a touch screen.



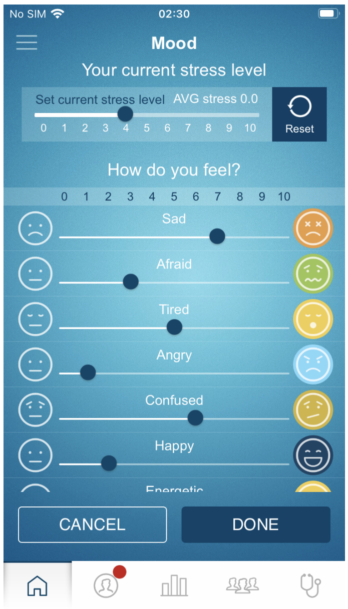


Figure 2.2: Apps where technical ability of the patient is in cause: RA Monitor (left) and Chronic Insight (right).

As mentioned before, people with rheumatic conditions have dexterity problems caused by swollen joints, hand pain or deformation of the fingers. Drag-and-drop gestures on touch displays, as well as swiping gestures and extended presses, are examples of things that may be difficult for people with dexterity problems (W3C, 2021a). As a result, when used, an alternative input method should be provided to enable users to interact with content. For example, for sliders, the drag of the slider thumb to a specific value can be difficult for people with dexterity problems, therefore, it should be possible to tap on the value the user wants to select on the slider.

The ability for users to place the finger (pointer) over the target is a frequent need for pointer interaction. The finger is larger and less precise than a mouse cursor with touch input (W3C, 2021a). A larger target makes it easier for people with hand dexterity issues to position the pointer and activate the target. For example, targets sizes should be taken into consideration when designing for users with dexterity problems, since the hand precision of these users can be compromised.

The Input Modalities Guidelines by the W3C introduced one criteria to consider when designing mobile products to accommodate accessibility issues, which may be relevant for people with rheumatic conditions:

> **Target Size.** This success criterion guarantee that target sizes are large enough for users to easily activate them, even if the user is accessing content on a small handheld touchscreen device with limited dexterity. Touch is particularly problematic as it is an input mechanism with coarse precision. A finger is larger than a mouse pointer and generally obstructs the user's view of the precise location on the screen that is being touched/activated. The issue can even be further complicated with responsive layouts on small screens like mobile, which need to accommodate different types of fine and coarse inputs (W3C, 2021c).

Google Material Design

Material is a design system created by Google to help teams build high-quality digital experiences for Android, iOS, Flutter and the web. The physical world's textures, especially how they reflect light and create shadows, serve as inspiration for material design (Google, 2014). The interactive building blocks known as Material Components come with a state system that may be used to transmit focus, selection, activation, error, hover, press, drag, and disabled states (Google, 2014).

Google's Material Design (Google, 2018) states that the accessibility requirements incorporated into Material components serve as a foundation for inclusive product design. Understanding the accessibility of your product can improve usability for all users, including those with hand dexterity issues. For example, those with rheumatic conditions may experience dexterity issues brought on by swollen joints, hand pain or deformed fingers.

Material Design's target guidelines can help users who have difficulty with small touch targets, to tap elements in apps. Google's Material Design introduces two layout guidelines that should be considered if an app is to accommodate the possible difficulties experienced by people with hand dexterity issues due to rheumatic conditions (Google, 2018):

> **Touch targets** "should be at least 48 x 48dp. A touch target this size results in a physical size of about 9mm, regardless of screen size. The recommended target size for touchscreen elements is 7-10mm. It may be appropriate to use larger touch targets to accommodate a larger spectrum of users."
>
> **Target spacing** "is the padding between icons. In most cases, targets separated by 8dp of space or more promote balanced information density and usability."

Apple Human Interface Guidelines

Apple's Human Interface Guidelines (HIG) (Apple, 2020) is a comprehensive resource for designers and developers developing for Apple platforms (iOS). It is a live document that gives the most recent design guidelines for Apple platforms, adjusting to new devices, technologies and upgrades. It has a long history that extends back to the early days of the graphical user interface (Apple, 2020).

An accessible app supports accessibility personalizations by design and gives everyone a great user experience, regardless of their physical abilities or how they use their iOS devices, as is the case for those with rheumatic conditions who may experience dexterity issues that affect how they interact with the environment and their devices (Apple, 2020).

Accessibility features, like display accommodations, expand the ways people can interact with their devices. (Apple, 2020) introduces three guidelines that should be considered if an app is to accommodate the possible difficulties experienced by people with hand dexterity issues due to rheumatic conditions:

> **Prefer simplified gestures for common interactions.** "Complex gestures such as multi-finger gestures, long presses or repeated button presses can be challenging for many people. Using the simplest gestures possible improves the experience for everyone who interacts with your app."
>
> **Provide alternative ways to perform gesture-based actions.** "Include an option for people who may not be able to perform a specific gesture. For example, if swiping deletes a row in a table, you can also provide an alternative way to delete items through an edit mode or by offering a Delete button in an item detail view."
>
> **Give all touchscreen controls and interactive elements a hit target that measures at least 44x44 pt.** "A touch target this size results in physical size of about 7mm, regardless of screen size. People with limited mobility need larger hit targets to help them interact with your app. It can be frustrating to interact with too-small controls in any platform, even when people use a pointer."

2.4 Mobile Apps for Rheumatic Conditions

The EULAR states that mobile health (mHealth) technologies can transform the mode and quality of healthcare, allowing people to take a more proactive role in their health and well-being (Najm et al., 2019). Using a health-related app might modify an individual's health beliefs and behaviours, improve knowledge and abilities in self-management of health, increase self-efficacy to manage symptoms, reduce health risk behaviours and lead to improved clinical outcomes (Mollard and Michaud, 2019). Smartphone technology (often coupled with wearable sensors) is increasingly used to collect health-related data via medical application interfaces (Najm et al., 2019). Mollard and Michaud (2019) classify mobile apps for rheumatic conditions centred on the patient in four categories: patient education, passive sensor monitoring, gamification apps and self-management. In the next sections, we use this classification to give an overview of the types of apps available for users with rheumatic conditions.

2.4.1 Patient Education

The Patient Education category includes applications that mention general information about the condition, medication, disease management and essential healthcare resources available to patients (Mollard and Michaud, 2019). These types of apps may be essential for newly diagnosed patients that seek immediate answers (example bellow in Fig. 2.3). The disadvantage of this this type of apps is that education alone has been shown to do very little to improve health outcomes in chronic illness (Bodenheimer et al., 2002). Furthermore, continued engagement is unlikely to happen beyond the initial usage of the app because, once information is consulted, there is no motivation to return to the app regularly (Mollard and Michaud, 2019).

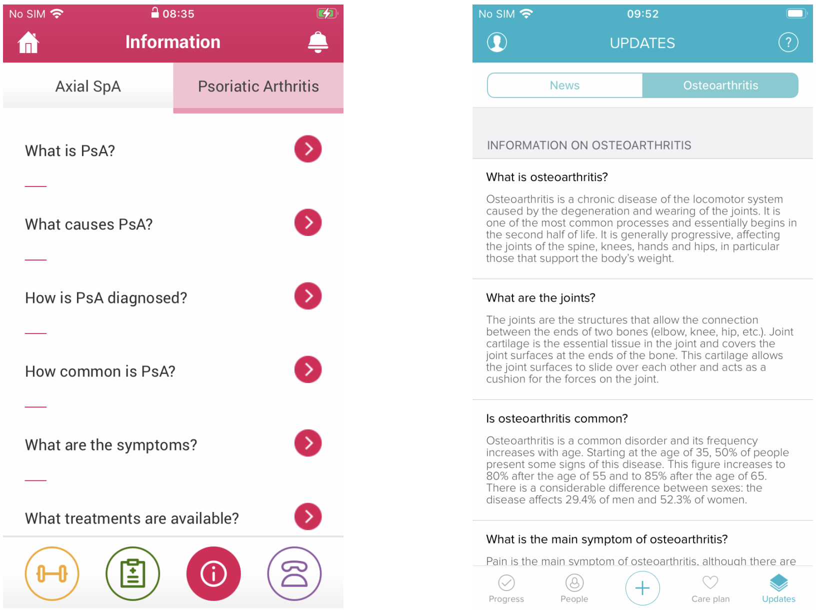


Figure 2.3: Patient Education apps showing basic information about PsA (left) and Ostheoarthritis (right).

2.4.2 Passive Sensor Monitoring

Passive sensor monitoring includes apps which use the sensors built into the mobile device to measure and track objective health information with minimal effort from the patient (Lowe and ÓLaighin, 2014). These include GPS, accelerometers, gyroscopes and magnetometers, tracking human movement, activity and sleep on mobile apps (Mollard and Michaud, 2019). The main advantage of passive measurement is that the patient does not grow fatigued with gathering data and is not burdened by the self-monitoring process (Mollard and Michaud, 2019). Activity-based data from passive monitoring has the potential to identify days with significant symptoms and specific measurements, such as stiffness and pain (Mollard and Michaud, 2019).

2.4.3 Apps with Gamification

Gamification aims to make routine activities more enjoyable and uses both game dynamics and mechanics (Wilson and McDonagh, 2014). For example, a medication adherence app may offer a reward for each medication taken on time and as prescribed. This might be a basic scoring system like receiving a virtual badge, or it could include applications that promote earning real-world monetary benefits (Mollard and Michaud, 2019). Gamification is primarily a motivator for behaviour change. Although not directly related to collecting disease information, a gaming app targeted at patients with rheumatic conditions could be feasible and beneficial. The Elsa app (Fig. 2.4 on the left) uses gamification to encourage users to log in to the app every day to track their condition by rewarding the user with a medal each day they log. The example on the right (Fig. 2.4) allows users to "unlock" new educational information as they read more and more.

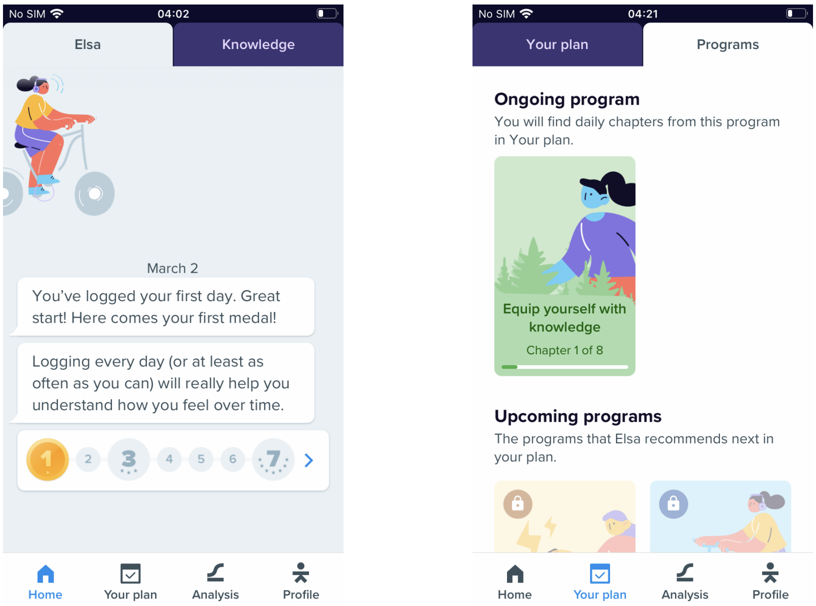


Figure 2.4: Gamification app showing different types of applications.

2.4.4 Self-management apps

The rapid advance of mobile technology and mobile health apps has been especially significant for people with rheumatic conditions requiring daily self-management for quality of life and longevity. Self-management requires individuals to have the confidence and ability to manage and live well with their disease (Mollard and Michaud, 2018).

Self-management apps for rheumatic conditions may include features such as self-monitoring, education, physical activity and lifestyle, connecting with health care providers or connecting with other individuals with the same conditions (Mollard and Michaud, 2021).

Self-monitoring apps

Self-monitoring apps, the main focus of this dissertation, allow people with rheumatic diseases to record daily symptoms, medication, treatments and reactions. Self-monitoring apps are a subcategory of self-management apps that are most closely connected with an app that enables recording and tracking illness activity, therapy and behaviour modification (Mollard and Michaud, 2018).

Many self-monitoring applications for rheumatoid conditions focus on what are known as Patient-Report Outcomes (PROs) (Mollard and Michaud, 2021), such as the example in Fig. 2.5 (left) where users are allowed to rank their pain level. In this type of app, patients can connect with their care providers and follow the activity of their rheumatic condition using Electronic Patient-Reported Outcomes (ePRO) (Colls et al., 2021). The UI in Fig. 2.5 (right) shows that users are able to print or share their tracked information with others. The ability to acquire disease activity information regularly via electronic means instead of a face-to-face visit makes ePROs a particularly appealing feature to include in self-monitoring apps (Solomon and Rudin, 2020).

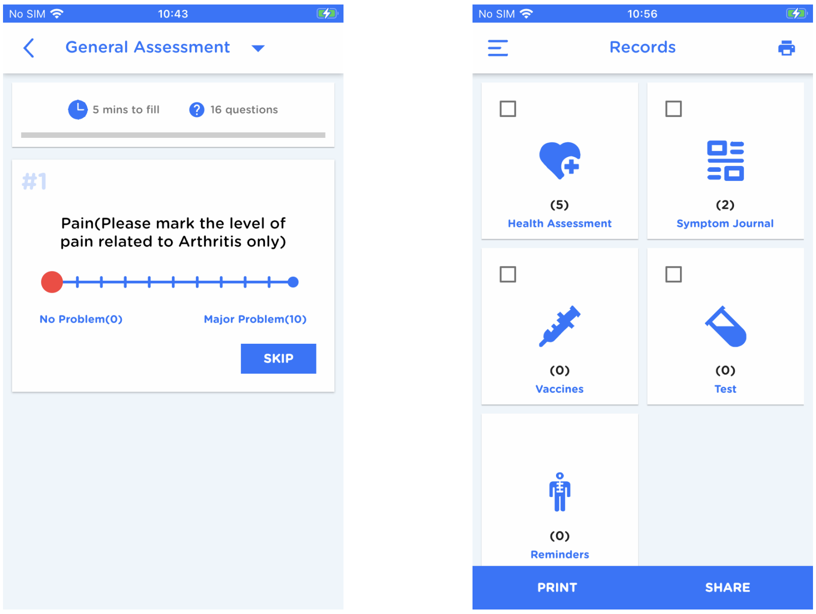


Figure 2.5: Self-monitoring apps showing the ranking of pain (left) and the ability to share information tracked (right).

Often, self-monitoring apps will provide a visual representation of what the individual has recorded through graphs and charts, allowing the individual to identify patterns (Mollard and Michaud, 2021). These patterns in symptom flare, treatment response and general day-to-day management, such as how often pain relievers are required, provide helpful information for the individual in making future decisions regarding self-management and health care. The UI in Fig. 2.6 shows visual representations of what the user tracked through an illustration of the human body (left), a point graphic (middle) and a column graphic (right). Individuals can also provide this data to their health care provider, emphasizing patterns while fostering better discussions related to their treatment response to prescribed therapies (Mollard and Michaud, 2021).

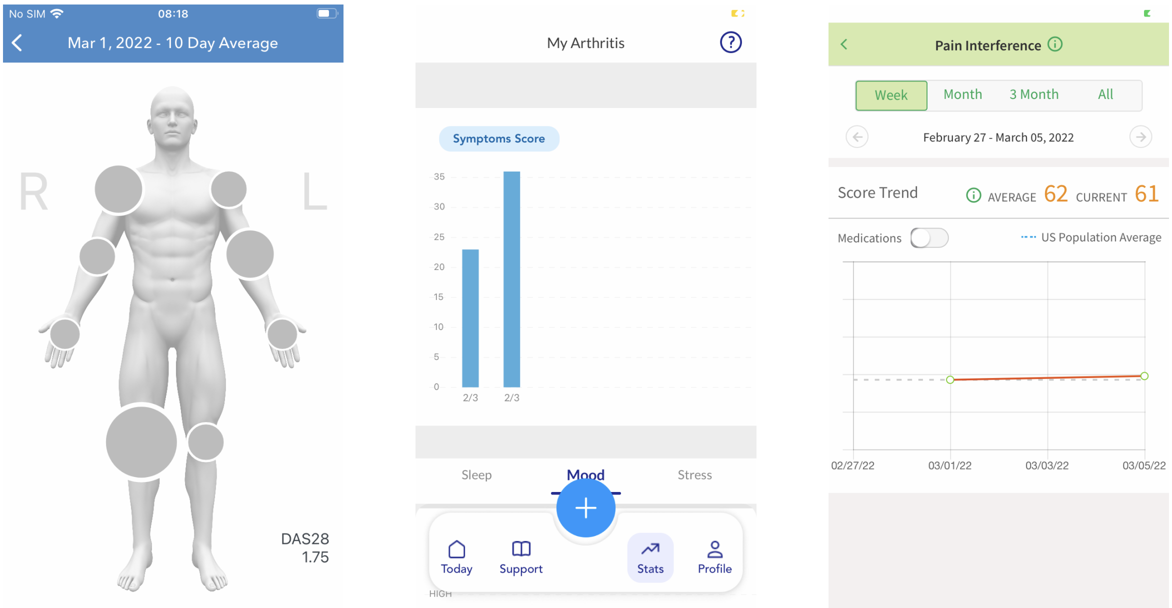


Figure 2.6: Self-monitoring apps showing visualisation of information through an human body illustration (left), a point graphic (middle) and a column graphic (right).

A study conducted by Mollard and Michaud (2018) showed that a self-management app that included the self-monitoring of symptoms, diet, weather, medications and other variables, as well as a novel hand-imaging feature that allowed the participant to photograph their hand with automatic analysis of changes to their hand arthritis, would be revolutionary for improving rheumatic condition self-management.

2.5 Design patterns

Having studied what characterises rheumatic conditions and their treatments and having reviewed the some of the existent apps aimed at supporting people with these conditions, it is also important to understand to what extent existing mobile apps accommodate for the specific needs of people with rheumatic conditions. This is where user interface design comes to the fore.

One of the main goals of this dissertation is to contribute to improving apps for people with rheumatic conditions, ensuring they are designed based on the best evidence possible in the future. Therefore, it is crucial to follow well-established design rules, in which guidelines, heuristics, principles, standards and design patterns are included. According to (Dix et al., 2004, p.287) and across this spectrum, principles are the most generic, in contrast to standards and guidelines, which are more specific, where guidelines are less authoritative than standards. Design Patterns "capture design practice and attempt to provide a generative structure to support the design process" (Dix et al., 2004, p. 282).

Design patterns are a form of documentation that captures and reuses design knowledge – abstracting the essential details of successful design so that these can be applied again and again in new situations – and describe a proven solution to specific problems that recur in different contexts (Dix et al., 2004, p. 284). The goal of design patterns is to save resources by providing a template that can be applied to multiple situations. They can also be improved over time saving time, in the design process.

As highlighted above, design patterns are part of a group of HCI information organisation tools that seek to guarantee good design, including guidelines, heuristics, principles and standards. All of these have different levels of authority and applicability. Guidelines are "a design and/or evaluation principle to be observed in order to get and/or guarantee the usability of a user interface for a given interactive task to be carried out by a given user population in a given context" (Seffah et al., 2005, p.50). Heuristics are more general principles that are not strictly accurate or trustworthy in every circumstance (Joyce, 2021). This dissertation focuses on design patterns because, when compared with other approaches, their advantages, such as providing an appropriate solution within a certain context and incorporating principles in their reasoning, are an added value. Guidelines have a succinct and straightforward format, whereas patterns are more complex, but yet more efficient to implement because patterns describe their logic and the design context they apply (William et al., 2009). Heuristics are broader and more abstract than design patterns since they are broad guidelines that steer the evaluator's judgment via a range of significant variables to evaluate (Dix et al., 2004, p. 282).

Among the early attempts to apply design knowledge in patterns, the first significant milestone is attributed to Christopher Alexander in the late 1970s. In his two books, A Pattern Language (Alexander, 1977) and A Timeless Way of Building, Christopher Alexander discusses the capture and use of design knowledge in the format of patterns and presents an extensive collection of pattern examples to help architects and engineers with the design of buildings, towns and other urban entities (Breiner and Meixner, 2010).

As Alexander (1977) states, "Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in a way that you can use this solution a million times over, without ever doing it the same way twice." In this way, a pattern is an invariant solution to a recurrent problem within a specific context (Breiner and Meixner, 2010):

- The context describes a recurring set of situations in which the pattern can be applied.
- A problem is referred to as a set of forces, goals and limitations in the context. In general, the problem specifies when the pattern should be used.
- The solution refers to a design form or a design rule that can resolve the forces and describes the elements that constitute a pattern and the relationships among these elements

Vokác (2006) states that “patterns are discovered, not invented”. According to him, patterns document the good practices found through the work done by numerous developers over a long period of time, to solve a certain problem. Because of the abstractions used, design patterns can impose structure on a system. As a result, identifying implemented design patterns may be valuable for understanding a current design and laying the groundwork for future work (Vokác, 2006).

Design patterns found in "A Pattern Language: Towns, Buildings, Construction" (Alexander, 1977, p.x) follow the same structure, where each has:

(i) a name which is an essential element to identify the pattern and should be short, and easy to remember (Borchers, 2001)

(ii) the pattern ranking, which ranges from zero to three asterisks and indicates the author’s level of confidence in a specific pattern (Borchers, 2001)

(iii) an image meant to depict an ideal example of that pattern (Alexander, 1977, p.x),

(iv) an introduction paragraph that places the present pattern in a context by connecting it to broader patterns

(v) a problem statement that identifies the problem to be solved

(vi) the problem description, which analyses why one solution was chosen over another, offers the problem’s empirical backdrop, investigates the validity of a pattern and provides the problem’s empirical background

(vii) the solution statement, which presents a broad solution to the problem (Alexander, 1977; Borchers, 2001)

(viii) a simple diagram of the solution

(ix) references to other smaller patterns that help complete the current pattern.

2.5.1 Design Patterns in HCI

The first workshop on pattern languages in user interface design was held at the Computer-Human Interaction (CHI) conference in 1997 (Kruschitz and Hitz, 2010). The workshop's stated goals were to find out if design patterns were being created and used in the HCI community, to share design pattern knowledge among participants to advance each other's knowledge of design patterns and to see how design patterns can adapt and continue to be developed within HCI practice (Kruschitz and Hitz, 2010).

A year later the first substantial set of patterns was proposed by Jenifer Tidwell in Common Ground: A Pattern Language for Human-Computer Interface Design (1999). The key elements that characterise a pattern remained the same despite the transition in pattern application. This work was first presented at PLOP'98 (Conference on Pattern Language of Programs) and the author proposed sixty patterns for designing interfaces, mostly computer apps and websites (Tidwell, 1998).

In addition to giving many patterns for general interface design, Tidwell discusses the advantages she sees in creating a pattern language for interface design in this document. These advantages are described as the ability to (Tidwell, 1998):

(i) capture collective interface design knowledge that domain experts or novices can easily use;

(ii) provide a common language to discuss interface design with colleagues, experts from other knowledge domains, customers and participatory design teams;

(iii) supply space to "think outside the toolkit" by adapting existing patterns to new problems; and

(iv) assist designers in staying focused on essential interface design elements.

UI design patterns offer a shared vocabulary between designers and users, which is closer to Alexander's goal for architectural design patterns than software design patterns, which developers utilize to construct the internals of a system (Seffah et al., 2005). The first book on using design patterns for websites was published in 2003 by Ian Graham — "A pattern language for Web usability" (Graham, 2003). The book describes the author's unique pattern language for websites known as Web Usability (WU). It contains 79 individual web usability patterns, is woven into a pattern language and covers usability, content, navigation and aesthetics.

Over the years, patterns started to be developed exclusively for mobile devices.

In 2012 Theresa Neil collected and categorised mobile patterns into a "Mobile Design Pattern Gallery". It provides more than 90 mobile app design patterns, illustrated by screenshots from Android, iOS and Windows Phone apps. Although platform-specific guidelines continue to be published, third-party developers and designers are beginning to publish online pattern languages for mobile platforms.

Android Design Patterns: Interaction Design Solutions for Developers was published in 2013, providing more than 75 patterns used to create versatile user interfaces for both smartphones and tablets. The book includes (i) patterns that cover the most common and complex types of user interactions, (ii) sample patterns for the welcome and home screens, searches, sorting and filtering, data entry, navigation, images and thumbnails, interaction with the environment and networks, and related patterns and anti-patterns, (iii) illustrated, step-by step instructions describing what the pattern is, how it works, when and why to use it and related patterns and anti-patterns.

A year later Google created Material Design (Google, 2014), an Android-oriented design language, with the purpose of delivering high-quality output across platforms while offering users control over clearly stated, pleasant-looking components that act like real-world things. Material Design designers may apply basic, natural laws from the physical world, principally concerning lighting and motion. The idea is that, by simulating the actual environment, they may lower users' cognitive demands by paying close attention to layout, visual language, and pattern library, increasing predictability and removing ambiguity. In 2018, Google released an updated version of Material Design (Google, 2018) to address a fundamental flaw in the original guidelines: they were too rigid, focusing on utility over style.

2.5.2 Advantages of using Design Patterns

Patterns and pattern languages are characterised by several features which, taken as a whole, distinguish them from other design rules (Dix et al., 2004, p.285). Above all, patterns are problem-oriented but not toolkit specific. It is not easy for designers to be experts in UI for all types of users, however, that does not mean that these UIs do not have to be well designed. Hence the interest in the output of this dissertation, the development of design patterns (Bayle et al., 1998). Overall, patterns have several benefits, including:

> **Context.** A pattern provides an appropriate solution within a certain context. The goal of patterns is to define a set of plausible contexts in which the given design advice should be applied. It is part of a broader pattern language that supports bigger and smaller patterns, providing the reader with critical contextual information about its position in the design process. Patterns are interconnected and collaborate to overcome the complexities of system design concerns (Alexander, 1977, p.xiii).
>
> **Provide examples of use.** Patterns are generated from real practice, not theoretical or hypothetical suggestions, and they capture design practice and incorporate knowledge about practical solutions. Patterns

use examples to emphasise their grounding in multiple examples of successful designs. Most of these examples are visual — drawings, photographs, diagrams, etc. — and contribute to further reinforcing the validity of a pattern (Bayle et al., 1998).

Easy to understand and apply. According to Alexander (1977), patterns should be written in a straightforward and non-technical manner. Patterns should facilitate talks with persons who are not domain experts. In contrast to software engineering patterns, HCI patterns should be accessible and clear to end-users (Bayle et al., 1998). Most importantly, they are generally intuitive and readable, allowing for communication among all stakeholders and usage by non-specialists since they allow them to solve problems (Dix et al., 2004, p.285).

Present supporting rationale. A pattern includes problem and solution statements and the underlying rationale of the choices made to arrive at a given solution. They are not neutral but rather incorporate principles in their reasoning. A pattern should explain why the solution is recommended and what trade-offs are involved. The selection of patterns and the recording of patterns are both high-value actions that reflect the writer's goals and motivations (Bayle et al., 1998).

Provide levels of abstraction. A pattern language usually organizes its patterns in a hierarchical form, starting with the broadest patterns and working down to the most particular. Within the same language, the different scopes of patterns convey design information at varying degrees of abstraction. The large-scale ones are more abstract, and the small-scale ones are more precise. Therefore, patterns can describe problems of several dimensions (Nilsson, 2009).

2.6 Summary

This dissertation focuses on three of the most common rheumatic conditions, namely RA, OA and PsA. Even though all three types of rheumatic conditions affect the joints of a person with a rheumatic condition, their causes are distinct. Two of the most prevalent symptoms of these conditions are pain and swelling of the joints. These symptoms influence their dexterity, which has an impact on how they engage with technology. As a result, paying attention to app design is crucial for increasing usability, adherence and therapeutic outcomes. There are some obstacles to overcome to provide apps that meet the expectations of users, such as hand pain and disability, accessibility and technical ability. There are guidelines provided by W3C, Google Material Design and Apple Human Interface Guidelines that must be followed to enable people with these conditions to operate their devices.

There are many patient-centred mobile apps for rheumatic conditions, such as patient education, passive sensor monitoring, gamification apps and self-management. Self-monitoring apps are a type of self-management app that allows people with rheumatic diseases to keep track of their daily symptoms, medications, treatments and reactions.

Design patterns are standard reference points for the experienced designer. They are reusable solutions to commonly occurring problems in a context, repeatedly applied to similar problems encountered in different contexts. Design patterns provide a common language between designers. Reusing design patterns provides general solutions documented in a format that does not require specifics tied to a particular problem.

One of the benefits of mobile app design patterns is helping to eliminate user experience risks since the pattern is tested before, not to need alternative and uncertain solutions. The other benefit is that that allows predictability. Patterns provide the user with a feeling of familiarity to enjoy the product without the necessity to waste time learning how to interact with the app.

Understanding the conditions, their symptoms and treatments, the care and self-monitoring of these people, the patient barriers and accessibility problems, and the different types of apps for rheumatic conditions, such as self-report apps, allow the researcher to gather the knowledge to review existing self-report and to document the findings of testing and iterations, providing a set of validated design patterns for people with rheumatic conditions.

Chapter 3

Methodology

Human-Computer Interaction (HCI) is the discipline that studies the quality of the interaction between people and technology (Dix et al., 2004), where the main goal of HCI professionals is to create practical, usable and used products. Since the beginning of HCI, technology, people and society have been rapidly changing (Harper et al., 2008). Designing bad technology that makes people unable to realise their potential and in the case of chronic patients, this is particularly serious. According to Dix et al. (2004), this biological response changes how one reacts to different situations and impacts one's interaction with computers to the point that if the user interface provides a good user experience, it is likely to be more successful.

Since the beginning of our work, it was clear that we should use an HCI design approach to develop solutions that were adequate to the characteristics of our target audience. The solutions originated from the research and work done will be presented in the form of design patterns to provide guidance to designers that will design for people with rheumatic conditions in the future. User-Centered Design and Design Patterns are key in this dissertation. This chapter provides an overview of these, the methodology we chose and the techniques we used in this context.

3.1 User-Centered Design

There are a number of HCI methodologies focused on creating better interactive systems. Among them we find User-Centered Design (UCD), the one that we will follow for this dissertation. User-Centred Design refers to a process that "requires developers to change their viewpoints and spend time walking in their consumers' shoes" (Kuniavsky et al., 2012). Perlman goes on to say that user participation in the design process is necessary for achieving a goal and that "various degrees of user engagement may be introduced in order to manage expectations" (Perlman, 2002). Perlman (2002) outlined three criteria that they hoped would lead to a "useful and simple to use computer system":

Early focus on users and tasks. This entails first determining who the users are by examining their cognitive, behavioural and attitudinal traits. To do so, it is required to observe users perform their regular tasks, to research the nature of those tasks and include users in the design process (Perlman, 2002).

Empirical measurement. Users engage with simulations and prototypes, their performance and reactions are captured, assessed and documented (Perlman, 2002).

Iterative design. When issues are discovered during testing, these issues are rectified, then further tests and observations are conducted to observe how the fixes affect the results. This means that design and development are iterative, with "design, test, measure and redesign" cycles repeated as needed (Perlman, 2002).

3.2 Design Patterns

Having a User-Centered Design approach in mind, developing design patterns to provide guidance to designers is an asset. A design pattern provides a general reusable solution for a common problem and allows designers to avoid constantly "reinventing the wheel". A pattern typically shows relationships and interactions between classes or objects (Seffah et al., 2005). The idea is to speed up the development process by providing well-tested, proven design paradigms.

Apps have a common look and feel because of design patterns. User interface (UI) design patterns are reusable/recurring components that designers use to solve common problems in user interface design. Design patterns of hamburgers [1] and bottom tabs [2] are examples of UI components that platforms make available to allow consistency, reuse and usability (Costa, 2021). It is always possible to use a custom-made component and not go according to design patterns, even though patterns arguably help to achieve better results.

In UI design, design patterns are used as a quick way to build interfaces that solve a problem. Furthermore, UI design patterns serve as blueprints that allow designers to choose the best and most used interfaces for the user's specific context. Patterns are not a one size fits all solution — each pattern needs to be adapted to a specific use case (Seffah et al., 2005). UI design patterns keep the cognitive load to a minimum by making the interface intuitive.

The design patterns created in this dissertation will provide guidance and a common language for designers designing apps for people with rheumatic conditions, keeping misunderstandings to a minimum and establishing consistency when multiple designers work on the same project.

[1] A hamburger icon, in user interface (UI) design, is a navigational symbol consisting of three stacked horizontal lines that indicate the location of a hidden menu. The icon got its name from the fact that its structure resembles a burger in a bun in a simplified graphic.

[2] Bottom tabs refers to a row of links, displayed at the bottom of the screen and is referred to as "Tab Bar" in iOS and as "Bottom Navigation Bar" on Android.

3.3 Research stages and techniques

This work is composed of four phases, with different activities, that result in a specific output that feeds the next phase. Figure 3.1 provides an overview of the methodology.

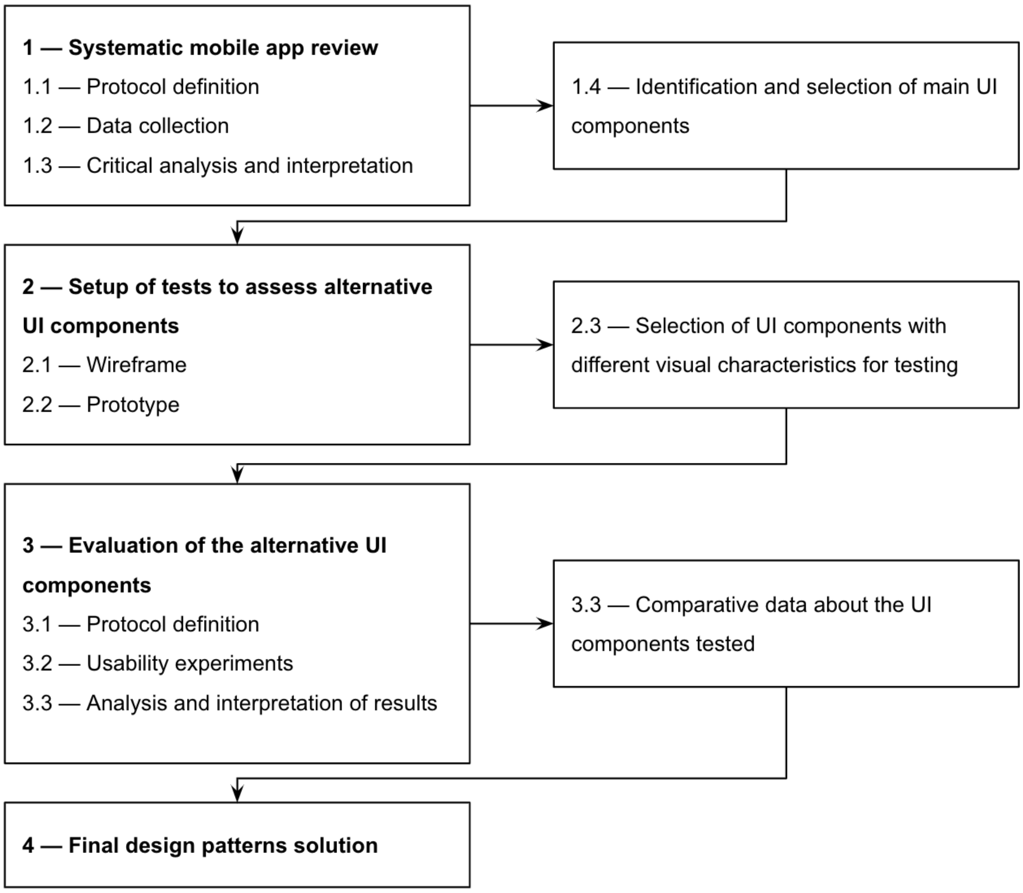


Figure 3.1: Research phases, methods and outputs.

3.3.1 Systematic mobile app review

The first research phase was a systematic mobile app review (Phase 1 — see fig. 3.1) that aimed to explore the characteristics, features and commonly used UI components in self-report mobile apps for rheumatic patients. To carry out this review, the researcher defined a protocol for searching apps (Task 1.1 — see fig. 3.1), chose mobile app databases, defined inclusion and exclusion criteria, and identified the app attributes to collect after the definition of the protocol and the data collection (Task 1.2 — see fig. 3.1). The data from the app selection was collected, organised and the criteria was applied. After the initial exclusion process, the apps were installed in a smartphone and the database was completed. Afterwards, the critical analysis and interpretation (Task 1.3 — see fig. 3.1) of data collection occurred. The researcher did a thematic analysis and interpreted the data collection to develop a deep understanding of the issue by analysing the apps included in the review. This careful analysis allowed for the characterisation and documentation of the features and of the most commonly used UI components of the apps included in the review. The outcome of this phase was a selection of the main UI components used in the apps reviewed (Task 1.4 — see fig. 3.1).

3.3.2 Setup of tests to assess alternative UI components

To compare the UI components identified previously, the researcher setup a set of UI screens and tests (Phase 2 — see fig. 3.1). The UI components that were designed have the same purpose but represent different visual characteristics that were evaluated against each other on a number of parameters. The creation of the screens was done by first producing wireframes (Task 2.1 — see fig. 3.1), a mock-up that presents the information that is displayed, gives an outline of the UI components and screen's structure and layout, and conveys the overall direction and description of the user interface. The second part of this phase was prototyping (Task 2.2 — see fig. 3.1). This involved the creation of a simple working model of app screens that incorporate the different UI components and allowed the researcher to collect data about their use.

The screens designed by the author of this dissertation were then implemented into a mobile test tool developed by Ricardo Graça and Nuno Cardoso, two developers from project COTIDIANA (Task 2.3 — see fig. 3.1)).

3.3.3 Evaluation of the alternative UI components

Evaluating the UI components with different visual characteristics for testing (Phase 3 — see fig. 3.1) was the third phase of the methodological approach. The evaluation process started with the protocol definition (Task 3.1 — see fig. 3.1), defining the way the evaluation session was conducted. The key activities were thought and planned, the observation's primary goal, the recruitment criteria was defined and the method of collection of results specified. Afterwards, the researcher conducted the usability experiments (Task 3.2 — see fig. 3.1). The researcher asked the participants to perform a set of tasks using the screens created in the previous phase. During the tests, specific metrics were recorded, including: task completion time, number of gesture interactions with component, or subjective preference. After the usability experiments were conducted, the researcher analysed and interpreted the results (Task 3.3 — see fig. 3.1). This was done by organising the usability issues identified and prioritising the issues based on criticality and impact, conducting comparative data about the UI components tested (Task 3.4 — see fig. 3.1).

3.3.4 Final design patterns solution

The four previous phases of the methodology all allow the researcher to create a set of UI design pattern solutions for people with rheumatic conditions based on the information gathered throughout the methodology process (Phase 4 — see fig. 3.1). This set of design patterns was based in information gathered throughout the usability experiments and the analysis and interpretations of the results.

3.4 Work plan

To structure the development of this dissertation, a work plan was elaborated. This plan *(Figure 3.2* and *Figure 3.4)* provides an overview of the work stages, the tasks and methods involved in it, as well as an estimate of the time needed to carry out each task. The work plan is divided into five main stages: *Literature Review & State of the Art (1)*, *Review and analysis of existing solutions (2)*, *Testing with users of UI components (3)*, *Design proposal of design patterns (4)* and *Writing and Dissemination (5)*.

The first stage, *Literature Review & State of the Art (1)*, started on the second week of September and lasted until the third week of November. This stage was mostly about understanding the context of the problem. It started by searching for articles, books and dissertations to read. Then, the reading and taking of notes started about the topics relevant to this research, i.e., *Rheumatic Conditions*, *The role of technology in supporting rheumatic conditions*, *Mobile Apps for Rheumatic Conditions*, *Design Patterns*, *Human-Computer Interaction* and *User Research Methods*.

Figure 3.2: Gantt Chart of the work plan for the first semester.

The second stage, *Review and analysis of existing solutions (2)*, started on the third week of November and lasted until the first week of April. This phase involved the elaboration of the review app protocol, the search, and selection of apps, the analysis of the apps and most used UI components, the expert review and selection of the UI components to test, the conduction of tests, and the creation of the design patterns.

From the beginning of April until the first week of June, the *Testing with users of design patterns (3)* took place. This phase included the definition of the protocol, the recruitment of the participants, the usability experiments, and the analysis of the results.

The final phase, the *Design proposal of design patterns (4)*, occurred in the first two weeks of June and was when, based on the results of the previous phase, the design patterns proposal was elaborated. Simultaneously to what has been referred to above, the researcher wrote and documented all stages of the work while developing the research.

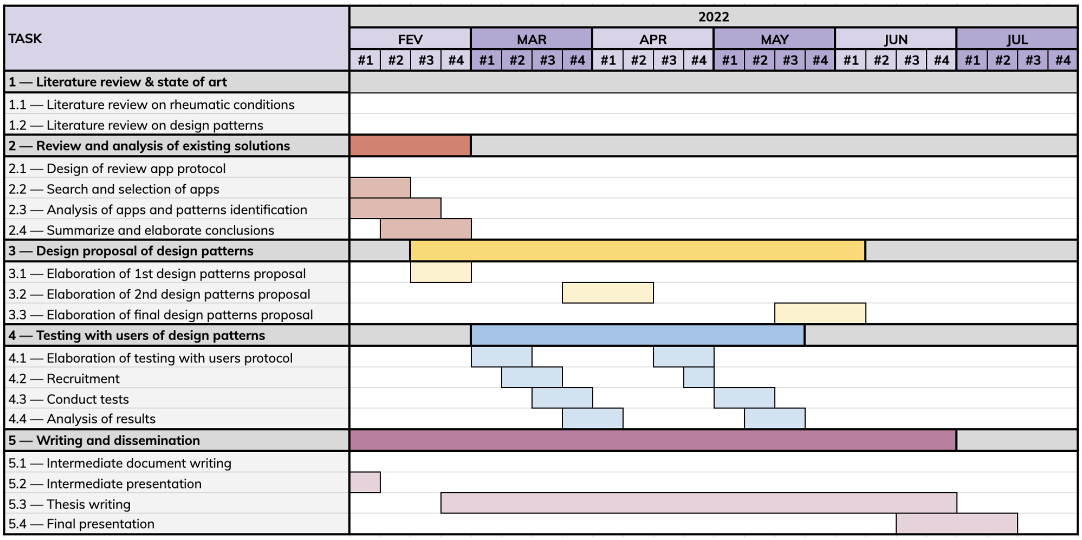


Figure 3.3: Initial Gantt Chart of the work plan for the second semester.

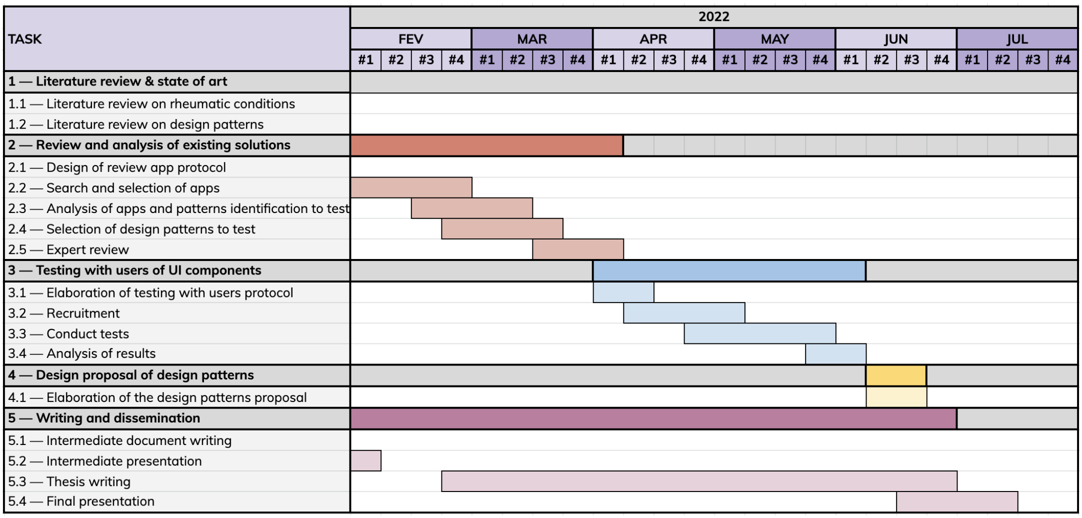


Figure 3.4: Gantt Chart of the work plan for the second semester

The comparison of the figures above shows that the work plan initially presented for the second semester was adjusted to eliminate the second phase of testing with users *(Fig. 3.3—4—Testing with users of design patterns)* and the iteration of the first proposal of design patterns based on the evidence collected in the first testing session with users (*Fig. 3.3—3.2—Elaboration of 2nd design patterns proposal)*. This elimination occurred since we felt that recruitment would take longer and that it would be more wise to just do more extensive testing phase instead of two. Other changes that occurred were the app review being extended to all rheumatic diseases, because of the possibility of apps for other diseases being better designed than the ones of the three diseases in the project. Furthermore, the perspective on design patterns also changed, causing the renaming of same tacks.

Chapter 4

Systematic mobile app review

The aim of the mobile app review and selection is to explore commonly used interfaces in self-report mobile apps for people with rheumatic conditions. This chapter presents the app review protocol, the data collected and analysed, the results of the app review: characteristics, features and UI components present in the apps included, the selection of UI components for testing, the pre-selection of these UI components and the validation of the pre-selected UI components through an expert review. The end output of this chapter is to discover and select the UI components that, besides complying with existing guidelines, are also the most commonly used in commercial mobile apps. The selected UI components will be included in the usability experiments based on the Android and iOS guidelines and to detail the validation with experts.

4.1 Mobile app review

4.1.1 App search

The focus of the review was on mobile apps and, as such, the app search was conducted on the two leading mobile app stores: *Android Google Play Store*, which caters to Android devices and *iOS Apple App Store*, which hosts mobile apps for iOS devices. These two stores collectively represent 99,3% of the total market share of mobile operating systems worldwide as of October 2021 (GlobalStats, 2021). The systematic search of all potential apps targeting patients with rheumatic conditions was made in March of 2022.

To reach apps for people with rheumatic conditions we searched for general terms, such as arthritis, as well as for specific condition names, e.g., Osteoarthritis. These diseases come from a list of the most common inflammatory or degenerative rheumatic diseases (EULAR, 2011). Moreover, we searched for terms in Portuguese and in English to find apps that were developed nationally or for an international market. The search terms used were[1]:

[1]The complete search expression was: "Ankylosing Spondylitis" OR "Ankylosing Spondylitis" OR "Rheumatoid arthritis" OR "Artrite Reumatóide" OR "Psoriatic arthritis" OR "Artrite

- *Arthritis / Artrite*
- *Ankylosing Spondylitis / Ankylosing Spondylitis*
- *Rheumatoid Arthritis / Artrite Reumatóide*
- *Psoriatic Arthritis / Artrite Psoriática*
- *Osteoarthritis / Osteoartrose*
- *Osteoporosis / Osteoporose*
- *Polymyalgia Rheumatic / Polimialgia Reumática*
- *Systemic Lupus Erythematosus / Lúpus Eritematoso Sistêmico*
- *Sjögren*
- *Myositis / Microsite*
- *Scleroderma / Esclerodermia*

Considering that this research focuses on the self-report of rheumatic patients about aspects of their health, inclusion criteria were that the apps included self-reporting features, such as self-reporting of pain, medication intake, or swollen joints.

Exclusion criteria were: i) impossible to register or use without external credentials, ii) healthcare app only displaying information on symptoms or similar information, iii) language of the app not in English or Portuguese, iv) repeated apps with different names, v) impossible to open or use due to errors, vi) apps for clinicians and not for patients, vii) app developed for other purposes (e.g., games, studies), viii) app impossible to install in Portugal, or ix) incompatible version.

To search for the apps and gather basic information about them we used *SerpAPI* (SerpApi, 2021). This web app allows searching by keywords in different country app stores, generating a JSON file with all the information about the available apps. The generated JSON files were converted to a Comma-Separated Values (CSV) file to simplify the management and organization of the information.

4.1.2 Data collection and analysis

The data collection of the apps was composed of, first, information extracted from SerpAPI and then complemented by information collected when installing and using the apps. The focus of the analysis was to uncover main UI components used, but the features of the apps and general app characteristics were also analysed (Table 4.3). Analysis was iterative and aligned with the thematic analysis technique (Braun and Clarke, 2006).

Psoriática" OR "Osteoarthritis" OR "Osteoartrose" OR "Polymyalgia rheumatic" OR "Polimialgia Reumática" OR "Lupus" OR "Lúpus" OR "Sjögren" OR "Myositis" OR "Microsite" OR "Scleroderma" OR "Esclerodermia"

The presented codes were a result of several rounds of analysis that covered all the main features of the apps analyzed. This analysis was conducted in Excel and resulted in a table composed of 94 columns, organised by three domains: assessment measures, codes of the features available and the UI components present in the apps. As each app was reviewed, the information about the features and the UI components it included were recorded in an Excel file [2]. The following tables present an overview of the app data collected organized into the three domains.

Table 4.1 presents the assessment measures (basic characteristics of apps collected from the app stores using SerpAPI) into the following: app ID, app name, app store, release date, cost (in euros), average app store rating and developer's name.

Assessment measure*	Description and definition
App ID	App ID as shown in the Google Play Store and/or Apple App Store.
App name	App name as shown in the Google Play Store and/or Apple App Store.
App store	Apple App Store and/or Google Play Store.
Release date	Date of the first upload of the app in the Google Play Store and/or Apple App Store.
Cost	Free apps or the cost of apps in EUR.
Average rating	Average qualification of the feedback that an app receives from the users who use the mobile app.
Developer's name	Name of the developer (ie, who developed and uploaded the app).

Table 4.1: App assessment measures of apps reviewed [3].

4.1.3 App review results

The search in the app stores yielded 759 records (Figure 4.1). Of the 759, 112 appeared in both Apple App Store and Google Play Store and the other 647 only appeared in one of the app stores. Even though the apps that appeared in both app stores were reviewed separately to gather potentially different design patterns, they were counted as the same instance of an app, which amounted for a total of 703 apps. Based on the app store description and app preview screens, 614 were excluded for not meeting the selection criteria, namely for not focussing on rheumatic conditions (n = 408), for being designed for clinicians or other users (n = 54), or for not including self-report features (n = 152).

A total of 89 apps was included for the review and analysis stage. Of these, 71 were excluded for: being impossible to register or use without external

[2] Excel available in *https://linktr.ee/dissertacao.petra*

[3] Basic characteristics of apps collected from the app stores using SerpAPI

credentials (n = 15), not being about rheumatic conditions (n = 13), lack of self-report features (n = 11), only displaying information on symptoms or similar information (n = 8), language not in English or Portuguese (n = 6), being a repeated app with different names (n = 5), being impossible to open or use due to errors (n = 5), being apps for clinicians and not for patients (n = 4), being app developed for another purpose (e.g., games, studies) (n = 2), being app impossible to install in Portugal, or for incompatible version (n = 1). A total of 18 apps remained in the final collection for further analysis. Figure 4.1 provides an overview of the various stages of the review process.

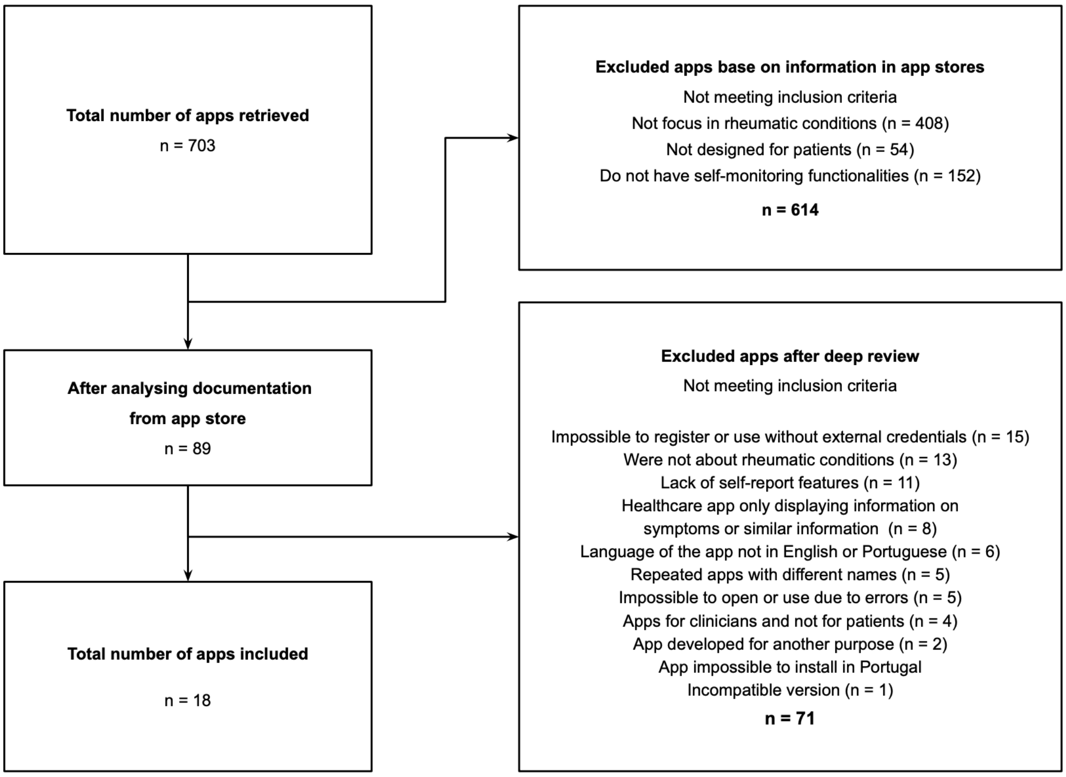


Figure 4.1: In-depth app review flowchart.

Overview of the characteristics of the apps included

The characteristics of the apps are summarised in Tables 4.2 The review includes 18 apps from Apple App Store and Google Play Store, where 11/18 are available in both app stores, 4/18 are only available on Apple App Store, and 3/18 are only available in Google Play Store. Regarding the publishing dates of the apps, 1 was published in 2011, 6 between 2014 and 2017, and 11 between 2018 and 2021.

All apps were specific for people with rheumatic conditions. Some of the apps (7) were designed to be used by people with different rheumatic conditions, the remaining targeted people with specific conditions, namely: 7 for people with rheumatoid arthritis, 5 for people with psoriatic arthritis, 2 for people with osteoarthritis, 2 for people with systemic lupus erythematosus, 2 for people with ankylosing spondylitis, 1 for people with scleroderma and 1 for people with sjogren.

App name	App ID	App Store	Release date	Price	Developer name
Arthritis Diary	945349814	iOS Play Store	2014	4,99€	cellHigh
Arthritis+Patient	1508917640	iOS Play Store	2020	Free	Azaya Technologies Inc.
ArthritisPower	1004705508	iOS Play Store	2015	Free	Global Healthy Living Foundation
Chronic Illness Monitor	1435161881	iOS	2018	4,99€	B12 Global Limited
Cliexa-RA	1077589407	iOS Play Store	2016	Free	CN4CE, LLC
DAS28/ACR-EULAR criteria	443707029	iOS Play Store	2011	Free	Keiji Matsui
Elsa – Impact your rheumatism	1455833439	iOS Play Store	2019	Free	Elsa Science AB
GRAPPA App	1346646781	iOS	2018	Free	Group for Research and Assessment of Psoriasis and Psoriatic Arthritis
Healthmatica	1175272405	iOS	2017	Free	Healthmatica
Jointfully Osteoarthritis	1068422271	iOS Play Store	2018	Free	MicroHealth LLC
Manage My Pain	1444320523	iOS Play Store	2019	Free	ManagingLife
My Arthritis	1431862637	iOS Play Store	2018	Free	AMPERSAND HEALTH LIMITED
MySpA	1378899849	iOS	2018	Free	Barts Health NHS Trust
Pain Diary - Pain Management Log	com.samantharoobol.painlog	Play Store	2011	Free	ManagingLife
RA Manager	840972490	iOS	2014	Free	@Point of Care
RA Monitor	1312851551	iOS Play Store	2017	Free	RPM Healthcare, LLC
RheumaKit	be.levelapp.rheumakit	Play Store	2016	Free	DNAlytics SA
Rheumatic Monitor	1545357629	iOS	2021	Free	BGU Medical Informatics Research Center

Table 4.2: Characteristics of the apps reviewed.

Features of the apps included

The features of the apps were organised, according to the codes in Table 4.3: educational information, general wellbeing monitoring, possibility of triggering self-report, functional capacity monitoring, quality of life monitoring, exercise management, triggers, medical management, information sharing, health events, notes/comments and symptom tracking.

Codes	Description and definition
Educational Information	Features of educational information where the information content is up to date, scientifically justifiable, acceptable to users, and evidence-based.
General wellbeing	Feature where the user is questioned about their general wellbeing. The questions/statements are about your general symptoms or about matters of weight and blood pressure.
Possibility triggering self-report	Feature that enables the users to introduce their possibility triggering self-report, some allow free text, others allow the user to choose by a list.
Functional capacity	Features that question the users about their functional capacity. The capacity of performing tasks and activities that users find necessary or desirable in their lives.
Quality of life	Feature that question the users about their quality of life. An individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns.
Exercise management	Features of exercise management where users are allowed to record information pertaining to exercise (eg, frequency, time, type).
Triggers	Feature that question the users about their triggers, action, or situation that can lead to contributing to the aggravation of the symptoms.
Medication management	Features of medication management where users are allowed to record medication name, dosing, time, or frequency.
Information sharing	Features of information sharing, where users are allowed to export or send directly from the app the information reported.
Health events	Features of health events where users can report appointments, exams, medical information, or any kind of interaction with the medical team.
Notes / Comments	Feature that allows the users to take notes or comments, these can be taken on a daily basis or on a general note.
Visuals or analysis of symptoms	Displays recorded information about symptoms reported as graphs or tables.
Symptom tracking	Prompts users to assess users general symptoms as follows: disease activity, pain, fatigue, morning stiffness, and functional ability.

Table 4.3: Codes related with the features of the apps reviewed

Based on the results obtained, it is possible to conclude that most apps lack key features to assist the self-report of rheumatic conditions such as quality of life, functional capacity and sharing of the information tracked. Only 4 out of the apps reviewed provided at least 8 features to support patients in managing their condition: *Arthritis+Patient, Elsa, My arthritis* and *RA Manager*. Other features of the included apps are shown in Table 4.4.

One of the goals of this dissertation was to review self-report apps for people with rheumatic conditions. Therefore the review of symptoms tracking was done in more depth to identify which symptoms are most commonly tracked.

App name	Educational information	Asks general wellbeing	Enables own logging	Function capacity	Quality of life	Exercise management	Triggers	Medication Management	Information sharing	Health event	Notes / Comments	Visuals or analysis	Symptom tracking						
													Fatigue	Skin	Sleep	Mental Health		Pain	Joint Assessment
																Mood	Stress		
Arthritis Diary	-	x	-	-	-	x	x	x	-	x	x	x	-	-	x	x	x	x	x
Arthritis+ Patient	x	x	-	-	-	-	-	x	x	x	x	x	x	-	x	x	-	x	x
ArthritisPower	x	-	-	x	-	-	-	x	x		x	x	x	-	-	-	-	x	-
Chronic Insights symptom diary	x	x	x	-	-	x	-	-	x	-	x	x	x	-	-	x	-	-	-
cliexa-RA	-	-	-	-	-	-	-	x	-	-	x	x	-	-	-	-	-	-	x
DAS28/ACR-EULAR criteria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Elsa – Impact your rheumatism	x	x	x	-	-	x	-	x	-	-	x	x	x	x	-	x	-	x	x
GeoPain:Home - 3D Chronic Pain & Symptom Manager	-	-	-	-	-	-	x	-	x	-	-	x	-	-	-	-	-	x	-
GRAPPA App	-	-	-	x	-	x	-	-	-	-	-	-	x	x	x	-	x	x	-
Jointfully Osteoarthritis	x	x	-	-	-	-	-	x	-	-	x	x	-	-	-	x	-	-	x
LupusMinder	x	-	x	-	-	-	-	x	x	x	x	-	-	-	-	-	-	x	-
Manage My Pain	x	-	-	x	-	-	-	x	x	-	x	x	-	-	-	x	-	x	-
My Arthritis	x	x	-	x	-	x	-	x	-	x	x	x	-	-	x	x	x	x	x
MySpA	x	x	x	x	x	x	-	-	-	-	-	x	x	x	-	-	-	-	x
Pain Diary - Pain Management Log	-	-	-	-	-	-	x	x	x	-	x	x	-	-	-	-	-	x	-
RA Manager	x	x	x	x	x	x	-	x	-	x	x	x	x	-	x	x	-	x	x
RA Monitor	x	-	-	x	-	-	-	x	x	x	x	x	x	-	-	x	x	-	x
Rheumatic Monitor	-	-	-	x	x	x	-	x	-	-	-	x	x	-	x	x	x	x	x

Table 4.4: Features of the apps reviewed.

Regarding symptom tracking, pain was the most commonly tracked symptom, being present in 11 of the 18 apps in the review. Examples of these are *Manage My Pain and Rheumatic Monitor*, as displayed in Figure 4.2 The pain self-report screens of those apps usually consist of a question/statements such as "Pain", "Pain Description", "Pain intensity", "Pain score", "Pain Overview", "How much pain have you felt?", "I wasn't affected by pain today." or "What best describes your pain? ". This statement/question is then accompanied by a scale (example below in Fig 4.2) to enter the answer. In addition to that, 3 of the apps, ask for the duration of the pain and 5 asked for a description of the pain. The scales used to quantify pain vary between 0-10 (with and without caption), 1-10 (with and without caption) and unstructured textual answer.

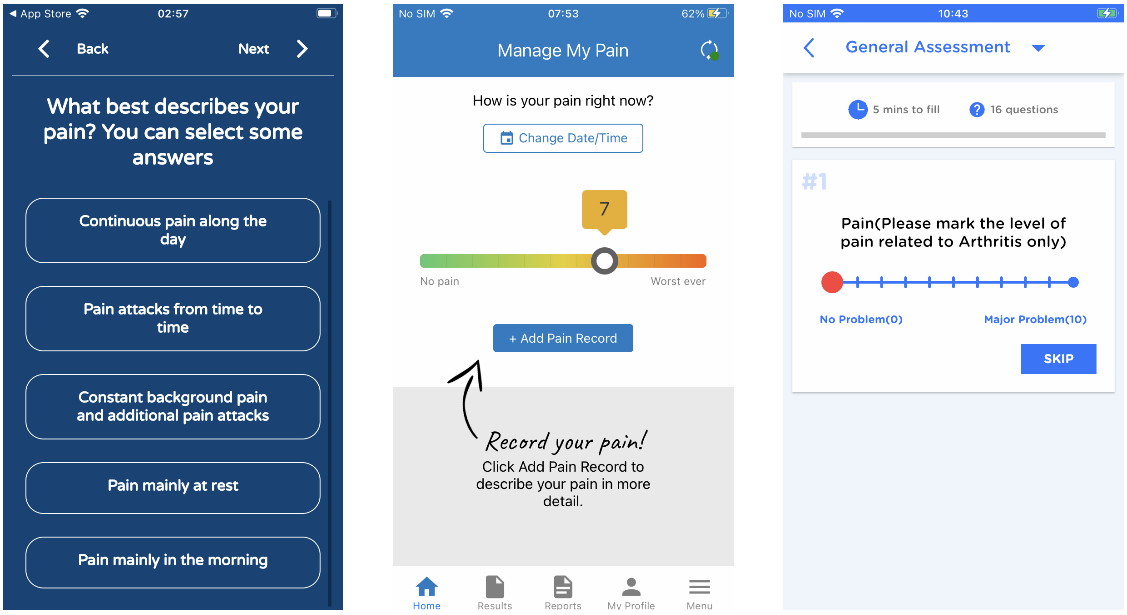


Figure 4.2: (L to R) Screenshots of apps: Rheumatic Monitor, Manage My Pain and Arthritis+Patient.

With regards to joint assessment self-reports, 11 apps incorporate such features as can be observed in the examples below of *Cliexa ra*, *Elsa* and *RA Monitor* (Fig. 4.3). Different apps approach joint assessment differently and allow users to assess joint stiffness, joint pain, joint swelling, joint inflammation, joint tenderness and/or joint warmth. The joint assessment self-report screens consist of a question/statements such as: "Symptoms description", "Please click on circles to indicate [affected] joints", "Do you have swollen or tender joints?", "Swollen Joints", "Joints" and "Mark the painful areas". Again, this is followed by a scale to enter patients' answers. The scales used to quantify those symptoms vary between 0-10, with and without caption, 1-10 with caption associated with them and unstructured textual answer.

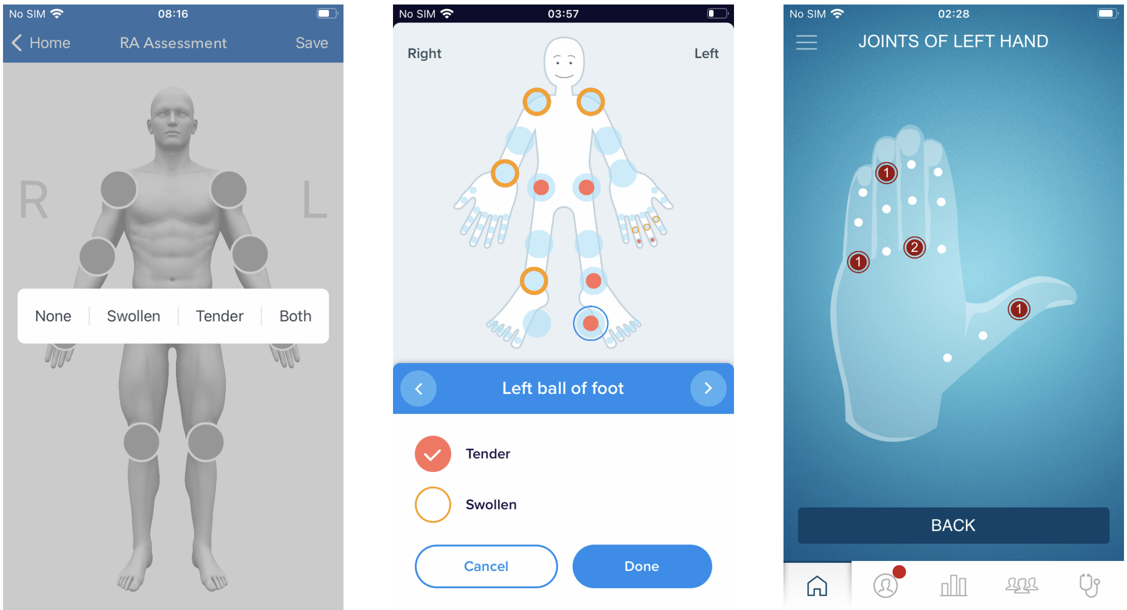


Figure 4.3: (L to R) Screenshots of apps: Cliexa ra, Elsa and RA Monitor.

In what concerns fatigue self-report, 10 of the apps included in the review incorporate this feature. Examples of these are *GRAPPA App* and *Elsa* (Fig. 4.4). The fatigue self-report screens consist of a question/statements such as "Fatigue", "How much fatigue have you felt?", "Did you experience fatigue last week?" and "Fatigue, tiredness, exhaustion, low energy". This is followed by a scale to enter the answer. In 8 of the apps, self-report is made through 0-10 scales, with and without caption, 0-3 scales and unstructured textual answer.

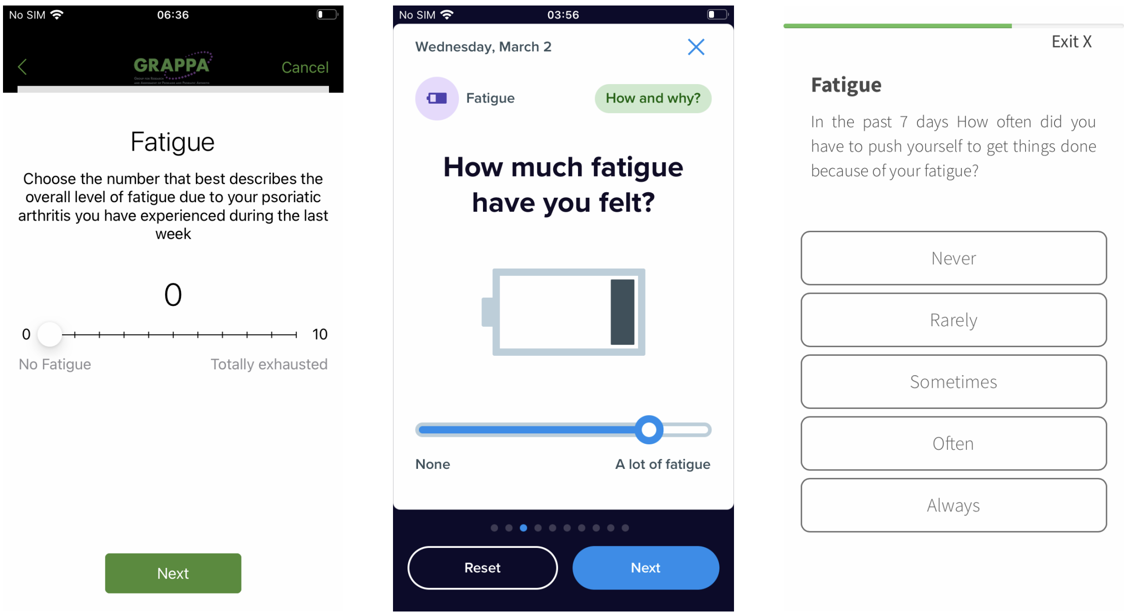


Figure 4.4: (L to R) Screenshots of apps: GRAPPA App, Elsa and Arthritis Power.

Of the apps reviewed, 10, provided educational information about symptoms and treatments, updated news and forums or blogs (e.g., *Jointfully Osteoarthritis*, Fig. 4.5). Of the 18 included apps, only 8 asked users about their general well-being, 8 incorporated features of sel-report of exercise and 8 (e.g., *MySpa* and *RA*

Manager displayed in 4.5) questioned their functional capacity.

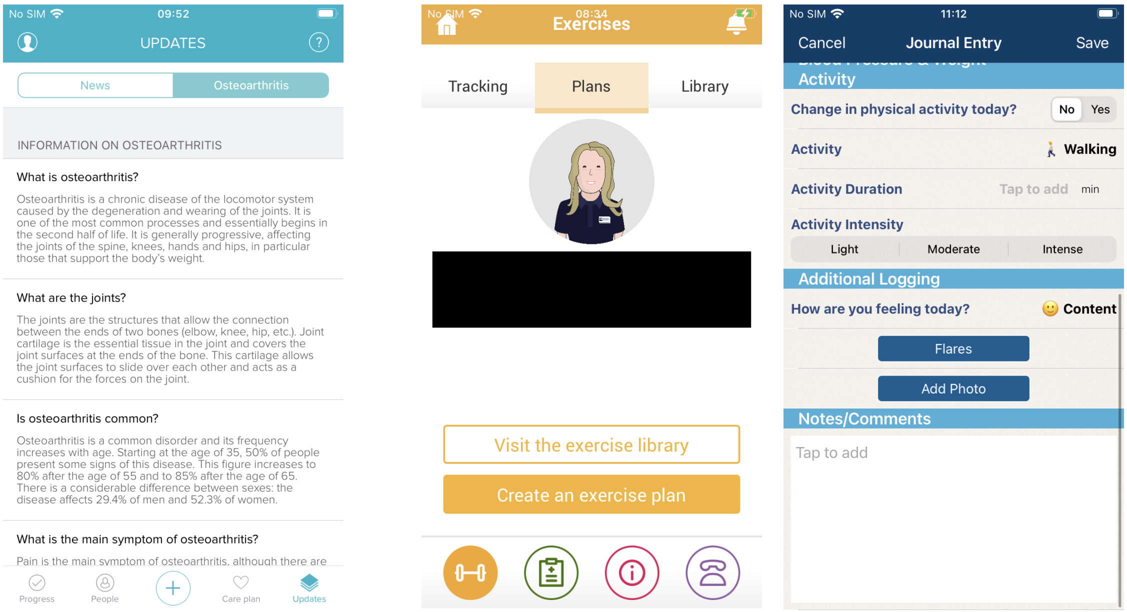


Figure 4.5: (L to R) Screenshot of apps: Jointfully Osteoarthritis, MySpa and RA Manager.

Medication management was another common feature among the analyzed apps, with 13 apps supporting medication management. From these, 5 apps provide users with a medication list, enabling them to add information about the medication they are taking and when (see e.g., *Arthritis Diary* in Fig. 4.6). Another 3 apps provide medication reminders, in addition to the medication list, offering smartphone notifications to the user when it is time to take their medication (see e.g., *My Arthritis* in Fig. 4.6). Most of the applications reviewed enable the user to report whether they have taken their medication as expected, enabling them, for example, to see their medication adherence rate after some time (see e.g., *Pain Management* in Fig. 4.6).

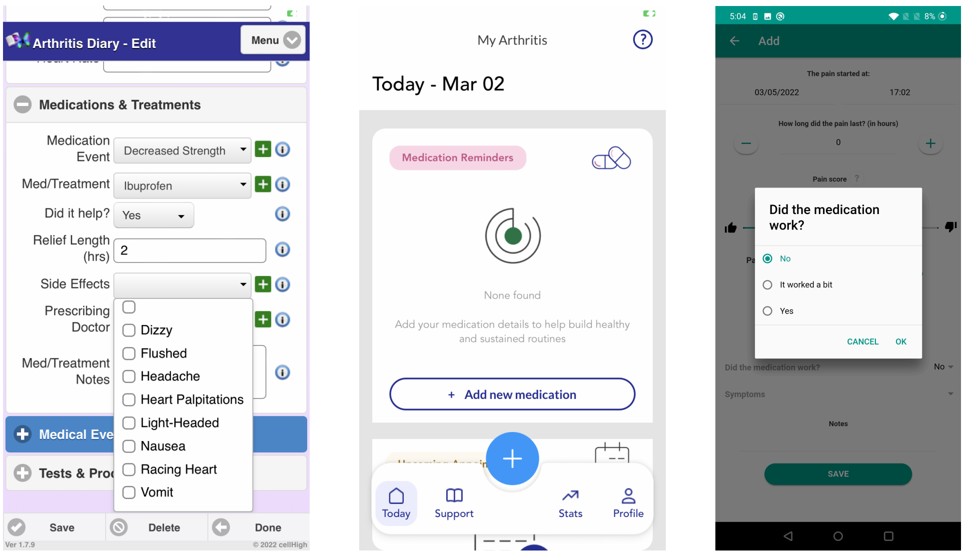


Figure 4.6: (L to R) Screenshots of apps: Arthritis Diary, My Arthritis and Pain Management.

UI components present in the apps reviewed

In order to understand user interfaces to support self-report we installed the apps and analysed the UI components used in existing self-report apps for people with rheumatic conditions. Table 4.5 summarises the six UI components used in the features of symptom tracking in the apps reviewed: (i) Body Graphic, (ii) Checkboxes, (iii) Selectors, (iv) Horizontal Sliders, (v) Vertical Sliders and (vi) Circular Sliders.

Symptoms tracked	Body Graphics	Checkboxes	Selectors	Horizontal Sliders	Vertical Sliders	Circular Sliders
Fatigue		MySpA	ArthritisPower RA Manager Rheumatic Monitor	Arthritis+ Patient Elsa GRAPPA App RA Manager RA Monitor		Chronic Insights symptom diary
Skin	Elsa		MySpA	GRAPPA App		
Sleep		Arthritis Diary	Rheumatic Monitor	Arthritis+ Patient GRAPPA App RA Manager	My Arthritis	
Mood		Arthritis Diary	Jointfully Osteoarthritis Manage My Pain Rheumatic Monitor	Arthritis+ Patient Elsa RA Manager RA Monitor	My Arthritis	Chronic Insights symptom diary
Stress		Arthritis Diary	Rheumatic Monitor	GRAPPA App RA Monitor	My Arthritis	
Pain	GeoPain	Arthritis Diary	ArthritisPower Manage My Pain My Arthritis Rheumatic Monitor	Arthritis+ Patient Elsa GeoPain GRAPPA App LupusMinder Pain Diary	My Arthritis	
Joint Assessment	Arthritis+ Patient cliexa-RA DAS28/ACR-EULAR criteria Elsa Jointfully Osteoarthritis MySpA RA Monitor Rheumatic Monitor	Arthritis Diary	My Arthritis RA Manager Rheumatic Monitor	Jointfully Osteoarthritis RA Manager		

Table 4.5: UI components for symptom tracked and respective apps.

One of the most commonly used UI components in symptom tracking features is **horizontal sliders** . These sliders vary in quantity per screen (see e.g., in Fig. 4.7 on the left), position on the screen, size (see e.g., in Fig. 4.7 in the middle) and different visual elements that compose the sliders, i.e.: tick marks, static value labels, without value labels, or following the slider thumb values label (see e.g., in Fig. 4.7 on the right).

Another commonly used UI component in symptom tracking features are **selectors**. They vary in different types of selectors: column selectors (see e.g., in Fig. 4.8 on the left) or in-line selectors (see e.g., in Fig. 4.8 in the middle), quantity per screen, the position on the screen, size and spacing to other selectors or other elements (see e.g., in Fig. 4.8 on the right).

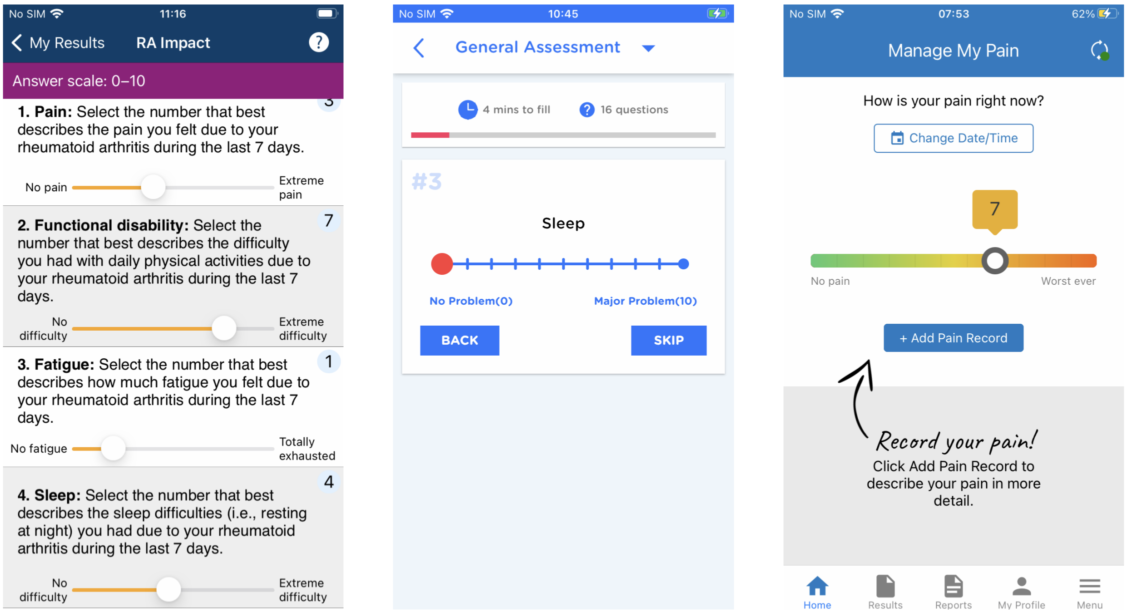


Figure 4.7: (L to R) Screenshots of apps: RA Manager, Arthritis+Patient and Manage My Pain.

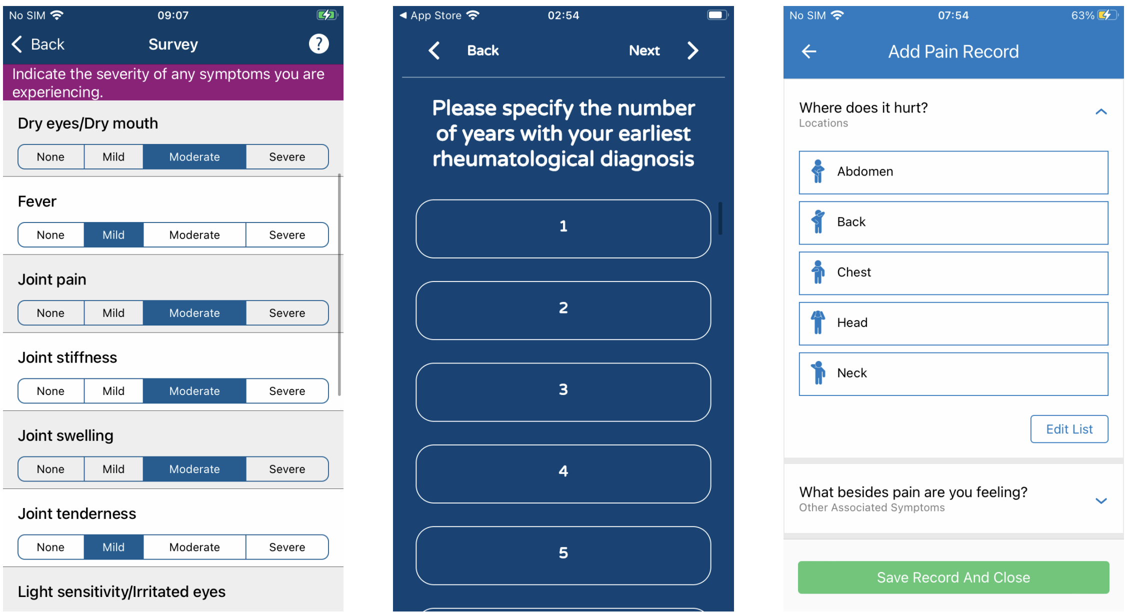


Figure 4.8: (L to R) Screenshots of apps: Rheumatic Monitor, RA Manager and Manage my pain.

Checkboxes are commonly used in all symptom tracking, except the tracking of skin conditions. They vary in quantity per screen (see e.g., in Fig. 4.9 on the left), in the position in the screen, in the target size box (see e.g., in Fig. 4.9 in the middle) and in different visual elements that compose the checkbox: target box below the caption or on the left side of the caption (see e.g., in Fig. 4.9 on the right).

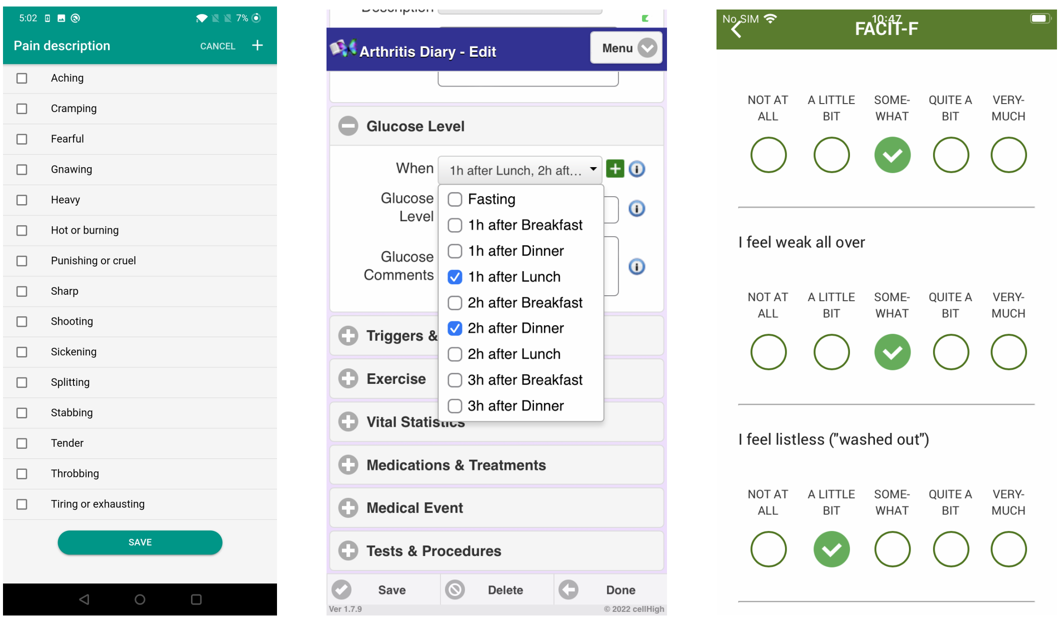


Figure 4.9: (L to R) Screenshots of apps: Pain Management, Arthritis Diary and MySpA.

Vertical sliders are incorporated in apps that track fatigue, sleep, mood, stress and pain. The results of our review show that vertical sliders vary in terms of their position on the screen (see e.g., in Fig. 4.10 on the left), size, with or without scale (see e.g., in Fig. 4.10 in the middle) and different visual elements that compose the sliders: tick marks, without value label or following the slider thumb value label (see e.g., in Fig. 4.10 on the right).

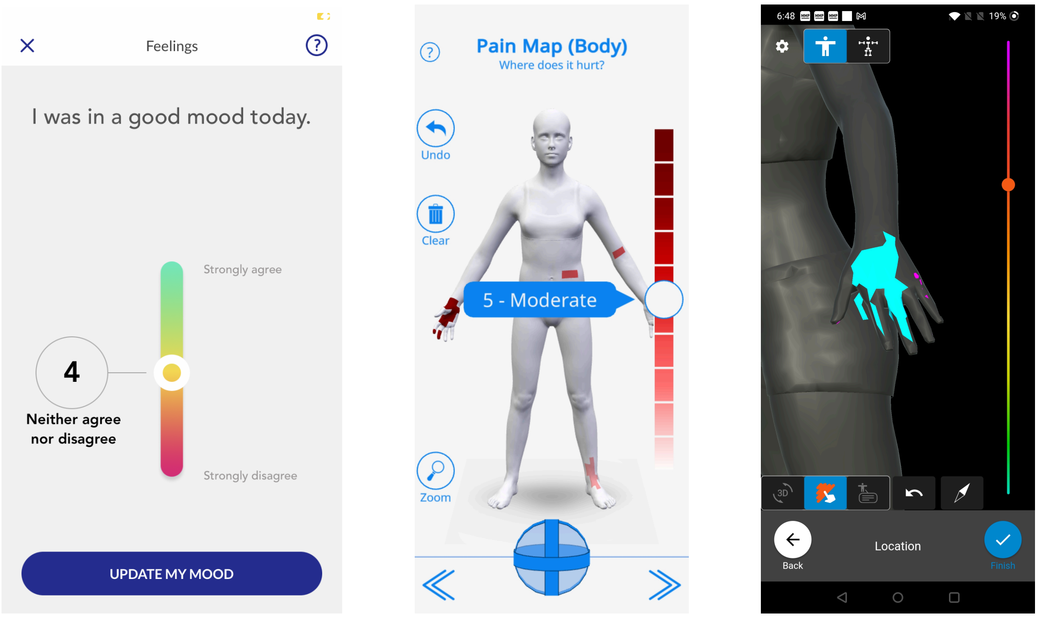


Figure 4.10: (L to R) Screenshots of apps: My Arthritis, Chronic Insights and GeoPain.

Incorporating a **body graphic** is used in apps that track the skin, pain and mainly joint assessment. The representations of the human body are presented with different illustrations, with different selector sizes, with or without scale (see e.g., in Fig. 4.11 on the left). Apps that use body graphics to assess joints present an overview of the human body with the possibility of selecting different joints (see e.g., in Fig. 4.11 in the middle). The selection of the hands and feet joints follows a different behavior (see e.g., in Fig. 4.11 on the right). When clicked, an amplified hand or foot is displayed, where it is then possible to enter the symptom/s or the scale of the referred symptom.

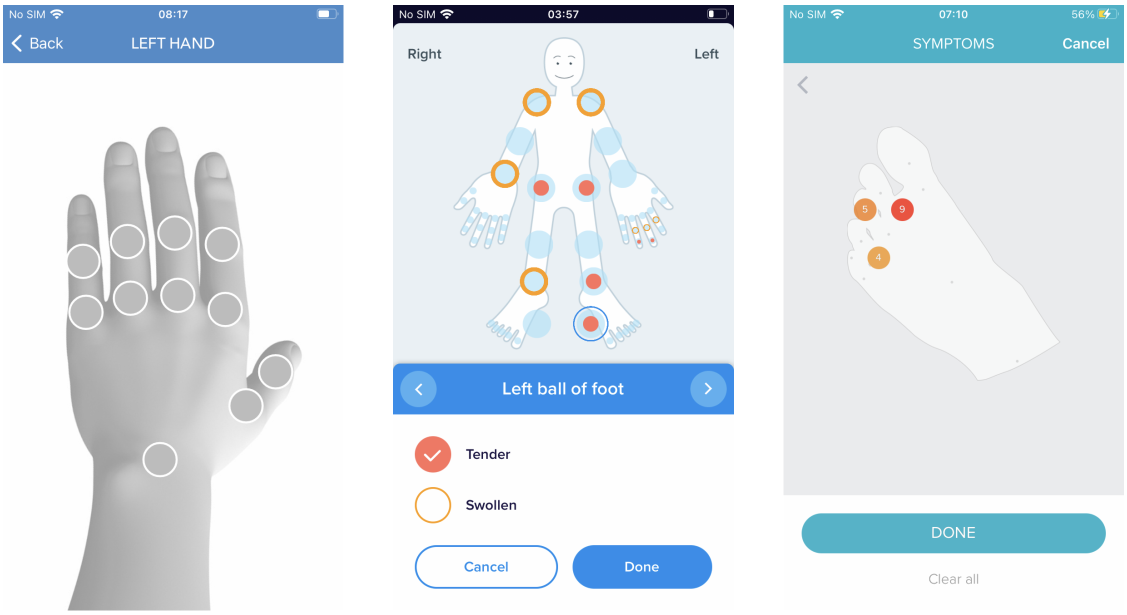


Figure 4.11: (L to R) Screenshots of apps: Cliexa ra, Elsa and Jointfully Osteoarthritis.

Circular sliders are more rarely used but are incorporated in apps that track fatigue and mood. This UI components was only used by one app in the review (see e.g., in Fig. 4.12), thereby it does not have variations.

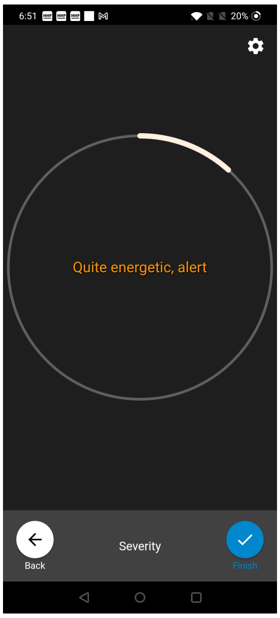


Figure 4.12: (L to R) Screenshot of app: Chronic Insights.

4.2 Selecting UI components to test

Having identified the most common components it was possible to proceed to the selection of UI components to test. This involved a pre-selection of the UI components and its validation of the pre-selection with experts.

4.2.1 Pre-selection of UI components

The selection process of the UI components to include in the usability experiments was based on the frequency of use in the apps reviewed and the respect for the guidelines recommended by Android Material Design 2 and 3 (Google, 2014, 2018) or the iOS Human Interface Guidelines (Apple, 2020). As described previously, the UI components present in the app review were horizontal sliders, vertical sliders, circular sliders, selectors, and the representation of the human body.

Horizontal and vertical sliders

> Guidelines suggest that horizontal sliders can be continuous, where users are allowed to set and select a value along with a subjective range (without tick marks), or discrete, where these can be adjusted to a specific value by referencing its value indicator (with tick marks where a slider

thumb will snap to) (Google, 2014). A value label displays the specific numeric value that corresponds with the slider thumb's placement (Google, 2014). Apple (2020) recommends the use of tick marks to increase clarity and accuracy, that people may appreciate the display of a value label. Contrary to this, Google (2014) makes no specific recommendation on the use of both elements, affirming that these possibilities are optional. Regarding the composition of the sliders, guidelines recommend that the active track minimum height should be 6dp, the inactive track minimum height should be of 4dp, the slider thumb minimum radius should 20dp and the discrete regions of the track should have a minimum radius of 2dp (Google, 2014).

Considering these recommendations, we decided to test **horizontal sliders** with the different characteristics that were present in the apps, including: (i) sliders with and without tick marks, (ii) slider showing a static value or a moving one above the slider thumb, (iii) sliders with different slider thumb sizes and (iv) sliders positioned on different positions of the screen.

Vertical sliders would be tested under similar conditions, except for the position onscreen. Although vertical sliders are not included in Android Material Design 2 and 3 (Google, 2014, 2018) or the iOS Human Interface Guidelines (Apple, 2020), they were included since they appear in several reviewed apps.

When selecting the UI components to test, we opted to exclude circular sliders for being the least common used of the six presented in the previous section and for not being mentioned or recommended in the Android Material Design 2 and 3 (Google, 2014, 2018) or the iOS Human Interface Guidelines (Apple, 2020).

Selectors

Guidelines for selectors enhance the need for each button to clearly communicate its purpose (Apple, 2020). In regards to selectors size, (Google, 2018) recommends the minimum height to be 56dp. Apple (2020) affirms that it's essential to leave adequate space around a selector so that people can identify it from neighbouring elements and information. Furthermore, guidelines recommend a minimum in-between button spacing of 12dp (Google, 2018; Apple, 2020). The selectors incorporated in a body graphic are considered toggle buttons. These allow a single choice to be selected or deselected. Regarding the size of this type of selectors, (Google, 2018) recommends a minimum size of 24dp.

Considering these recommendations, we decided to test **selectors** with the different characteristics that were present in the apps, including: (i) different spacing and (ii) different sizes.

The type of selector included column selectors, in-line selectors, in-circle selectors and carousel selectors. The last two types of selectors were excluded for not appearing in the Android Material Design 2 and 3 (Google, 2014, 2018) nor the iOS Human Interface Guidelines (Apple, 2020) and for being the least commonly used.

Checkboxes

Google (2014) defines a checkbox as a square button with a check to denote its current state. The visual style of checkboxes helps them align well and communicate grouping (Apple, 2020). The minimum size of a checkbox should be 24dp (Google, 2014).

After consulting the Android Material Design 2 and 3 (Google, 2014, 2018) and the iOS Human Interface Guidelines (Apple, 2020), the checkboxes were not included as a UI components to be tested. This decision was based on the recommendations advising that checkboxes work as selectors. Being that the selection of an option is possible by pressing the whole selector and not only by pressing the target box. Therefore, since in the review we were presented with different types of selectors that included the checkboxes as one, we decided to exclude the checkboxes from the usability experiments (Google, 2014).

Body graphic

Considering these body graphics presented in the apps reviewed, we decided to test **body graphics** with the different characteristics that were present in the apps, including: (i) different size selectors. Although body graphics are not the most commonly used UI components, they are characteristic of self-report applications for people with rheumatic diseases. Thus, we found it crucial to test different visual characteristics of it.

In sum, the excluded UI components were checkboxes and circular sliders and the included UI components were horizontal sliders, vertical sliders, column selectors, in-line selectors and the human body.

In verifying the characteristics of the UI components reviewed in relation to the guidelines, it was possible to concluded that most apps fail to comply with the guidelines recommended by Android Material Design 2 and 3 (Google, 2014, 2018) or the iOS Human Interface Guidelines (Apple, 2020). This was the case for: incorporating button sizes (e.g., Fig. 4.13, left), in-between button spacing (e.g., Fig. 4.13, middle-left), slider thumb size (e.g., Fig. 4.13, middle-right) and checkbox target size box that were not designed as recommended (e.g., Fig. 4.13, right).

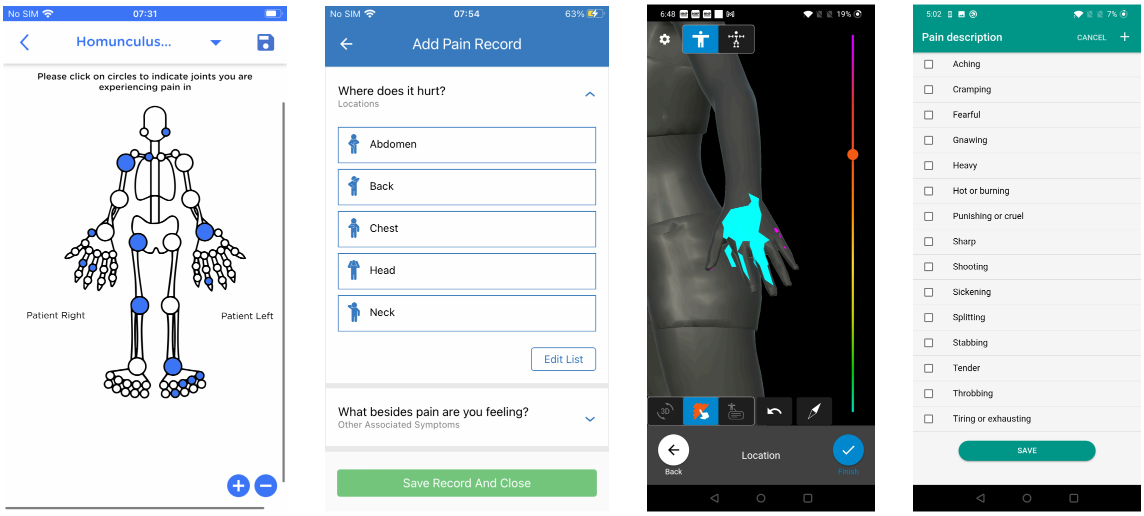


Figure 4.13: Apps that failed to comply with official guidelines.

4.2.2 Validation of pre-selected UI components through expert review

After the six UI components were pre-selected based on their frequency of use and compliance with existing guidelines, we conducted an expert review to validate our pre-selection of the UI components. The expert review involved a group of experts composed of three experienced user experience and visual communication designers and the two dissertation advisers. The expert review was separated into two different phases, which we describe next.

The review started with a Powerpoint presentation by the researcher. This presentation provided an overview of the app review selection process, an overview of the apps captured and the apps' features. This was followed by an overview of the existing UI components in the dataset of apps and their different visual characteristics, along with the rationale for selecting UI components for the next phase of testing. In the second phase, all experts engaged in a discussion about the previous topics.

The main findings of the first phase of the expert review were that:

- The UI component selection was duly justified;
- App navigation should be considered when designing the usability experiment tool, an aspect that had not been previously been considered;
- The usability experiment should strip UI components from questions or context to ensure assessment was focused on the component and not on other issues that might prevent quick comprehension;
- Existing app screens with the UI components should not be used. Instead, new screens should be designed for the tests so that the interaction could be focused on the UI components and not the screen itself.

The UI components included in the usability experiments, as validated by the experts were: (i) horizontal sliders, (ii) vertical sliders, (iii) column selectors, (iv) in-line selectors and (v) body graphic, considering the visual characteristics presented in the previous section.

Taking into consideration the conclusions drawn from the expert review, a decision was made that the usability experiments would focus on entering information through UI components and not on understanding descriptive questions or scales. Thus the screen of the usability experiments only use direct instructions. It was also decided that the screens with the UI components would have a simple navigation, based on the navigation present in the apps reviewed. All the details of the usability experiments are explained in the next chapter.

4.3 Summary

The aim of the mobile app review and selection was to investigate commonly used user interfaces in self-report mobile apps for people with rheumatic conditions. The chapter outlined the systematic app review conducted with the apps that enabled self-report, for example of pain, medication intake or swollen joints. A total of 18 apps remained after the criteria was applied and were analysed in detail.

The app data gathered of the 18 apps was composed of, first, information extracted from SerpAPI and then, complemented by information collected when installing and using the apps. The app review allowed the researcher to identify the features included in apps. The features identified were: educational information, general wellbeing monitoring, possibility of triggering self-report, functional capacity monitoring, quality of life monitoring, exercise management, triggers, medical management, information sharing, health events, notes/comments and symptom tracking. Based on the findings, one can conclude that most apps lack the possibility to report quality of life, functional capability, while disabling the possibility of sharing the information gathered for tracking rheumatic illnesses. Only four of the 18 apps – *Arthritis+Patient, Elsa, My arthritis* and *RA Manager* – offer most of the features reviewed.

To investigate and design a self-report user interface for people with rheumatic conditions, we first identified the main UI components that were commonly used in existing self-report apps for people with rheumatic conditions. The six UI components used in the features of symptom tracking in the apps reviewed were: (i) Body Graphic, (ii) Checkboxes, (iii) Selectors, (iv) Horizontal Sliders, (v) Vertical Sliders and (vi) Circular Sliders. After consulting the Android Material Design 2 and 3 and the iOS Human Interface Guidelines, checkboxes and circular sliders were not be included as a UI components to assess in the usability experiments.

Additionally, most apps reviewed failed to comply with other guidelines (e.g., small buttons), giving the impression that they were not designed considering end-users physical abilities or that they skipped usability tests. Consequently, healthcare providers, patients with rheumatic conditions and app developers should collaborate to develop high-quality, evidence-based apps that consider patients' needs and health care professionals' perspectives.

The excluded UI components were checkboxes and circular sliders and the included UI components were horizontal sliders, vertical sliders, column selectors, in-line selectors and the human body. After the six UI components were preselected based on their frequency of use and existing guidelines compliance, we conducted an expert review to validate our pre-selection of the UI components. The chosen UI elements were tested in usability experiments in accordance with Android and iOS guidelines and the validation discussed in detail with experts.

Chapter 5

Usability experiments

As explained in the previous chapter, the UI components tested were the ones that, besides complying with existing guidelines, were also commonly used in commercial mobile apps. This chapter will describe the test conditions and the results of the usability experiments.

In producing these different alternatives for each UI component, we made sure that our proposals complied with all relevant Android Material Design 2 and 3 guidelines (Google, 2014, 2018). Besides understanding the touch performance of participants with dexterity problems, such as limited hand movement or touch precision, we aimed to better understand what could make specific UI components more discoverable or otherwise challenging by examining their characteristics.

5.1 Test conditions

Five usability experiments were created to test each of the UI components: horizontal sliders, vertical sliders, column selectors, in-line selectors and a body graphic. Each component was tested in multiple tasks and is named as a category to facilitate the referencing: A - horizontal sliders, B - vertical sliders, C - column selectors, D - in-line selectors and E - body graphic. Each category then included different tests with different objectives.

Category A. The category that tested **horizontal sliders** (A) included three different tests. The first one (A1) tested different ways of displaying the selected number on the slider (hidden, static, moving with slider thumb), the second one (A2) tested different positions of the sliders on the screen and the third one (A3) had the objective of testing different sizes of the slider thumb (Table 5.1).

Category B. The category that tested **vertical sliders** (B) included two different tests. The first one (B1) tested different ways of displaying the selected number on the slide and the second one (B2) tested different sizes of the slider thumb (Table 5.2).

Category C. The category that tested **column selectors** (C) included three different tests. The first one (C1) tested the size according to the guidelines defined by (Google, 2018), the second one (C2) tested 1.25x the size defined in the guidelines and the third one (C3) tested selectors at 1.5x the size according to the guidelines ((Table 5.3)).

Category D. The category that tested **in-line selectors** (D) included two different tests. The first one (D1) aimed to test different positions of the selector and the second one (D2) of testing different sizes of the selector (Table 5.4).

Category E. The category that tested the **body graphic** (E) included only one type of test which aimed to assess different sizes of the selector in the body graphic (Table 5.5).

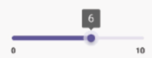
Horizontal sliders				
Test ID	**Evaluation component**	**Research questions**	**UI component tested**	**Representative image**
A1	Types of sliders	Do tick marks in sliders affect precision?	Sliders with tick marks and without a value label	
		Does displaying the selected number on the slider affect precision?	Sliders without tick marks and with a static value label	
		Do different ways of displaying the selected number on the slide affect precision?	Sliders without tick marks and with a value label following the thumb	
A2	Position of the slider in the screen	Does a different position in the screen affect precision?	Slider positioned in the middle of the screen	
			Slider positioned at the bottom of the screen	
A3	Size of the slider thumb of the slider	Does a larger size slider thumb affect precision?	Slider with recommended size slider thumb	
			Slider with 1.25x larger size slider thumb than recommended	
			Slider with 1.5x larger size slider thumb than recommended	

Table 5.1: Overview of the tests conducted for horizontal sliders.

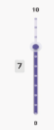
Vertical sliders				
Test ID	**Evaluation component**	**Research questions**	**UI component tested**	**Representative image**
B1	Types of sliders	Do tick marks in sliders affect precision? Does displaying the selected number on the slider affect precision? Do different ways of displaying the selected number on the slide affect precision?	Sliders centred in the middle of the screen	
			Sliders without tick marks and a static value label	
			Sliders without tick marks and a value label following the slider thumb	
B2	Size of the slider thumb of the slider	Does a larger size slider thumb affect precision?	Slider with recommended size slider thumb	
			Slider with 1.25x larger size slider thumb than recommended	
			Slider with 1.5x larger size slider thumb than recommended	

Table 5.2: Overview of the tests conducted for vertical sliders.

Column Selectors				
Test ID	**Evaluation component**	**Research questions**	**UI component tested**	**Representative image**
C1	Size according to guidelines	Does button in-between spacing affect precision?	Test selectors with size and spaced according to Android Material Design 3	
			Test selectors with size recommended and spaced 1.25x larger than Android Material Design 3	
			Test selectors with size recommended and spaced 1.5x larger than Android Material Design 3	
C2	Size 1.25x guidelines	Does a larger size button and button in-between spacing affect precision?	Test selectors with size 1.25x larger than recommended and spaced according to Android Material Design 3	
			Test selectors with size 1.25x larger than recommended and spaced 1.25x larger than Android Material Design 3	
			"Test selectors with size 1.25x larger than recommended and spaced 1.5x larger than Android Material Design 3	
C3	Size 1.5x guidelines	Does a larger size button and button in-between spacing affect precision?	Test selectors with size 1.5x larger than recommended and spaced according to Android Material Design 3	
			Test selectors with size 1.5x larger than recommended and spaced 1.25x larger than Android Material Design 3	
			"Test selectors with size 1.5x larger than recommended and spaced 1.5x larger than Android Material Design 3	

Table 5.3: Overview of the tests conducted for column selectors.

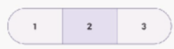
In-line Selectors				
Test ID	**Evaluation component**	**Research questions**	**UI component tested**	**Representative image**
D1	Position of the selector in the screen	Does a different position in the screen affect precision?	Test selectors positioned in the middle of the screen	
			Test selectors positioned at the bottom of the screen	
D2	Size of the selector	Does a larger size button affect precision?	Test selectors with a size 1.25x larger than the one recommended by the Android Material Design 3	
			Test selectors with a size 1.5x larger than the one recommended by the Android Material Design 3	

Table 5.4: Overview of the tests conducted for in-line selectors.

Body graphic				
Test ID	**Evaluation component**	**Research questions**	**UI component tested**	**Representative image**
E1	Size of the buttons in the body graphic	Does a larger size button affect precision?	Test selectors with the size recommended by the Android Material Design 3	
			Test selectors with a size 1.25x larger than recommended by Android Material Design 3	
			test selectors with a size 1.5x larger than recommended by Android Material Design 3	

Table 5.5: Overview of the tests conducted for body graphic.

5.2 Materials and apparatus

The study was conducted on a OnePlus 7T, an Android smartphone that measures 160.9 x74.4 mm and has a resolution of 1080x2400px at 402 ppi. The smartphone screen was recorded with an app and a GoPro HERO7 was used on a tripod fixed onto the table where the tests took place to film the hands of participants interacting with the smartphone. All participants performed the tasks while sitting on a chair in front of a table and were asked to hold the device as they typically use their smartphone.

Each test screen was composed of an instruction on top, the UI component to test in the centre and some navigation buttons at the bottom of the screen (start, next). When pressed, the *start button* allowed the participant to interact with the UI component and started counting the time of the activity. The time stopped counting when the participant pressed the *next button*, allowing the participant to go to the *next screen* and a similar process was repeated for the next screen. The app also recorded the time and the number of times the participant interacted with the UI component, allowing the researcher to understand and count the number of wrong interactions the participant had with the UI component. The *next button* was only activated when the person correctly performed the task described on the screen, requiring the participant to enter the number displayed on the screen correctly, before it was possible to proceed to the next screen. This interactivity, flow and log collection was repeated for all screens. Each test included 3 to 4 tasks and there were similar instructions in some of the tests to enable direct comparison when discussing the results between tests.

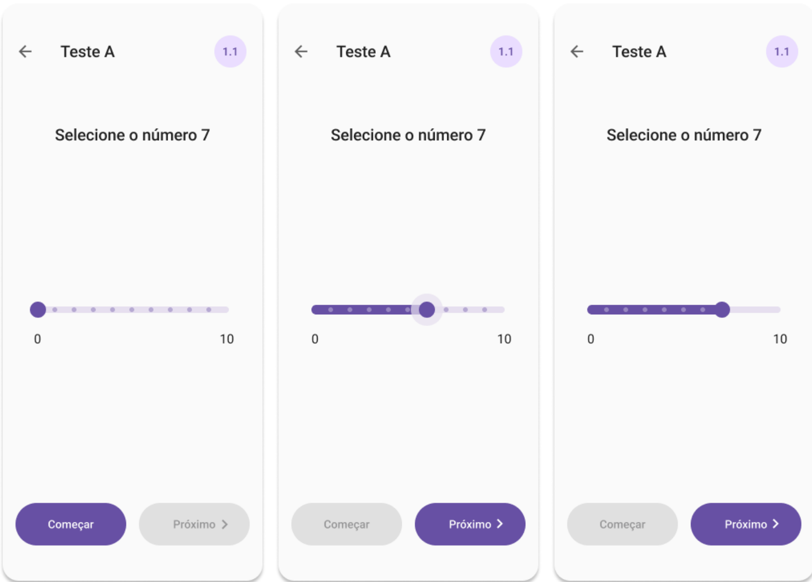


Figure 5.1: Flow of the *start button* and *next button*.

The researcher elaborated all the prototypes of the screen of the test on *Figma*, defining the flow of the app, such as the position, size and different characteristics of the UI components. Based on the specification, two developers from Fraunhofer Portugal created a mobile test tool for supporting the usability experiments developed in *Flutter*. Each time a test was finished, a detailed log of the test was created and saved on the smartphone storage. At the end of each session, the researcher transferred the logs to the computer to enable later analysis.

The data logs registered the number of the participant, the ID of the screen, the time spent on that screen, the time the participant pressed the *start button*, the time the participant pressed the *next button* and the time(s) the participant interacted with the UI component. This allowed for counting the number of errors and the number of gesture interactions with each UI component, per screen.

5.3 Test procedures

Having greeted the participants, an overview of the tests was presented to them. Afterwards, participants were asked to sign the informed consent form (see Appendix A for further detail) after which the different tasks, the flow of the screens and how the interaction worked were explained to the participants. We also let participants know that at any moment, they could interrupt the test if they felt the need for it. The activities were presented and completed by the participants always in the same order (see Appendix B for further detail).

For each type of test, a post-test questionnaire was conducted in order to assess participants' subjective ease of usage regarding the UI component with different visual characteristics (see Appendix C and Appendix D for further detail). We asked participants to choose from the different visual characteristics which they felt were easier to use if any and in one specific case, which one they felt more pain when interacting with.

Finally, at the end of the session, we asked the participants for their overall opinion about the tests and to make any suggestions they saw fit. Lastly, we thanked the participants for their time and availability.

5.4 Participants

The sample of participants consisted of 20 adults (16 female and 4 male) aged between 31 and 80 years who voluntarily participated in this study and agreed to be recorded while doing so. Participants were recruited by an online survey distributed by the Portuguese League against Rheumatic Conditions and/or referred by a rheumatologist, and/or by personal contacts. The inclusion criteria were having osteoarthritis, rheumatoid arthritis or psoriatic arthritis, and previous experience using a smartphone. We did not collect any data that allowed for the identification of participants. 45% Of participants had rheumatoid arthritis, 30% had psoriatic arthritis, 20% of participants had osteoarthritis and

5% had both osteoarthritis and rheumatoid arthritis. All participants used their smartphones multiple times a day and the majority of the participants did not take notes about their rheumatic condition.

All participants were asked about the situations in which they take notes about their rheumatic condition from the following options: (1) when experiencing new medication side effects (for example, when starting, stopping, or replacing medication), (2) when experiencing new symptoms or functional decline, (3) when experiencing crises, (4) when you need to reduce medication for some reason (e.g., cold, surgery), (5) I take notes in other situations (specify), or (6) none of the above. The following table (Table 5.6) presents a summary of participants' characteristics.

Participant nº	Age range	Gender	Frequency of usage of smartphone	Rheumatic condition	Rheumatic condition diagnoses (in years)	Situations where takes notes about the rheumatic conditions
1	41-50	F	Multiple times a day	OA	3	- When experiencing new symptoms or functional decline
2	41-50	F	Multiple times a day	RA	45	- When experiencing new drug side effects (for example, when starting, stopping, or replacing medication) - When experiencing new symptoms or functional decline
3	51-60	F	Multiple times a day	RA	8	- When experiencing new drug side effects (for example, when starting, stopping, or replacing medication)
4	41-50	F	Multiple times a day	RA	40	- None of the above
5	31-40	F	Multiple times a day	RA	4	- None of the above
6	51-60	F	Multiple times a day	RA	6	- None of the above
7	51-60	F	Multiple times a day	PsA	10	- None of the above
8	41-50	M	Multiple times a day	PsA	7	- None of the above
9	61-70	M	Multiple times a day	RA & OA	12 & 5	- None of the above
10	51-60	F	Multiple times a day	OA	1	- None of the above
11	51-60	F	Multiple times a day	PsA	23	- None of the above
12	41-50	M	Multiple times a day	RA	30	- None of the above
13	71-80	F	Multiple times a day	PsA	50	- None of the above
14	51-60	F	Multiple times a day	PsA	25	- None of the above
15	41-50	F	Multiple times a day	RA	12	- None of the above
16	61-70	M	Multiple times a day	PsA	2	- None of the above
17	51-60	F	Multiple times a day	RA	10	- None of the above
18	51-60	F	Multiple times a day	RA	11	- None of the above
19	71-80	F	Multiple times a day	OA	8	- None of the above
20	51-60	F	Multiple times a day	OA	3	- None of the above

Table 5.6: Participants' characteristics.

5.5 Data analysis and results

Having presented the test conditions, apparatus and the procedures, we were ready to conduct the tests. The following section presents the data analysis and the different tests in further detail and the results of each one individually.

The analysis of the data collected in the usability experiments was based on the task completion times and the number of gesture interactions. In this research, **task completion times** were viewed as the total amount of time a participant took from pressing the *start button*, to completing the task and pressing the *next button*. We performed Wilcoxon tests (Childs et al., 2021) to compare the performance in terms of task completion time between the same tasks on a specific test and to determine the influence of a different visual characteristic on average task completion times.

The **number of interactions** was understood as the number of times the participant interacted with the UI component to complete the task. Participants did not exhibit significant differences in relation to the number of gesture interactions in the same task ($p>.05$). Considering the influence of different visual characteristics on the number of gesture interactions per task, we performed the Wilcoxon test (Childs et al., 2021).

Additionally, a **correlation between task completion time and the number of gesture interactions** was performed. To test the possible existence of an association between the task completion time and the number of gesture interactions with screen elements, we used Spearman's correlation coefficient (Childs et al., 2021).

Participants were asked to choose the UI component they felt was easier to use and the one they felt more pain using. In order to analyze these, we calculated frequency tables.

5.5.1 Horizontal sliders

The following sections provide further detail regarding each of the three tests conducted for horizontal sliders and the outcome of each one of them.

Type of horizontal sliders

Test A1 was designed to test different types of sliders. All sliders were designed with the size recommended (slider thumb size = 20dp) by the Android Material Design 2 (Google, 2014) and for this type of test, all sliders were positioned in the middle of the screen. Table 5.7 shows an overview of test A1 and Figure 5.2 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
A1.1	Sliders with tick marks and without a value label	Test sliders with tick marks without a value label	Select the numbers 1, 2, 6, and 8
A1.2	Sliders without tick marks and with a static value label	Test sliders without tick marks and a static value label	Select the numbers 1, 4, 8 and 9
A1.3	Sliders without tick marks and with a value label following the thumb	Test sliders without tick marks and a value label following the thumb	Select the numbers 2, 4, 6 and 9.

Table 5.7: Overview of test A1.

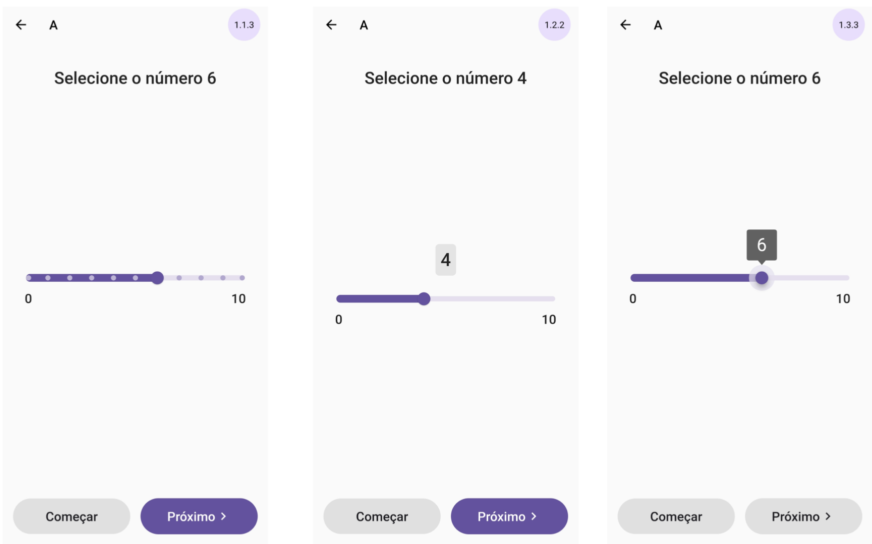


Figure 5.2: (L to R) Screenshot of a A1.1 test, A1.2 test and A1.3 test.

Results

The different slider types (tick marks, static value, moving value) obtained similar results in what concerns the task completion times and the number of gestures needed for completing the task. Nevertheless, there were some differences that would favour the sliders showing values. Looking at the average completion times in all tasks (see Table 5.8), we see that the slider with the moving value obtained the smallest completion time (3,93s), which is 35% faster than the worst performing option (the slider with tick marks - 5,31s). However, differences are not significant between the different options (p>.05). When we compare only the pair values that were the same in the different slider types (e.g., value 1 in A1.1. and A1.2, see Table 5.8), we find 3 pairs with significant differences in a group of 12, thus we cannot affirm there is a significant correlation between slider type and performance. Regarding the number of gesture interactions, the differences are very small between the options (<0,2) and no significant differences were found.

As for the participant's ease of usage, 7/20 of the participants demonstrated a preference for horizontal slider with the static value, 5/20 preferred slider with the moving value and 5/20 demonstrated no preference.

Design component		Sliders with tick marks and without a value label (A1.1)	Sliders without tick marks and with a static value label (A1.2)	Sliders without tick marks and with a value label following the thumb (A1.3)
Avg. number of interactions		1,26	1,4	1,21
Avg. task completion time		5,31	5,1	3,93
Avg. task completion time per the same task	T1	4,6	5,11	3,76
	T2	3,01	5,46	4,01
	T3	9,09	5,36	3,99
	T4	4,53	4,45	3,95

Table 5.8: Results from the test A1.

In summary, the horizontal sliders displaying a moving value deliver the best overall performance. However, tick marks may be added to the slider to align with the subjective preference from participants. Participants might be choosing the option with tick marks because they can visually see their target and click on it, something which they cannot achieve with the sliders without tick marks.

Position of the horizontal slider on the screen

Test A2 was designed to test different positions of the sliders on the screen. All sliders were designed with the size recommended (slider thumb size = 20dp) by the Android Material Design 2 (Google, 2014) and for this type of test, all sliders had tick marks and a static value label. Table 5.9 shows an overview of test A1 and Figure 5.3 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
A2.1	Slider centered in the middle of the screen	Test sliders with tick marks without a value label	Select the numbers 2, 3, 6, and 8
A2.2	Slider centered at the bottom of the screen	Test sliders centered at the bottom of the screen	Select the numbers 1, 3, 7 and 8

Table 5.9: Overview of test A2.

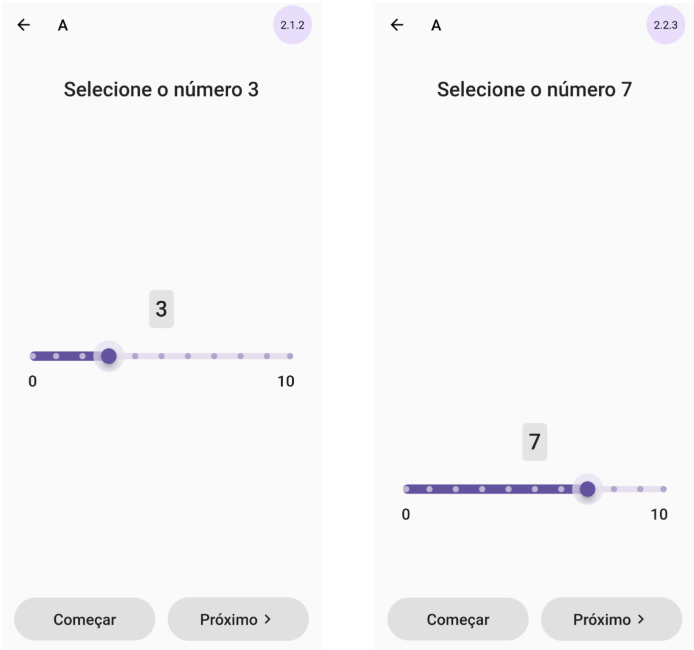


Figure 5.3: (L to R) Screenshot of a A2.1 test, A2.2 test and A2.3 test.

Results

The different positions of the horizontal sliders on the screen (middle, bottom) obtained similar results in what concerns the task completion times and the number of gestures needed for completing the task, with no significant difference observed (p>.05). Pair comparisons (e.g., value 2 in A2.1. and A2.2, see Table 5.22), we found no significant differences (p>.05). As for the participant's ease of usage, overall, 12/20 of the participants did not have a preference for any of the positions, and 7/20 preferred the slider positioned in the middle of the screen.

Design component		Slider centered in the middle of the screen (A2.1)	Slider centered at the bottom of the screen (A2.2)
Avg. number of interactions		1,03	1
Avg. task completion time		3,27	3,33
Avg. task completion time per the same task	T1	3,15	2,61
	T2	3,06	2,89
	T3	3,65	3,624
	T4	3,24	3,33

Table 5.10: Results from test A2.

Accordingly, the different positions of horizontal sliders on the screen showed no difference in performance or in participants' preferences.

Size of the slider thumb of the horizontal slider

Test A3 was designed to test different sizes of the slider thumb. All sliders were positioned in the middle of the screen, had tick marks and a static value label being displayed. Table 5.11 shows an overview of test A1 and Figure 5.4 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
A3.1	Slider with recommended thumb size	Test sliders with a thumb-size recommended (20dp) by the Android Material Design 2	Select the numbers 2, 3, 6, and 8
A3.2	Slider with 1.25x larger thumb size than recommended	Test sliders with a thumb 1.25x larger (25dp) than the one recommended by the Android Material Design 2	Select the numbers 2, 3, 6 and 9
A3.3	Slider with 1.5x larger thumb size than recommended	Test sliders with a thumb 1.5x larger (30dp) than the one recommended by the Android Material Design 2	Select the numbers 1, 3, 7 and 9

Table 5.11: Overview of test A3.

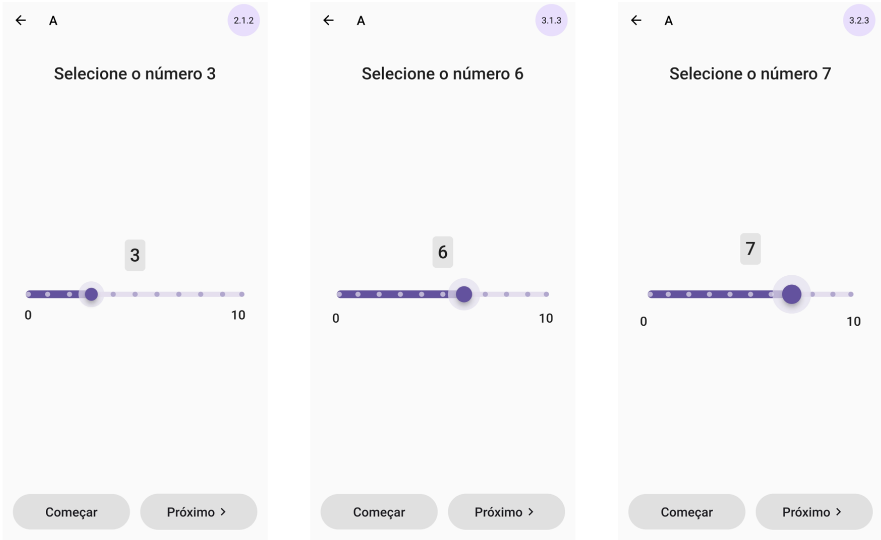


Figure 5.4: (L to R) Screenshot of a A3.1 test, A3.2 test and A3.3 test.

Results

Participants took almost the same time completing the test with all of the slider thumb size options. The differences observed in the averages are of 0,1s or smaller. Pair comparisons (e.g. value 2 between A3.1 and A3.2 - see Table 5.12) also did not reveal significant differences (p>.05). The number of interactions are also extremely similar. As for the participant's ease of usage, overall, 13/20 of the participants did not demonstrate a preference for any slider thumb sizes.

Design component		Slider with recommended thumb-size (A3.1)	Slider with 1.25x larger thumb-size than recommended (A3.2)	Slider with 1.5x larger thumb-size than recommended (A3.3)
Avg. number of interactions		1,03	1.05	1.05
Avg. task completion time		3,27	3,29	3,16
Avg. task completion time per the same task	T1	3,15	2,92	2,81
	T2	3,06	2,96	3,34
	T3	3,65	3,42	3,39
	T4	3,24	3,85	3,12

Table 5.12: Results from test A3.

As a consequence of these results, any of the thumb sizes would be appropriate for the users. Probably the smaller value would be better in case of space restrictions.

Main findings of horizontal sliders

Sliders with a moving value label appear to be the best type of sliders for horizontal sliders. However, tick marks may be added to the slider to align with the subjective preference from participants. Slider position can be at the centre or bottom of the screen, according to what works better. The different slider thumb sizes in horizontal sliders showed no conclusions as to which would be a better option, thus making the recommended slider thumb size adequate.

5.5.2 Vertical sliders

The following sections provide further detail regarding each of the three tests conducted for vertical sliders and the outcome of each one of them.

Type of vertical sliders

Test B1 was designed to test different types of sliders. All sliders were designed with the size recommended (slider thumb size = 20dp) by the Android Material Design 2 (Google, 2014) and for this type of test, all sliders were positioned in the middle of the screen. Table 5.13 shows an overview of test A1 and Figure 5.5 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
B1.1	Sliders with tick marks and without a value label	Test sliders centered in the middle of the screen	Select the numbers 1, 4, 6, and 9
B1.2	Sliders without tick marks and with a static value label	Test sliders without tick marks and a static value label	Select the numbers 1, 3, 6 and 8
B1.3	Sliders without tick marks and with a value label following the thumb	Test sliders without tick marks and a value label following the thumb	Select the numbers 2, 3, 8 and 9

Table 5.13: Overview of test B1.

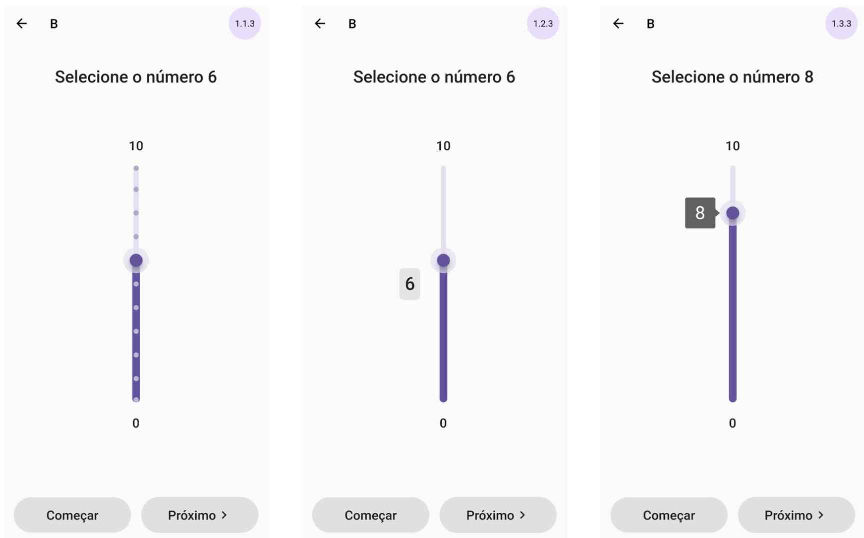


Figure 5.5: (L to R) Screenshot of a B1.1 test, B1.2 test and B1.3 test.

Results

The different slider types (tick marks, static value, moving value) obtained similar results in what concerns the task completion times and the number of gestures needed for completing the task. Nevertheless, there were some differences that would favour the sliders showing values. Looking at the average completion times in all tasks (see Table 5.14), we see that the slider with the moving value obtained the smallest completion time (3,55s), which is 52% faster than the worst performing option (the slider with tick marks - 5,4s). However, differences are not significant between the different types of slider (p>.05). Regarding pair comparisons (e.g. value 3 between B1.1 and B2.2 - see Table 5.14) and the number of gesture interaction, no significant differences were revealed (p>.05). As for the participant's ease of usage, overall, 9/20 of participants demonstrated a preference for vertical sliders a moving value label.

Design component		Sliders with tick marks and without a value label (B1.1)	Sliders without tick marks and with a static value label (B1.2)	Sliders without tick marks and with a value label following the thumb (B1.3)
Avg. number of interactions		1,2	1,28	1,14
Avg. task completion time		5,4	3,92	3,55
Avg. task completion time per the same task	T1	3,74	3,42	3,54
	T2	6,53	4,25	3,4
	T3	7,82	4,15	3,98
	T4	3,53	3,86	3,28

Table 5.14: Results from test B1.

Results show that the vertical sliders with a moving value would be the most adequate choice based on the performance of the test and participants' preferences.

Size of the slider thumb of the vertical slider

Test B2 was designed to test different sizes of the slider thumb of the sliders. All sliders were positioned in the middle of the screen and had tick marks and a static value label. Table 5.15 shows an overview of test A1 and Figure 5.6 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
B2.1	Slider with recommended thumb-size	Test sliders with a thumb-size recommended (20dp) by the Android Material Design 2	Select the numbers 1, 2, 7, and 9
B2.2	Slider with 1.25x larger thumb-size than recommended	Test sliders with a thumb 1.25x larger (25dp) than the one recommended by the Android Material Design 2	Select the numbers 1, 3, 6 and 8
B2.3	Slider with 1.5x larger thumb-size than recommended	Test sliders with a thumb 1.5x larger (30dp) than the one recommended by the Android Material Design 2	Select the numbers 2, 3, 8 and 9

Table 5.15: Overview of test B2.

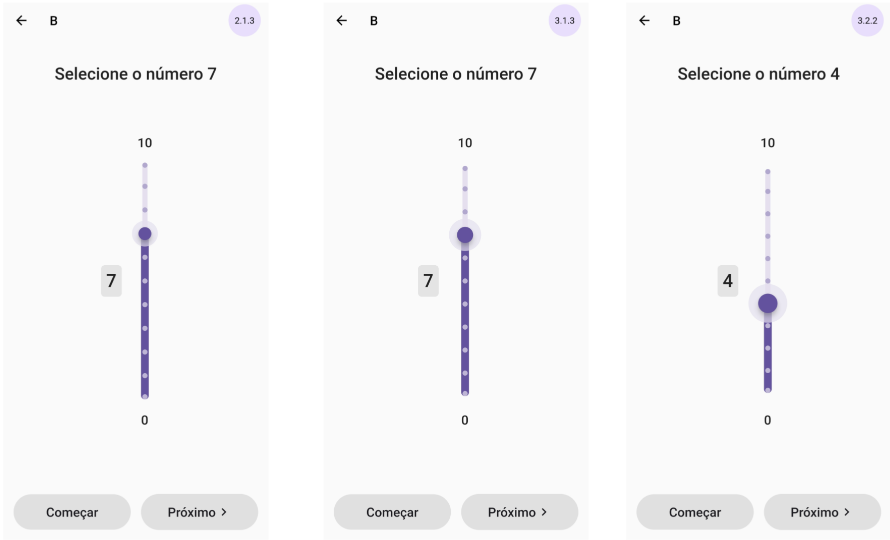


Figure 5.6: (L to R) Screenshot of B2.1 test, B2.2 test and B2.3 test.

Results

Participants took almost the same time completing the test with all of the slider thumb size options. The differences observed in the averages are of 0,1s or smaller. Pair comparisons (e.g. value 1 between A3.1 and A3.2 - see Table 5.16) also did not reveal significant differences (p>.05). The number of interactions are also extremely similar. As for the participant's ease of usage, overall, 14/20 of the participants did not demonstrate a preference for any slider thumb sizes.

Design component		Slider with recommended thumb-size (B2.1)	Slider with 1.25x larger thumb-size than recommended (B2.2)	Slider with 1.5x larger thumb-size than recommended (B2.3)
Avg. number of interactions		1	1.05	1.05
Avg. task completion time		3,11	3,16	3,05
Avg. task completion time per the same task	T1	2,58	2,27	2,28
	T2	2,66	2,05	3,14
	T3	4,1	3,51	3,32
	T4	3,1	3,37	2,96

Table 5.16: Results from test B2.

As a consequence of these results, any of the thumb sizes would be appropriate for the users. Probably the smaller value would be better in case of space restrictions.

Main findings of vertical sliders

As shown in the results of the tests, sliders with a moving value appears to be the best type of sliders for vertical sliders and the preference of the participants. However, the different positions of vertical sliders on the screen showed no conclusions as to which would be a better option.

5.5.3 Column Selectors

The following sections provide further detail regarding each of the three tests conducted for column selectors and the outcome of each one of them.

Column selectors size according to guidelines

Test C1 was designed to test different spacing of sliders. All sliders were designed with the size recommended (selector size = 56dp) by the Android Material Design 3 (Google, 2018) and for this type of test, all selectors were positioned on the screen. Table 5.17 shows an overview of test A1 and Figure 5.7 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
C1.1	Selectors with an in-between button according to guidelines	Test selectors with size (56dp) and in-between button spacing (12dp) according to Android Material Design 3	Select the numbers 5, 1, and 3
C1.2	Selectors with in-between button 1.25x larger (18dp) than according to guidelines	Test selectors with size recommended (56dp) and in-between button spacing 1.5x larger (18dp) than Android Material Design 3	Select the numbers 2, 5 and 1
C1.3	Selectors with in-between button 1.5x larger (24dp) than according to guidelines	Test selectors with a size recommended (56dp) and in-between button spacing 2x larger (24dp) than Android Material Design 3	Select the numbers 1, 3 and 5

Table 5.17: Overview of test C1.

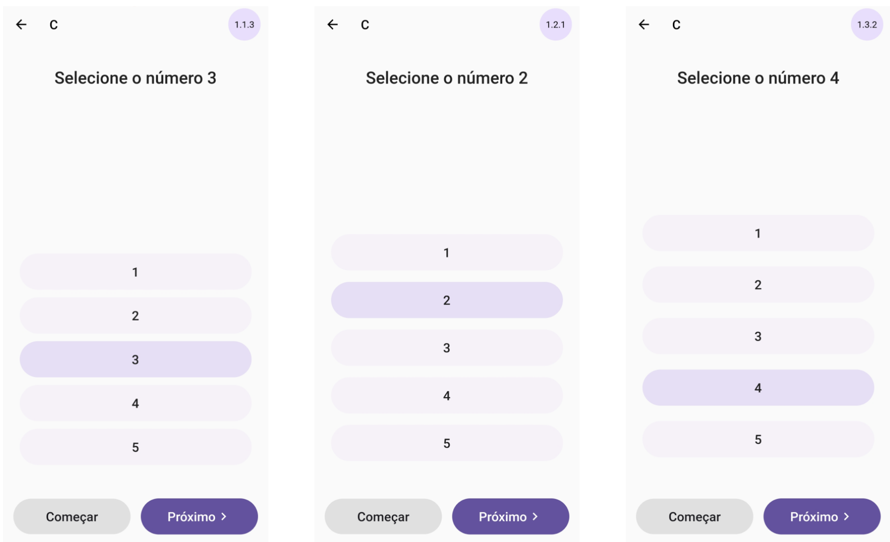


Figure 5.7: (L to R) Screenshot of C1.1 test, C1.2 test and C1.3 test.

Column selectors size 1.25x the recommended guidelines

Test C2 was designed to test different spacing of sliders. All sliders were designed with a size 1.25x larger (selector size = 70dp) than the recommended by the

Android Material Design 3 (Google, 2018) and for this type of test, all selectors were positioned on the screen. Table 5.18 shows an overview of test A1 and Figure 5.8 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
C2.1	Selectors with in-between button spacing (12dp) according to guidelines	Test selectors with a size 1.25x larger (70dp) than recommended and in-between button spacing (12dp) according to Android Material Design 3	Select the numbers 1, 4 and 2
C2.2	Selectors with in-between button spacing 1.25x larger (18dp) than according to guidelines	Test selectors with size 1.25x larger (70dp) than recommended and in-between button spacing 1.5x larger (18dp) than Android Material Design 3	Select the numbers 3, 1 and 4
C2.3	Selectors with in-between button spacing 1.5x larger (24dp) than according to guidelines	Test selectors with size 1.25x larger (70dp) than recommended and in-between button spacing 2x larger (24dp) than Android Material Design 3	Select the numbers 4, 2 and 1

Table 5.18: Overview of test C2.

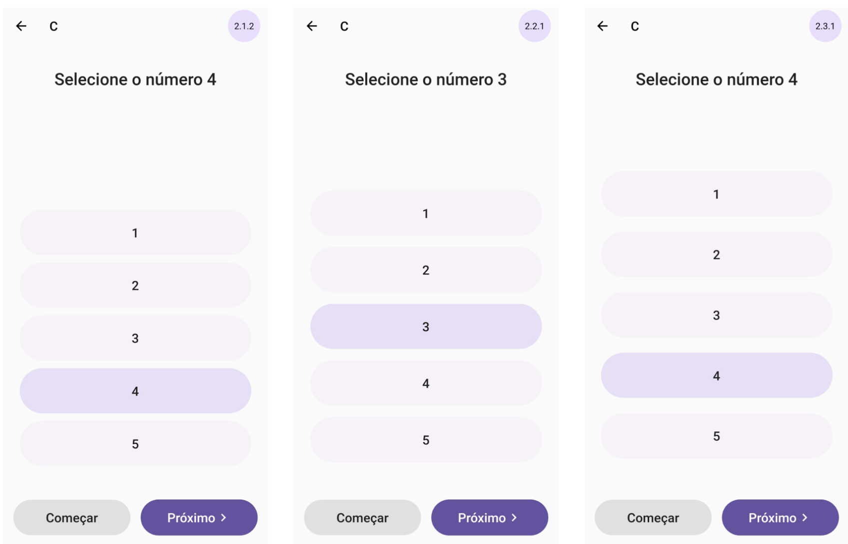


Figure 5.8: (L to R) Screenshot of C2.1 test, C2.2 test and C2.3 test.

Column selectors size 1.5x the recommended guidelines

Test C3 was designed to test different spacing of sliders. All sliders were designed with a size 1.5x larger (selector size = 84dp) than the recommended by the Android Material Design 3 (Google, 2018) and for this type of test, all selectors were positioned on the screen. Table 5.19 shows an overview of test A1 and Figure 5.9 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
C3.1	Selectors with an in-between button (12dp) according to guidelines	Test selectors with a size 1.5x larger (84dp) than recommended and in-between button spacing (12dp) according to Android Material Design 3	Select the numbers 4, 1 and 3
C3.2	Selectors with in-between button 1.25x larger (18dp) than according to guidelines	Test selectors with size 1.5x larger (84dp) than recommended and in-between button spacing 1.5x larger (18dp) than Android Material Design 3	Select the numbers 1, 4 and 2
C3.3	Selectors with in-between button 1.5x larger (24dp) than according to guidelines	Test selectors with size 1.5x larger (84dp) than recommended and in-between button spacing 2x larger (24dp) than Android Material Design 3	Select the numbers 3, 4 and 1

Table 5.19: Overview of test C3.

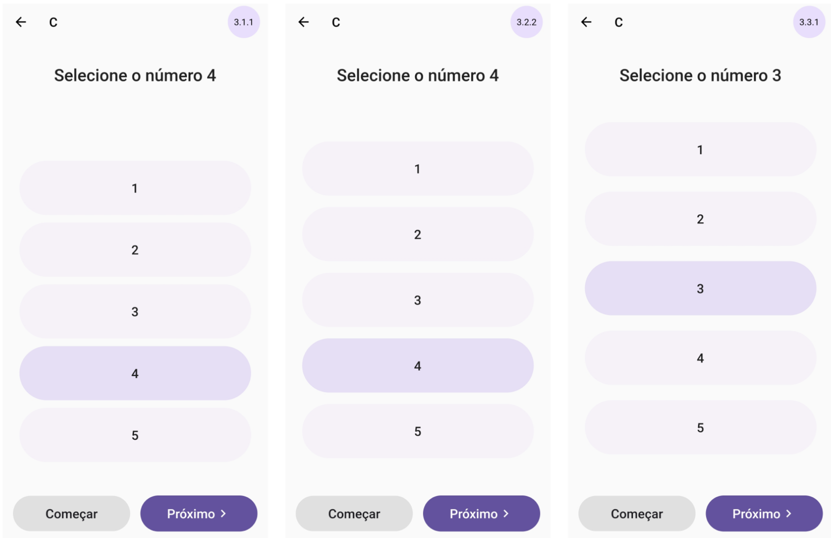


Figure 5.9: (L to R) Screenshot of C3.1 test, C3.2 test and C3.3 test.

Results

Looking at the average completion times in all tasks (see Table 5.20), we see that:

- For column selectors with a recommended size (56dp), an in-between button spacing 1.5x larger than recommended (18dp) obtain the smaller task completion time (1,91s), however, the differences observed in the averages of 0.1s or smaller.
- Regarding column selectors with a size 1.25x larger than recommended (70dp), an in-between button spacing 2x larger than recommended (24dp) obtain the smaller task completion time (1,79s), however, the differences observed in the averages of 0.1s or smaller.
- As for column selectors with a size 1.5x larger than recommended (84dp), an in-between button spacing 2x larger than recommended (24dp) obtain

the smaller task completion time (1,77s), however, the differences observed in the averages of 0.1s or smaller.

- Regarding the number of gesture interactions, there are no significant differences between the options.

Therefore, the results show that with the increase of the size there should be a increase of the in-between button spacing. However, the differences observed are small. As a consequence of these results, probably the smaller value would be better in case of space restrictions.

Design component		Selectors with recommended size	Selectors with a size 1.25x larger than the recommended	Selectors with a size 1.5x larger than the recommended
Avg. task completion time per the same task	Recomended in-between button spacing	2,09	1,91	1,88
	In-between button spacing 1.5x larger than recommended	1,91	1,81	1,98
	In-between button spacing 2x larger than recommended	1,96	1,79	1,77
Avg. number of interactions	Recomended in-between button spacing	1	1	1
	In-between button spacing 1.5x larger than recommended	1	1	1
	In-between button spacing 2x larger than recommended	1	1	1

Table 5.20: Results from three different sizes of column selectors.

5.5.4 In-line Selectors

The following sections provide further detail regarding each of the three tests conducted for in-line selectors and the outcome of each one of them.

Position of the in-line selector in the screen

Test D1 was designed to test different positions of the sliders on the screen. All selectors were designed with the size (selector size = 56dp) recommended by the Android Material Design 3 (Google, 2018) and for this type of test, all selectors were positioned on the screen. Table 5.21 shows an overview of test A1 and Figure 5.10 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
D1.1	Selector positioned in the middle of the screen	Test selectors positioned in the middle of the screen	Select the numbers 1, 3, and 2
D1.2	Selector positioned at the bottom of the screen	Test selectors positioned at the bottom of the screen	Select the numbers 2, 3 and 1

Table 5.21: Overview of test D1.

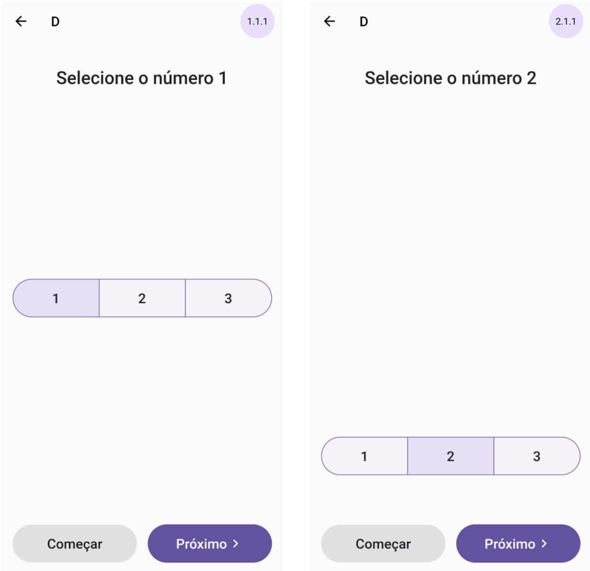


Figure 5.10: (L to R) Screenshot of D1.1 test and D1.2 test.

Results

The different positions of the in-line selectors on the screen (middle, bottom) obtained similar results in what concerns the task completion times and the number of gestures needed for completing the task, with no significant difference observed (p>.05). Pair comparisons (e.g., value 2 in D1.1. and D1.2, see Table 5.22), we found no significant differences (p>.05). As for the participant's ease of usage, overall, 10/20 preferred the slider positioned in the middle of the screen and 6/20 of the participants did not have a preference for any of the positions.

Design component		Selector positioned in the middle of the screen (D1.1)	Selector positioned at the bottom of the screen (D1.2)
Avg. number of interactions		1	1
Avg. task completion time		1,74	1,61
Avg. task completion time per the same task	T1	1,83	1,88
	T2	1,72	1,58
	T3	1,67	1,37

Table 5.22: Results from test D1.

Accordingly, the different positions of in-line selectors on the screen showed no difference in performance or in participants' preferences.

Size of the in-line selectors

Test D2 was designed to test different sizes of selectors. All selectors were positioned on the screen. Table 5.23 shows an overview of test A1 and Figure 5.11 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
D2.1	Selectors with size (56dp) according to guidelines	Test selectors with a size (56dp) recommended by the Android Material Design 3	Select the numbers 1, 3, and 2
D2.2	Selectors with size 1.25x larger (70dp) than according to guidelines	Test selectors with a size 1.25x larger (70dp) than the one recommended by the Android Material Design 3	Select the numbers 3, 1, and 2
D2.3	Selectors with size 1.5x larger (84dp) than according to guidelines	Test selectors with a size 1.5x larger (84dp) than the one recommended by the Android Material Design 3	Select the numbers 2, 1 and 3

Table 5.23: Overview of test D2.

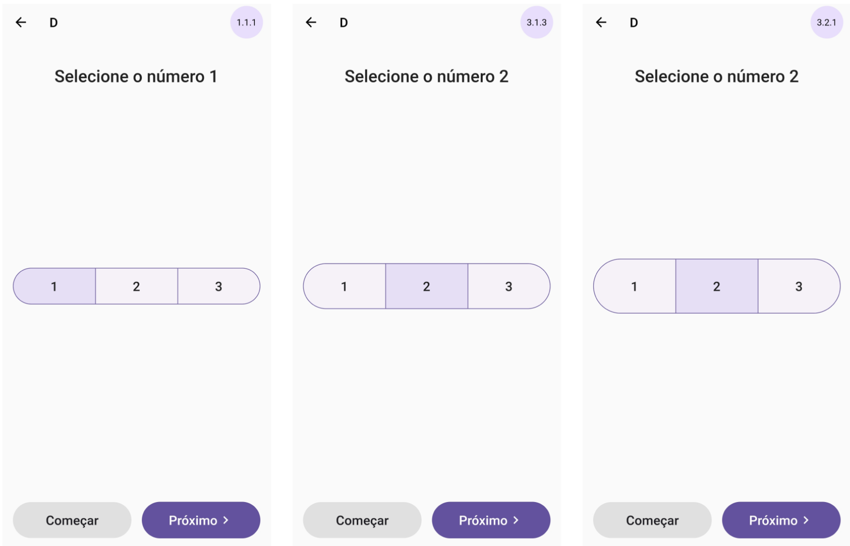


Figure 5.11: (L to R) Screenshot of D2.1 test, D2.2 test and D2.3 test.

Results

Participants were faster at completing tasks in in-line selectors with a size 1.5x larger than recommended that with other in-line selectors sizes. Looking at the average completion times in all tasks (see Table 5.24), we see that the in-line selectors with a size 1.5x larger than recommended obtained the smallest completion time (1,54s), which is 18% faster than the worst performing option (in-line selector with a size 1.25x larger than recommended - 1,81s). However, differences are not significant between the different options (p>.05). Pair comparisons (e.g. value 2 between D2.1 and D2.2 - see Table 5.24) also did not reveal significant differences (p>.05). The number of interactions are also extremely similar. As for the participant's ease of usage, overall, 18/20 of the participants did not demonstrate a preference for any in-line selector size.

Thus, the in-line selectors with a size 1.5x larger than according to guidelines would be the most adequate choice based on the performance of the test. However, participants showed no preference for any of the in-line selector sizes.

Design component		Selectors with recommended size (D2.1)	Selectors with a size 1.25x larger than the recommended (D2.2)	Selectors with a size 1.5x larger than the recommended (D2.3)
Avg. number of interactions		1	1	1
Avg. task completion time		1,74	1,81	1,54
Avg. task completion time per the same task	T1	1,83	2,25	1,55
	T2	1,72	1,74	1,46
	T3	1,67	1,43	1,61

Table 5.24: Results from test D2.

Main findings for in-line selectors

As a consequence of these results, any of the in-line selector sizes would be appropriate for the users. Probably the smaller value would be better in case of space restrictions. Accordingly, the different positions of in-line selectors on the screen showed no difference in performance or in participants' preferences.

5.5.5 Comparison between UI components

Regarding the participant's preference between horizontal sliders, vertical sliders, column selectors and in-line selectors, participants clearly point to an overall feeling that column selectors were easier to use, which was chosen by 17/20 of participants. Regarding participants' opinions about which UI component they felt triggering more pain while used, 18/20 of the participants stated they felt no differences between UI components.

5.5.6 Body graphic

The following section provides further detail regarding each of the three tests conducted for the body graphic and the outcome of each one of them. Table 5.25 shows an overview of test E1 and Figure 5.12 presents the differences in the UI components.

Test ID	UI Component	Objective	Tasks
E1.1	Selector with size (24dp) according to guidelines	Test selectors with the size (24dp) recommended by the Android Material Design 3	Select the right elbow, the left foot, the left hip and the right knee
E1.2	Selectors with a size 1.5x larger (36dp) than recommended by guidelines	Test selectors with a size 1.5x larger (36dp) than recommended by Android Material Design 3	Select the right elbow, the left shoulder, the left hip and the right hand
E1.3	Selectors with a size 2x larger (48dp) than recommended by guidelines	test selectors with a size 2x larger (48dp) than recommended by Android Material Design 3	Select the right knee, the left foot, the right hand and the left shoulder

Table 5.25: Overview of test E1.

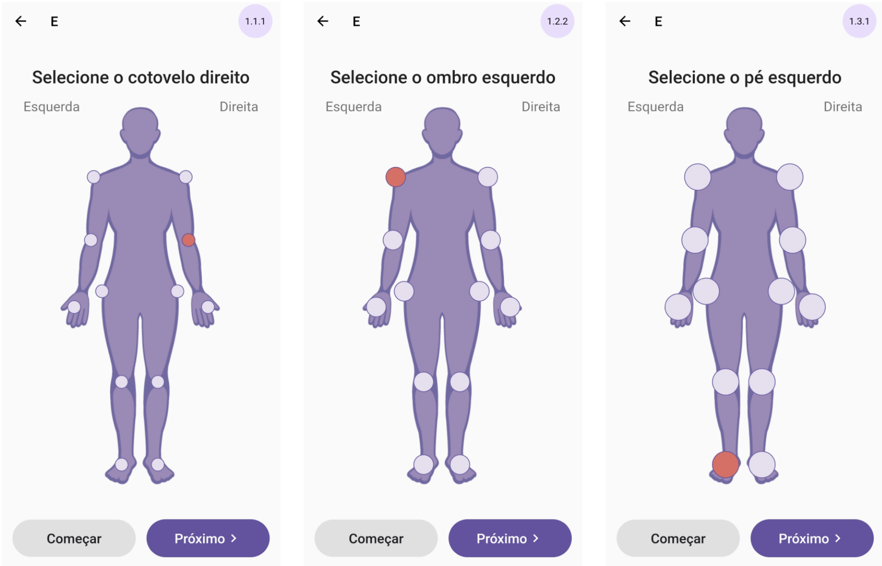


Figure 5.12: (L to R) Screenshot of E1.1 test, E1.2 test and E1.3 test.

Results

Participants were faster at completing tasks in body graphic with selectors with a size 2x larger than recommended that with other selector sizes. Looking at the average completion times in all tasks (see Table 5.26), we see that the body graphic with selectors with a size 2x larger than recommended obtained the smallest completion time (2,35s), which is 51% faster than the worst performing option (body graphic with selectors with the recommended size - 4,84), significant between the different options. Pair comparisons (e.g. value 3 between E1.1 and E1.2 - see Table 5.26) also did not reveal significant differences (p>.05). The number of interactions are also extremely similar. As for the participant's ease of usage, overall, 13/20 demonstrated a preference for a body graphic with selectors with a size 2x larger than recommended.

Design component		Selectors with recommended size (E1.1)	Selectors with a size 1.5x larger then the recommended (E1.2)	Selectors with a size 2x larger then the recommended (E1.3)
Avg. number of interactions		1	1.04	1
Avg. task completion time		4,84	3,45	2,35
Avg. task completion time per the same task	T1	5,75	3,99	2,22
	T2	3,83	2,71	2,19
	T3	5,44	3,13	2,57
	T4	4,34	3,99	2,43

Table 5.26: Results from test E1.

Main findings of selector in the body graphic

As shown by the results of the tests, the body graphic with selectors with a size 2x larger than recommended would be the most indicated choice based on the performance of the test and participants' preferences.

5.6 Main findings and reflections

The aim of the usability experiments outlined in this chapter was to test the UI component patterns found in the previous chapter to the test. The purpose was to evaluate the usability and interaction performance of participants with rheumatic conditions in terms of task completion time, the number of gesture interactions and participants' preferences.

The UI components tested were: horizontal sliders, vertical sliders, column selectors, in-line selectors and a body graphic. Accordingly, the results from this study can be summarised as follows.

For **horizontal sliders**:

- Sliders without tick marks and with a moving value label appear to be the best type of sliders for horizontal sliders. However, tick marks may be added to the slider to align with the subjective preference from participants.
- The different positions of horizontal sliders on the screen showed no conclusions as to which would be a better option, therefore it should be used the one that works better.
- The different slider thumb sizes in horizontal sliders showed no conclusions as to which would be a better option, thus making the recommended slider thumb size adequate.

For **vertical sliders**:

- Sliders without tick marks and with a value label following the slider thumb appear to be the best type of sliders for vertical sliders and the preference of the participants.
- The different positions of vertical sliders on the screen showed no conclusions as to which would be a better option.

For **column selectors**:

- A size 1.5x larger than recommended appears to be the best size for column selectors with in-between button spacing according to guidelines.
- A size 1.25x larger than recommended appears to be the best size for column selectors with in-between button spacing 2x larger than according to guidelines.
- A size 1.5x larger than recommended appears to be the best size for column selectors with in-between button spacing 2x larger than according to guidelines.

For **in-line selectors**:

- The different positions of in-line selectors on the screen showed no conclusions as to which would be a better option, however, the participants' preference was for in-line selectors positioned in the middle of the screen.
- In-line selectors with a size 1.5x larger than according to guidelines appear to be the best size for in-line selectors.

For **body graphics**:

- Selectors with a size 2x larger than recommended appear to be the best size for body graphics with selectors and considering the preference of the participants.

Regarding **participants' UI component preferences**:

- Column selectors were pointed by the participants to be the easiest to use.
- None of the UI components were considered more painful when used by the participants.

Chapter 6

Self-report user interface design patterns for people with rheumatic conditions

This chapter presents the user interface design patterns created based on the main findings of our research phase. The section starts by presenting the goals in creating this set of patterns and the structure of the patterns. Finally the patterns themselves are presented.

6.1 Patterns goals and contribution

Our research aimed to further the design and validation of self-report user interfaces for people with rheumatic conditions. In this context, our intention is that the patterns, presented in this section, provide guidance regarding (i) the most adequate slider elements characteristics of horizontal and vertical sliders, (ii) the most adequate size and in-between button spacing for selector, as well as (iii) selector size for a body graphic.

In this context, the primary goal of the patterns is to describe our findings in an easily understandable and accessible format, so that all practitioners working on smartphone interfaces for people with rheumatic conditions could benefit from the findings of our research in the form of design guidelines. Thus, we hope to contribute to improving the usability of smartphone user interfaces designed for people with rheumatic conditions in the future.

6.2 Patterns structure

Our patterns are based on Christopher Alexander's "A Pattern Language: Towns, Buildings, and Construction" (1977), which was later adopted by Jan Borchers in "A Pattern Approach to Interaction Design" (2001).

Each pattern starts with its name written in small caps. Then, each pattern is given a unique ranking that reflects the authors' level of confidence in it. This ranking can vary from zero to two asterisks, with zero indicating the lowest level of confidence and two asterisks indicating the highest level of confidence possible.

After the context is set, the problem statement is presented in bold, and it is followed by a longer problem description. Contradictory forces are discussed and the problem's empirical background is presented in the problem description.

Finally, the solution appears in bold and includes references to other patterns that are relevant. This is followed by an image of a real-world application of the patterns.

6.3 RECOMMENDED SLIDER CHARACTERISTICS FOR SLIDERS *

...you've reached the point in the project where you must make decisions about the appropriate slider characteristics for sliders. The sliders' properties are significant since they will affect whether users may observe and pick a value (or range) from the slider, as well as perform relevant actions and activities along with the flow of your UI.

+++

Selecting a slider with the most appropriate characteristics for a specific group of users required a thorough study of their unique characteristics, expectations and preferences. For certain populations such as those with rheumatic conditions, official UI guidelines such as Google Material Design and Apple iOS Human Interface Guidelines do not provide recommendations in picking a specific element group of characteristics for sliders. Value labels and tick marks are optional, according to the official guidelines (Google, 2014).

To create a more comfortable and enjoyable user experience, sliders should be designed to match the special demands of people with rheumatic conditions. Since, patients with rheumatic diseases have hand discomfort and disability, which limits how mobile devices can be utilised, for example, by making data input difficult or requiring coarse precision (Mollard and Michaud, 2019).

Previous research has explored the effects of sliders affects the offset errors when users input data (Colley et al., 2019) and (Zaina et al., 2022) found that sliders with continuous control can have a harmful effect as, often, it becomes difficult to select a specific value in a large interval.

Accordingly, our own work revealed that participants were quicker with sliders with a moving value label. For this type of slider characteristic, participants' mean task completion time was 41% faster than with sliders with tick marks and 10% faster than with sliders a static value label.

Additionally, our research also studied the performance of sliders with tick marks. The results showed that the value label is necessary, nonetheless, the use of tick marks assists the user, therefore, this characteristic can also be included when designing sliders for people with rheumatic conditions. Regarding the position of the slider on the screen, our research found that position was not a determinant factor of performance, thus, making the position of the slider an option for the designer/developer. Furthermore, the recommended slider thumb size of the slider (20dp) was revealed to be sufficient for users with rheumatic conditions.

Therefore...

For sliders that require a high level of efficiency, sliders should be designed with a moving value label. The incorporation of tick marks and the position of the slider on the screen are optional and a slider thumb size as recommended by official guidelines is adequate.

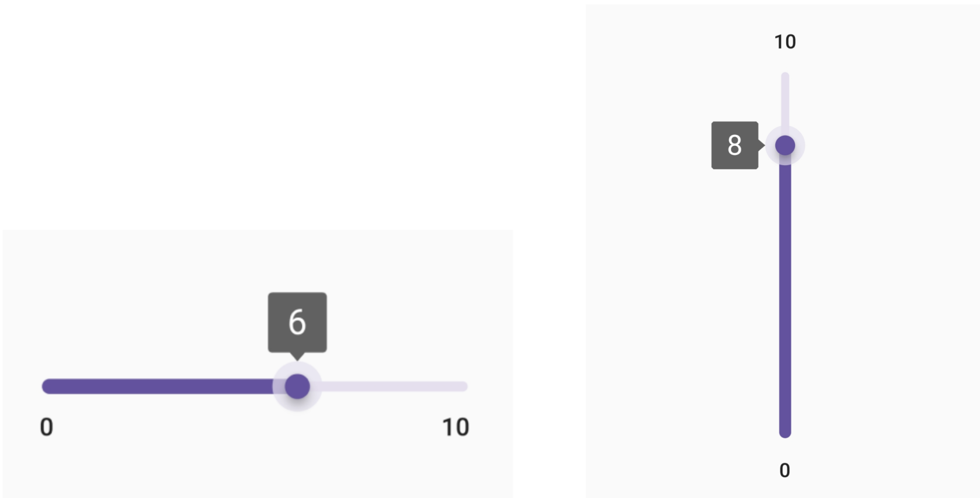


Figure 6.1: Illustration of RECOMMENDED SLIDER CHARACTERISTICS FOR VERTICAL SLIDERS *.

6.4 RECOMMENDED SELECTORS *

...you are now in a phase of the project where decisions need to be made regarding adequate size for selectors. Choosing selectors' size is an important decision as it will determine the levels of comfort, and efficiency with which your users are able to complete necessary actions and tasks throughout the flow of your UI.

+++

Choosing a selector's size for a given group of users requires a thorough understanding of their particular characteristics, expectations, and preferences. Official UI guidelines such as Google Material Design and Apple iOS Human Interface Guidelines do not provide guidance in choosing a selector's size for specific groups such as people with rheumatic conditions. Although W3C provides a succession criteria on target sizes being large enough for users to easily activate them, this criteria does not recommend a specific target size for people with rheumatic conditions.

Previous research has explored the use of large icons and buttons to improve accessibility for users with dexterity impairments (Parmanto and Brad, 2019) and (Yu et al., 2017) found that users with a higher degree of dexterity impairment demonstrated more problems in task completion and prefer the use of larger buttons. Consequently, most guidelines that are currently available do not aid designers in creating smartphone UIs that adequately respond to people with rheumatic conditions specific characteristics.

It is known that the severity of hand impairment, dexterity, movement control, hand coordination, and limited hand mobility increases as rheumatic diseases worsen citepMollard2021. These conditions can have a significant impact on movement, resulting in symptoms like pain, stiffness, rigidity and sluggish movement (Mollard and Michaud, 2019). Selectors are therefore more difficult to select when their size is reduced.

Inevitably, accurately acquiring small targets becomes increasingly difficult as the conditions progress. Providing targets that are too small makes a UI more difficult to use and could result in frustration and anxiety among people with rheumatic conditions (Czaja and Sharit, 1998) and should therefore be avoided.

Furthermore, our own research revealed that people with rheumatic conditions took less time to select an option in 56dp size column selectors when these had an in-between button spacing of 24dp, where the registered mean completion times of this in-between target was 1.88 seconds.

Accordingly, our own research revealed that for larger in-between buttons spacing there is a significance for larger dimensions of selectors (1.25x larger than recommended - 70dp). However, since this significance is very low, which indicates this dimension is not crucial for bettering user performance. Additionally, the size recommended by the official guidelines does not behave very differently from a larger size, therefore, the size recommended by the official guidelines for selectors can be used. Thus, ideally, a selector's size should be larger than the recommended by official guidelines, nonetheless, the recommenced size also works for people with rheumatic conditions. Additionally, in-line selectors were also studied, so we can say that regardless of whether the selectors are in a row or in a column, the recommendations are the same.

Additionally, our own research revealed that people with rheumatic conditions took less time to select an option in column selectors with the official guidelines recommended size (56dp) when these had an in-between button spacing of 24dp (2x larger than the recommended by official guidelines), where the registered mean task completion time of this in-between target was 1.88 seconds. Additionally, our research showed that, even without significance, ideally, as selectors' sizes increase, so should the in-between button spacing.

the results show that with the increase of the size there should be a increase of the in-between button spacing. However, the differences observed are small. Additionally, even without significance, ideally, as selectors' sizes increase, so should the in-between button spacing, however, probably the smaller in-between button spacing works in case of space restrictions.

Therefore...

For people with rheumatic conditions, selectors' size should be 1.5x larger than recommended (70dp) with an in-between button spacing 2x larger than recommended (24dp). Otherwise, the size and in-between button spacing recommended by the official guidelines - size (56dp) and in-between button spacing (12dp) - also should work.

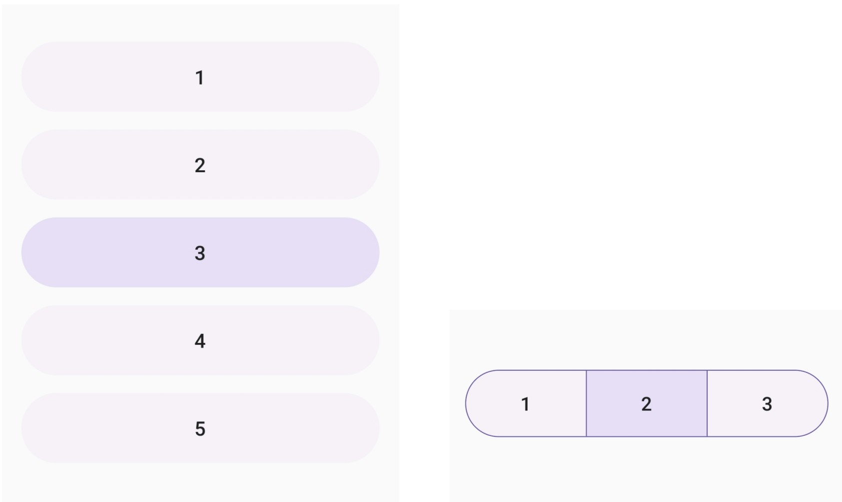


Figure 6.2: Illustration of RECOMMENDED SELECTORS *.

6.5 RECOMMENDED SELECTOR SIZE FOR A BODY GRAPHIC **

...you are now in a phase of the project where decisions need to be made regarding adequate selector size for a body graphic. Choosing a selector's size for a body graphic is an important decision as it will determine the levels of self-report quality, accuracy and comfort with which your users are able to get things done on your interface.

+++

As a result of the increase in rheumatic diseases in today's society, sensory and psychomotor abilities deteriorate and these changes may make selector sizes for a body graphic obsolete. Furthermore, present smartphone user interface guidelines do not address specialized groups, such as persons with rheumatic diseases.

People with rheumatic conditions have dexterity problems caused by swollen joints, hand pain, or deformation of the fingers. Many self-monitoring applications for rheumatic conditions focus on what are known as PROs (patient-reported outcomes) (Mollard and Michaud, 2021). The tracking of symptoms, such as the assessment of the joints, is one of the main features of these apps (Yuqing and Hong, 2021). Usually, apps that use body graphics with selectors to assess joints present an overview of the human body with the possibility of selecting different joints.

Official UI guidelines such as Google Material Design and Apple iOS Human Interface Guidelines do not provide guidance in choosing a size for the selectors in the body graphics for specific groups such as people with rheumatic conditions. Official smartphone Android Material Design guidelines recommend minimum toggle buttons to be 24dp, raising issues such as selector occlusion while performing a gesture and/or accidentally touching a neighbouring selector.

Additionally, people with rheumatic conditions have limited movement control, hand coordination, and hand movement (Grainger and Al, 2020), which affects their precision and the way they interact with smartphones.

Accordingly, our own research revealed that people with rheumatic conditions took less time to select the right part of the body graphic when these had a selector size of 48dp, where the registered mean task completion times of this size selectors were 2.35 seconds. Participants were 70% faster in comparison with a body graphic with selectors with the recommended.

Therefore...

For people with rheumatic conditions performing tasks that require high-performance measures in a body graphic, design selectors with a size of 56dp (2x the recommended by official guidelines).

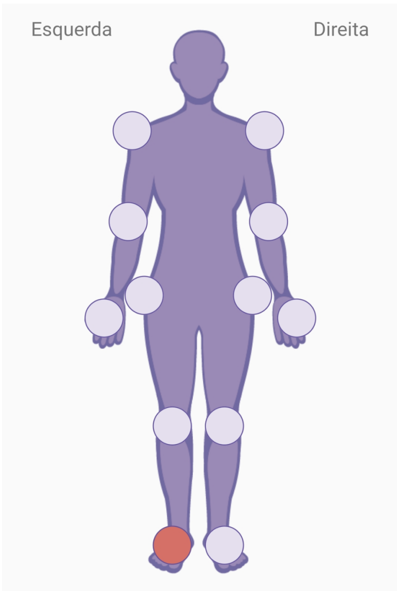


Figure 6.3: Illustration of RECOMMENDED SELECTOR SIZE FOR A BODY GRAPHIC **.

Chapter 7

Discussion

Chapter 6 described the procedures and results of our phase of testing with users, summarised and discussed our main findings. The previous chapter then introduced the patterns developed based on the finding of our usability experiments. This chapter now discusses our work and results stating our (i) contribution as well as the (ii) strengths and limitations of the work.

7.1 Contribution

Our literature review concluded that pain, joint assessment and mental health were the symptoms that affected people with rheumatic conditions the most. The app review results, described in Chapter 4, confirmed that these are also the most prevalent symptom tracking features incorporated in apps for people with rheumatic conditions. Additionally, the app review revealed that the most common features of available apps for people with rheumatic were educational information, medication management and symptom tracking.

Previous work by (Yuqing and Hong, 2021) defended that "health care providers, patients with Ankylosing Spondylitis, and app developers should collaborate to develop high-quality, evidence-based apps that take into account patients' needs and health care professionals' perspectives." (Yuqing and Hong, 2021). However, our review of the UI components included in apps for people with rheumatic conditions concluded that apps failed to comply with the success criteria of W3C (W3C, 2021b) or with the guidelines recommended by Android Material Design 2 and 3 (Google, 2014, 2018) or the iOS Human Interface Guidelines (Apple, 2020). Existing apps include small-sized buttons giving the impression that they were not designed with end-users in mind or skipped usability tests. Consequently, health care providers, patients with rheumatic conditions and app developers should collaborate to develop high-quality, evidence-based apps that consider patients' needs and health care professionals' perspectives.

The usability experiments performed in the context of this dissertation contribute to the corpus of knowledge on how to correctly design horizontal sliders, vertical sliders, column selectors, in-line selectors and the use of the human body to report symptoms by assessing these issues with people with rheumatic conditions. Based on the results obtained through usability tests with 20 participants with rheumatic conditions allowed for the creation of design advice for smartphone user interface design regarding design components in existing apps for people with rheumatic conditions. In sum, the usability experiments with users allowed for (i) a better understanding of different visual characteristics of sliders, (ii) determining the best button height and in-between button sizes and (iii) assessing the best positions of the design components in the screen and (iv) the definitions of the adequate width of buttons incorporated in the human body to report symptoms.

Our literature review revealed that rheumatic conditions are most common in middle-aged people. Previous research had confirmed that smartphone interfaces for older adults are designed with substantial targets in many cases, but that could indeed be limiting performance instead of enhancing it (Leitao and Silva, 2012). Our findings regarding column selectors size show that with the increase of the size there should be a increase of the in-between button spacing. However, the differences observed are small. As a consequence of these results, probably the smaller value would be better in case of space restrictions..

Another contribution of this dissertation is the interaction design patterns that were produced based on our literature review and empirical research findings. The purpose of these design patterns is to provide easy-to-understand guidelines to anyone working on interfaces for people with rheumatic conditions. As a result our research introduces a set of design patterns with condensed but explanatory qualities that may provide better and more easily accessible information for experienced and novice designers working with persons with rheumatic conditions.

Furthermore, one of the essential qualities of design patterns is that they serve as a standard language for all project stakeholders to communicate effectively (Dix et al., 2004). Multidisciplinary teams are prevalent in developing interfaces and other systems, with participants ranging from HCI practitioners, designers, software developers, administrative personnel and actual end-users. As a result, the design patterns produced in this research aim to establish a common language that would facilitate users with rheumatic conditions to participate in developing a smartphone interface actively. These patters further provide a platform for communication between all team members involved in creating these interfaces.

7.2 Strengths and limitations

In this section, we will present the strengths and limitations of our research. One of the strengths of this dissertation is that it assessed a broad range of app characteristics and features, such as symptom tracking, educational information and medication management. Our research is also based in experiments supported by a solid methodology and the participants' sample is large enough to allow significance. The presented design patterns were developed based on robust evidences and contribute for an area where guidelines were missing.

This study also has several limitations. One limitation is that we only focused on English and Portuguese-language apps available on the two most popular app stores (App app store and Google play store) and thus missed apps available in other languages or on other app stores. We searched for apps in two of the most popular app stores (the Google Play Store and Apple App Stores) for Portugal's Android and iOS operating systems. However, this study did not include apps exclusively in other app stores (e.g., Microsoft). Also, it only focused on publicly available apps, which could have left out other apps available to more restricted groups of people.

Another limitation of our work pertains to our participants' sample. Throughout the testing, the gender distribution of participants was unequal, with more females than males. Given that users volunteered to participate, we had no control over the gender of the participants since these were volunteers and that we thus had no control over the gender of the participants this could not be avoided. However, given the nature of our testing, we do not believe that a more evenly distributed gender distribution would impact our findings, as the variables we examined in our tests should not be affected by gender.

In terms of sample size, our work involved 20 participants. The validation of design patterns will be continued with more participants in the future to strengthen our results. However, during our research, we found that after conducting tests with a few users, we started to see the results repeating, as the number of interactions and the task conclusion time was not differing significantly. Even though our findings cannot be statistically generalise due to the limited sample size, they provide useful insight into the understanding of self-report user interfaces for people with rheumatic conditions and how these users engage with mobile interaction design components. In this context, the insight provided by our results could, in the future, be the basis for further investigation with a larger sample of people with rheumatic conditions.

Finally, our participants were all adults from Portugal with varying technological proficiency levels. Our findings could be different if we were to carry out our research in different cultural and socioeconomic contexts and with people with and without rheumatic conditions.

Chapter 8

Conclusions and future work

8.1 Conclusions

This work researched what adaptations are required in order to design self-report applications for people with rheumatic conditions, providing interfaces that people with these conditions will be able to use. The research was done in the scope of the *COTIDIANA* project, a project that intends to create a mobile solution that enables holistic and efficient patient monitoring, for clinical care and drug trials.

Our research revealed that current smartphone UI components are not immediately usable by people with rheumatic conditions. However, in many cases, the official recommendations about the UI components are compatible and adequate for people with rheumatic conditions, as is the case of the slider thumb size in horizontal and vertical sliders e the in-line selector sizes.

Our research, allowed us to create a set of three design patterns: (i) RECOMMENDED SLIDER CHARACTERISTICS FOR SLIDERS *, (ii) RECOMMENDED SELECTORS * and (iii) RECOMMENDED SELECTOR SIZE FOR A BODY GRAPHIC **.

8.2 Future work

Our research found that people with rheumatic conditions were faster when sliders were 1.5x larger than according to guidelines or when the in-line selector was centred at the bottom of the screen. However, no significant difference was observed in these cases. In this context, it would be interesting to further this research with a larger number of people with rheumatic conditions, in order to corroborate or dispute these findings.

Furthermore, we believe that the reason that justifies the nonexistence of a correlation between task completion time and the number of gesture interactions is the fact that participants may take longer to perform a task because they are interpreting the instruction and not because they need an elevated number of gesture interactions to complete the task. Since most participants only interact once with the design component this may also justify the reason given previously. However, as the usability experiments were only conducted with people with rheumatic conditions, it would be necessary to, in the future, conduct the same usability tests with people without these conditions in order to understand if, in fact, people with rheumatic conditions are slower due to their health condition.

Additionally, the conduction of the usability test with people without dexterity problems would be interesting in order to have comparative data that allowed a deeper analysis of the adequate changes in design components most suffer in order to be suitable for people with rheumatic conditions.

Finally, the pattern set presented in Section 6 intends to be the beginning of a full-fledged pattern language. This language would consider a wide range of aspects related to a self-report user interface design for people with rheumatic conditions. These considerations could include subjects such as information architecture, the display of information, navigation mechanisms, general layout considerations, as well as user input and output mechanisms. All these could be the focus of future research.

References

Christopher Alexander. *A Pattern Language: Towns, Buildings, Construction*. Oxford University Press, 1977. URL http://www.amazon.fr/exec/obidos/ASIN/0195019199/citeulike04-21.

Apple. ios human interface guidelines, 2020. URL https://developer.apple.com/design/human-interface-guidelines/guidelines/overview/.

Elisabeth Bayle, Rachel Bellamy, George Casaday, Thomas Erickson, Sally Fincher, Beki Grinter, Ben Gross, Diane Lehder, Hans Marmolin, Brian Moore, Colin Potts, Grant Skousen, and John Thomas. Putting it all together: Towards a pattern language for interaction design: A chi 97 workshop. *SIGCHI Bull.*, 30:17–23, 1 1998. ISSN 0736-6906. doi: 10.1145/280571.280580. URL https://doi.org/10.1145/280571.280580.

Thomas Bodenheimer, Kate Lorig, Halsted Holman, and Kevin Grumbach. Patient self-management of chronic disease in primary care. *INNOVATIONS IN PRIMARY CARE*, 2002. URL http://jama.jamanetwork.com/.

W. H. Boehncke, A. Qureshi, J. F. Merola, D. Thaçi, G. G. Krueger, J. Walsh, N. Kim, and A. B. Gottlieb. Diagnosing and treating psoriatic arthritis: An update. *British Journal of Dermatology*, 170:772–786, 2014. ISSN 13652133. doi: 10.1111/bjd.12748.

Jan O Borchers. A pattern approach to interaction design . *Springer-Verlag London Limited*, 15:359–376, 2001.

Virginia Braun and Victoria Clarke. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3:77–101, 2006. doi: 10.1191/1478088706qp063oa. URL https://www.tandfonline.com/doi/abs/10.1191/1478088706qp063oa.

Kai. Breiner and Gerrit Meixner. *The Evolution of Design Patterns in HCI: From Pattern Languages to Pattern-Oriented Design*. Association for Computing Machinery, 2010. ISBN 9781450302463.

Dylan Z. Childs, Bethan J. Hindle, and Philip H. Warren. Chapter 33 non-parametric tests | aps 240: Data analysis and statistics with r, 2021. URL https://dzchilds.github.io/stats-for-bio/non-parametric-tests.html.

Ashley Colley, Sven Mayer, and Niels Henze. Investigating the effect of orientation and visual style on touchscreen slider performance. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–9, 2019. doi: 10.1145/3290605.3300419. URL https://doi.org/10.1145/3290605.3300419.

Josh Colls, Yvonne C. Lee, Chang Xu, Cassandra Corrigan, Fengxin Lu, Georgia Marquez-Grap, Meredith Murray, Dong H. Suh, and Daniel H. Solomon. Patient adherence with a smartphone app for patient-reported outcomes in rheumatoid arthritis. *Rheumatology (United Kingdom)*, 60:108–112, 1 2021. ISSN 14620332. doi: 10.1093/rheumatology/keaa202.

Chad Cook, Ricardo Pietrobon, and Eric Hegedus. Osteoarthritis and the impact on quality of life health indicators. *Rheumatology International*, 27:315–321, 2 2007. ISSN 01728172. doi: 10.1007/s00296-006-0269-2.

R Costa. Ui patterns: design solutions to common problems - justinmind, 2021. URL `https://www.justinmind.com/ui-design/patterns`.

S. J. Czaja and J. Sharit. Age differences in attitudes toward computers. *The journals of gerontology*, pages 329–340, 1998. URL `https://doi.org/10.1093/geronb/53b.5.p329`.

Alan Dix, Janet Finlay, Gregory D. Abon, and Russel Beale. *Human-Computer Interaction*. Pearson Education, 2004.

Gleison Vieira Duarte, César Faillace, and Jozélio Freire De Carvalho. Psoriatic arthritis. *Best Practice and Research: Clinical Rheumatology*, 26:147–156, 2012. ISSN 15321770. doi: 10.1016/j.berh.2012.01.003.

EULAR. Eular website. Technical report, EULAR, 2011. URL `www.eular.org`.

GlobalStats. Mobile operating system market share worldwide | statcounter global stats, 2021. URL `https://gs.statcounter.com/os-market-share/mobile/worldwide`.

S. Glyn-Jones, A. J.R. Palmer, R. Agricola, A. J. Price, T. L. Vincent, H. Weinans, and A. J. Carr. Osteoarthritis. *The Lancet*, 386:376–387, 7 2015. ISSN 1474547X. doi: 10.1016/S0140-6736(14)60802-3.

Google. Material design 2, 2014. URL `https://material.io/`.

Google. Material design 3, 2018. URL `https://m3.material.io/`.

Ian Graham. *A pattern language for Web usability / Ian Graham.* Addison-Wesley, 2003. ISBN 0201788888.

Et Grainger and Al. Patient and clinician views on an app for rheumatoid arthritis disease monitoring: Function, implementation and implications. *International Journal of Rheumatic Diseases*, 2020.

Tania Gudu and Laure Gossec. Quality of life in psoriatic arthritis. *Expert Review of Clinical Immunology*, 14:405–417, 5 2018. ISSN 17448409. doi: 10.1080/1744666X.2018.1468252.

Richard Harper, Tom Rodden, Yvonne Rogers, and Abigail Sellen. *Being Human: Human-Computer Interaction in the Year 2020*. Microsoft Research Ltd, October 2008. URL `https://www.microsoft.com/en-us/research/publication/being-human-human-computer-interaction-in-the-year-2020/`.

David J. Hunter, Jason J. McDougall, and Francis J. Keefe. The symptoms of osteoarthritis and the genesis of pain. *Rheumatic Disease Clinics of North America*, 34:623–643, 8 2008. ISSN 0889857X. doi: 10.1016/j.rdc.2008.05.004.

Alita Joyce. Design-pattern guidelines: Study guide, 2021. URL https://www.nngroup.com/articles/design-pattern-guidelines/.

W F Kean, R Kean, and W W Buchanan. Osteoarthritis: symptoms, signs and source of pain. *Inn ammopharmacology*, 12:3–31, 2004.

Gabrielle Kingsley, Ian C. Scott, and David L. Scott. Quality of life and the outcome of established rheumatoid arthritis. *Best Practice and Research: Clinical Rheumatology*, 25:585–606, 2011. ISSN 15321770. doi: 10.1016/j.berh.2011.10.003.

Christian Kruschitz and Martin Hitz. Human-computer interaction design patterns: Structure, methods, and tools. *International Journalon Advances in Software*, 2010. URL www.iaria.org.

Clemens Scott Kruse, Michael Mileski, and Joshua Moreno. Mobile health solutions for the aging population: A systematic narrative analysis. *Journal of Telemedicine and Telecare*, 23:439–451, 5 2017. ISSN 17581109. doi: 10.1177/1357633X16649790.

Mike Kuniavsky, Elizabeth Goodman, and Andrea Moed. *Observing the User Experience, Second Edition: A Practitioner's Guide to User Research*. Morgan Kaufmann Publishers Inc., 2nd edition, 2012. ISBN 0123848695.

Tore K. Kvien and T. Uhlig. Quality of life in rheumatoid arthritis. *Scandinavian Journal of Rheumatology*, 34:333–341, 2005. ISSN 03009742. doi: 10.1080/03009740500327727.

Roxanne Leitao and Paula Alexandra Silva. Target and spacing sizes for smartphone user interfaces for older adults: Design patterns based on an evaluation with users. *19th Conference on Pattern Languages of Programs*, 2012. URL https://mural.maynoothuniversity.ie/6045/.

Shane A. Lowe and Gearóid ÓLaighin. Monitoring human health behaviour in one's living environment: A technological review. *Medical Engineering and Physics*, 36:147–168, 2 2014. ISSN 13504533. doi: 10.1016/j.medengphy.2013.11.010.

Vikas Majithia and Stephen A. Geraci. Rheumatoid arthritis: Diagnosis and management. *American Journal of Medicine*, 120:936–939, 2007. ISSN 00029343. doi: 10.1016/j.amjmed.2007.04.005.

S. P. McKenna, L. C. Doward, D. Whalley, A. Tennant, P. Emery, and D. J. Veale. Development of the psaqol: A quality of life instrument specific to psoriatic arthritis. *Annals of the Rheumatic Diseases*, 63:162–169, 2 2004. ISSN 00034967. doi: 10.1136/ard.2003.006296.

Philip Mease and Bernard S. Goffe. Diagnosis and treatment of psoriatic arthritis. *Journal of the American Academy of Dermatology*, 52:1–19, 1 2005. ISSN 01909622. doi: 10.1016/j.jaad.2004.06.013.

I. M. Michalek, B. Loring, and S. M. John. A systematic review of worldwide epidemiology of psoriasis. *Journal of the European Academy of Dermatology and Venereology*, 31:205–212, 2 2017. ISSN 14683083. doi: 10.1111/jdv.13854.

Elizabeth Mollard and Kaleb Michaud. A mobile app with optical imaging for the self-management of hand rheumatoid arthritis: Pilot study. *JMIR mHealth and uHealth*, 6, 10 2018. ISSN 22915222. doi: 10.2196/12221.

Elizabeth Mollard and Kaleb Michaud. Mobile apps for rheumatoid arthritis: Opportunities and challenges. *Rheumatic Disease Clinics of North America*, 45: 197–209, 5 2019. ISSN 15583163. doi: 10.1016/j.rdc.2019.01.011.

Elizabeth Mollard and Kaleb Michaud. Self-management of rheumatoid arthritis: Mobile applications. *Current Rheumatology Reports*, 23, 1 2021. ISSN 15346307. doi: 10.1007/s11926-020-00968-7.

Aurélie Najm, Elena Nikiphorou, Marie Kostine, Christophe Richez, John D. Pauling, Axel Finckh, Valentin Ritschl, Yeliz Prior, Petra Balážová, Simon Stones, Zoltan Szekanecz, Annamaria Iagnocco, Sofia Ramiro, Francisca Sivera, Maxime Dougados, Loreto Carmona, Gerd Burmester, DIeter Wiek, Laure Gossec, and Francis Berenbaum. Eular points to consider for the development, evaluation and implementation of mobile health applications aiding self-management in people living with rheumatic and musculoskeletal diseases. *RMD Open*, 5, 9 2019. ISSN 20565933. doi: 10.1136/rmdopen-2019-001014.

Erik G Nilsson. Design patterns for user interface for mobile applications. *Adv. Eng. Softw.*, 40:1318–1328, 12 2009. ISSN 0965-9978. doi: 10.1016/j.advengsoft.2009.01.017. URL https://doi.org/10.1016/j.advengsoft.2009.01.017.

Yu Daihuaand Parmanto and Bambangand Dicianno Brad. An mhealth app for users with dexterity impairments: Accessibility study. *JMIR Mhealth Uhealth*, 7:e202, 1 2019. ISSN 2291-5222. doi: 10.2196/mhealth.9931. URL http://www.ncbi.nlm.nih.gov/pubmed/30622096.

G. Perlman. *Interaction Design: Beyond Human-Computer Interaction*. J. Wiley & Sons, 2002.

Daniela Pohl and Susanne Benseler. *Systemic inflammatory and autoimmune disorders*, volume 112, pages 1243–1252. Elsevier B.V., 2013. doi: 10.1016/B978-0-444-52910-7.00047-7.

L Pollard, E H Choy, and ; D L Scott. The consequences of rheumatoid arthritis: Quality of life measures in the individual patient. *Clin Exp Rheumatol*, 23:43–52, 2005. URL http://www.arc.org.uk.

Lisanne Renskers, Sanne A.A. Rongen-Van Dartel, Anita M.P. Huis, and Piet L.C.M. Van Riel. Patients' experiences regarding self-monitoring of the disease course: An observational pilot study in patients with inflammatory rheumatic diseases at a rheumatology outpatient clinic in the netherlands. *BMJ Open*, 10, 8 2020. ISSN 20446055. doi: 10.1136/bmjopen-2019-033321.

H. Repping-Wuts, P. Van Riel, and T. Van Achterberg. Fatigue in patients with rheumatoid arthritis: What is known and what is needed. *Rheumatology*, 48: 207–209, 2009. ISSN 14620324. doi: 10.1093/rheumatology/ken399.

Piet Van Riel, Rieke Alten, Bernard Combe, Diana Abdulganieva, Paola Bousquet, Molly Courtenay, Cinzia Curiale, Antonio Gómez-Centeno, Glenn Haugeberg, Burkhard Leeb, Kari Puolakka, Angelo Ravelli, Bernhard Rintelen, and Piercarlo Sarzi-Puttini. Improving inflammatory arthritis management through tighter monitoring of patients and the use of innovative electronic tools. *Rheumatic & Musculoskeletal Diseases*, 2016. doi: 10.1136/rmdopen-2016. URL http://dx.doi.org/.

O Sangha. Epidemiology of rheumatic diseases. *Bavarian Public Health Research Center*, 2000.

Piercarlo Sarzi-Puttini, Marco A. Cimmino, Raffaele Scarpa, Roberto Caporali, Fabio Parazzini, Augusto Zaninelli, Fabiola Atzeni, and Bianca Canesi. Osteoarthritis: An overview of the disease and its treatment strategies. *Seminars in Arthritis and Rheumatism*, 35:1–10, 8 2005. ISSN 00490172. doi: 10.1016/j.semarthrit.2005.01.013.

Ahmed Seffah, Jan Guilliksen, and Michel C. Desmarais. *HUMAN-CENTERED SOFTWARE ENGINEERING — INTEGRATING USABILITY IN THE SOFTWARE DEVELOPMENT LIFECYCLE*. Springer, 2005.

SerpApi. Serpapi playground, 2021. URL https://serpapi.com/playground?engine=apple_app_store&term=rheumatic&country=us&lang=en-us&num=15&page=0.

Josef S. Smolen, Daniel Aletaha, Johannes W.J. Bijlsma, Ferdinand C. Breedveld, Dimitrios Boumpas, Gerd Burmester, Bernard Combe, Maurizio Cutolo, Maarten De Wit, Maxime Dougados, Paul Emery, Alan Gibofsky, Juan Jesus Gomez-Reino, Boulos Haraoui, Joachim Kalden, Edward C. Keystone, Tore K. Kvien, Iain McInnes, Emilio Martin-Mola, Carlomaurizio Montecucco, Monika Schoels, and Desirée Van Der Heijde. Treating rheumatoid arthritis to target: Recommendations of an international task force. *Annals of the Rheumatic Diseases*, 69:631–637, 2010. ISSN 14682060. doi: 10.1136/ard.2009.123919.

Daniel H. Solomon and Robert S. Rudin. Digital health technologies: opportunities and challenges in rheumatology. *Nature Reviews Rheumatology*, 16:525–535, 9 2020. ISSN 17594804. doi: 10.1038/s41584-020-0461-x.

Jeffrey A. Sparks. In the clinic® rheumatoid arthritis. *Annals of Internal Medicine*, 170:ITC1–ITC15, 1 2019. ISSN 15393704. doi: 10.7326/AITC201901010.

Jenifer Tidwell. Interaction design patterns: P29. *PLoP'98 conference*, 1998. URL http://www.mit.edu/~jtidwell/interaction_patterns.html.

Arto T. Toivanen, Markku Heliövaara, Olli Impivaara, Jari P.A. Arokoski, Paul Knekt, Hanna Lauren, and Heikki Kröger. Obesity, physically demanding work and traumatic knee injury are major risk factors for knee osteoarthritis-a population-based study with a follow-up of 22 years. *Rheumatology*, 49:308–314, 2 2010. ISSN 14620324. doi: 10.1093/rheumatology/kep388.

Marek Vokác. An efficient tool for recovering design patterns from c++ code. *Journal of Object Technology*, 5:139–157, 6 2006. doi: 10.5381/jot.2006.5.1.a6.

M. J.H. Voshaar, I. Nota, M. A.F.J. Van De Laar, and B. J.F. Van Den Bemt. Patient-centred care in established rheumatoid arthritis. *Best Practice and Research: Clinical Rheumatology*, 29:643–663, 2015. ISSN 15321770. doi: 10.1016/j.berh.2015.09.007.

W3C. Understanding guideline 2.5: Input modalities, 2021a. URL `https://www.w3.org/WAI/WCAG21/Understanding/input-modalities`.

W3C. Understanding success criterion 2.5.2: Pointer cancellation, 2021b. URL `https://www.w3.org/WAI/WCAG21/Understanding/pointer-cancellation`.

W3C. Understanding success criterion 2.5.5: Target size, 2021c. URL `https://www.w3.org/WAI/WCAG21/Understanding/target-size`.

Paco M.J. Welsing, Robert B.M. Landewé, Piet L.C.M. Van Riel, Maarten Boers, Anke M. Van Gestel, Sjef Van Der Linden, Hilde L. Swinkels, and Désirée M.F.M. Van Der Heijde. The relationship between disease activity and radiologic progression in patients with rheumatoid arthritis: A longitudinal analysis. *Arthritis and Rheumatism*, 50:2082–2093, 7 2004. ISSN 00043591. doi: 10.1002/art.20350.

Mary H. Wilde and Suzanne Garvin. A concept analysis of self-monitoring. *Journal of Advanced Nursing*, 57:339–350, 2 2007. ISSN 03092402. doi: 10.1111/j.1365-2648.2006.04089.x.

William, Jorge Joaquim, Dix Alan, Silva Paula Alexandra Kotzé Paula, and Wong, editors. *Teaching Usability Principles with Patterns and Guidelines*, 2009. Springer US. ISBN 978-0-387-89022-7.

Andrew S. Wilson and Janet E. McDonagh. A gamification model to encourage positive healthcare behaviours in young people with long term conditions. *EAI Endorsed Transactions on Game-Based Learning*, 1:e3, 5 2014. ISSN 2034-8800. doi: 10.4108/sg.1.2.e3.

Daihua X Yu, Bambang Parmanto, Brad E Dicianno, Valerie J Watzlaf, and Katherine D Seelman. Accessibility needs and challenges of a mhealth system for patients with dexterity impairments. *Disability and Rehabilitation: Assistive Technology*, 12:56–64, 2017. doi: 10.3109/17483107.2015.1063171. URL `https://doi.org/10.3109/17483107.2015.1063171`. PMID: 26153097.

Yuqing and Hong. Evaluating chinese mobile health apps for ankylosing spondylitis management: Systematic app search. *JMIR Mhealth Uhealth*, 9: e27234, 7 2021. ISSN 2291-5222. doi: 10.2196/27234. URL `http://www.ncbi.nlm.nih.gov/pubmed/34259644`.

Luciana A M Zaina, Renata P M Fortes, Vitor Casadei, Leornardo Seiji Nozaki, and Débora Maria Barroso Paiva. Preventing accessibility barriers: Guidelines for using user interface design patterns in mobile applications. *Journal of Systems and Software*, 186:111213, 2022. ISSN 0164-1212. doi: https://doi.org/10.1016/j.jss.2021.111213. URL `https://www.sciencedirect.com/science/article/pii/S0164121221002831`.

Appendices

Appendix A

Consent to participate in research

CONSENTIMENTO PARA PARTICIPAÇÃO EM INVESTIGAÇÃO

O projeto COTIDIANA, desenvolvido pela Associação Fraunhofer Portugal Research, Comprehensive Health Research Centre (NOVA Medical School, UNL), Definition 12 AG, Mag. Andreas Raffeiner, Medical University of Vienna e Pryv SA, e financiado pelo programa AAL da Comissão Europeia, está a desenvolver uma aplicação para smartphone para uso clínico de monitorização de sintomas de saúde em doentes com doenças do foro reumático.

Nesta fase, estamos a reunir os requisitos do sistema COTIDIANA e gostaríamos de convidá-lo a realizar algumas tarefas de destreza manual no smartphone fornecid. Iremos recolher alguns dados demográficos, como sexo, idade, nível de escolaridade, bem como dados relacionados com a doença, como nome da doença ou em que condições toma notas sobre a sua condição.

Todos os dados recolhidos são confidenciais e serão utilizados exclusivamente no âmbito deste estudo. A análise dos dados recolhidos será feita pela Associação Fraunhofer Portugal Research, Medical University of Vienna, e Comprehensive Health Research Centre (NOVA Medical School). A Associação Fraunhofer Portugal Research irá tomar todas as medias necessárias para salvaguardar a privacidade e segurança dos dados recolhidos por forma a evitar que venham a ser acedidos por terceiros não autorizados. Os seus dados pessoais serão destruídos no final do projeto (Julho 2023). Um subconjunto dos dados recolhidos poderá ser partilhado, de forma anónima, com a comunidade científica para o avanço da investigação sobre doenças reumáticas. As gravações de vídeo da sessão serão eliminadas assim que os dados forem anotados.

A sua participação é voluntária, podendo em qualquer altura cessá-la sem nenhum tipo de consequência. Também poderá pedir a retificação o destruição da informação pessoal recolhida a qualquer momento. Agradecemos muito o seu contributo, fundamental para a nossa investigação!

O/A participante:

Declaro ter lido e compreendido este documento, bem como as informações verbais fornecidas e aceito participar nesta investigação. Permito a utilização dos dados que forneço de forma voluntária, para os fins descritos. Declaro ainda que autorizo a publicação de dados anónimos nos diversos meios de comunicação social, em publicações científicas e conferências ou outro tipo de evento científico ou de divulgação do projeto.

Nome do/a participante: ______________________________

Assinatura do/a participante: ______________________________

Data: __ / __ / __

Investigador responsável do estudo:

Nome: Petra Grego

Telefone: 916497371

E-mail: petra.grego@aicos.fraunhofer.pt

ESTE DOCUMENTO É FEITO EM DUPLICADO: UM PARA O PARTICIPANTE E OUTRO PARA O INVESTIGADOR.

Figure A.1: Consent to participate in research.

Appendix B

Usability experiments script

Pre-session script

First of all, I would like to thank you for your participation in this study. My name is Petra Grego, and I'm in the last year of the master's degree in Design and Multimedia at the University of Coimbra. In my final project I am investigating how to improve the introduction of information in applications for people with rheumatic diseases.

Now I'm going to present an overview of this test:

1. Before we start, I will ask you to read it and, if you agree, sign an informed consent form. Essentially, this form serves to obtain your authorization for data collection during the activity that we will do next. It is important to note that your personal data will not be disclosed to third parties.
2. The test will consist of 11 tasks, each of which will be divided into distinct two moments: i) Task: Where you will perform the tasks themselves ii) Questionnaire: Where you will answer one/two questions about the tasks you just finished

Session script

1. Finally, I would like to inform you that you can interrupt the session at any time if you need a break or want to ask a question. Do you have any questions before?
2. Start the test: i) Task ii) Questionnaire

Post-session script

Before we finish, do you have any questions or comments? [Wait and answer accordingly]. I would like you thank you for participating in this study. Your contribution has been of great importance to our work. Thank you.

Appendix C

Observation grids

Participant: ________ **Date:** ___ / ___ / _____

Pre-test questionnaire

Observation

Questions

What is your age?

18-20 21-30 31-40 41-50 51-60 61-70 71-80 >= 81

What gender do you identify with?

- ☐ Female ☐ Male ☐ Non binary ☐ Rather not answer

What is the highest level of education you have completed?

- ☐ High school ☐ Bachelor degree ☐ Masters degree ☐ PhD

What do you do for a living?

____

How much time do you spend on your cell phone?

- ☐ Multiple times a week ☐ 1x per day ☐ Multiplas time a day

What is the name of your rheumatic condition(s)?

____

How many years ago were you diagnosed with the disease?

____

In what situations do you take notes about your condition?

- ☐ When experiencing new medication side effects (for example, when starting, stopping, or replacing medication)
- ☐ When experiencing new symptoms or functional decline
- ☐ When experiencing crises
- ☐ When you need to reduce medication for some reason (e.g. cold, surgery)
- ☐ I take notes in other situations (specify): ____
- ☐ None of the above

Do you use apps where you make notes about your symptoms? How often do you use it?

____

1

Table C.1: Observation grids 1.

Test A — 1

Observation

Question

Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?

A B C ◯ Did not feel a difference / Did not notice

Test A — 2

Observation

Question

Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?

A B ◯ Did not feel a difference / Did not notice

Test A — 3

Observation

Question

Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?

A B ◯ Did not feel a difference / Did not notice

2

Table C.2: Observation grids 2.

Test B — 1
Observation
Question
Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one? A B C ◯ Did not feel a difference / Did not notice

Teste — 2
Observation
Chega a mão para cima
Question
Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one? A B ◯ Did not feel a difference / Did not notice

3

Table C.3: Observation grids 3.

Test C — 1
Observation
Question
Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?
A B C ○ Did not feel a difference / Did not notice

Test C — 2
Observation
Question
Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?
A B C ○ Did not feel a difference / Did not notice

Test C — 3
Observation
Question
Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?
A B C ○ Did not feel a difference / Did not notice

4

Table C.4: Observation grids 4.

Test D — 1/2

Observation

Question

Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?

A B ◯ Did not feel a difference / Did not notice

Test D — 3

Observation

Question

Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one?

A B ◯ Não sentiu diferença/ Não reparou

Post-test questionary

Considering the tasks performed so far, did any of the components (horizontal/vertical sliders, column or row selectors...) seem easier to use to complete the requested selection? If yes, which one?

◯ Horizontal sliders ◯ Vertical sliders ◯ Column selectors ◯ In-line selectors ◯ None

Considering the tasks performed so far, did any of the components (horizontal/vertical sliders, column or row selectors...) cause you more pain when using it to complete the requested selection? If yes, which one?

◯ Horizontal sliders ◯ Vertical sliders ◯ Column selectors ◯ In-line selectors ◯ None

5

Table C.5: Observation grids 5.

Test E — 1
Observation
Question
Considering the previous screens, did any seem easier to use to complete the requested selection? If yes, which one? A B C ◯ Did not feel a difference / Did not notice

6

Table C.6: Observation grids 6.

Appendix D

Questionnaire options

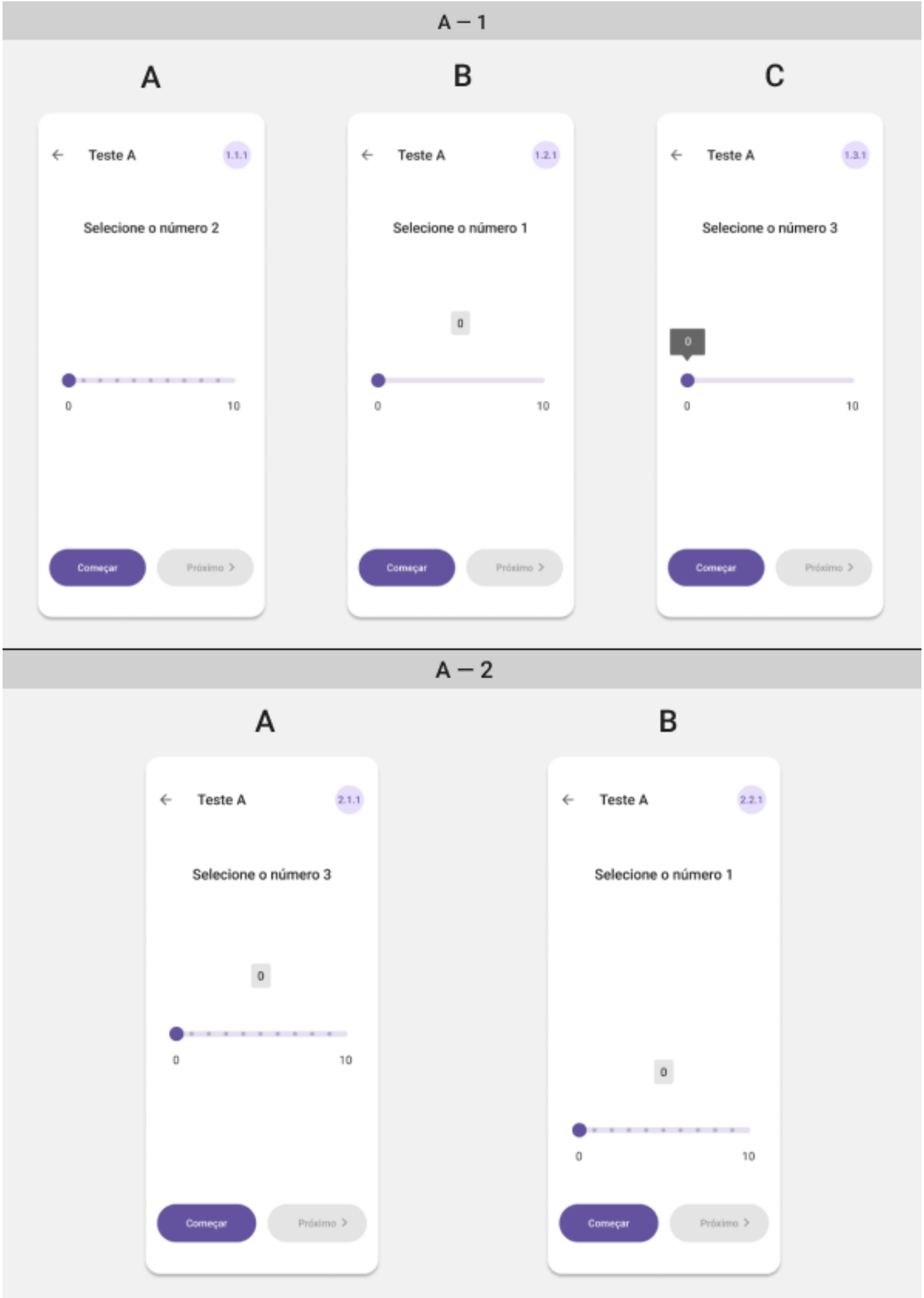


Figure D.1: Questionnaire options 1.

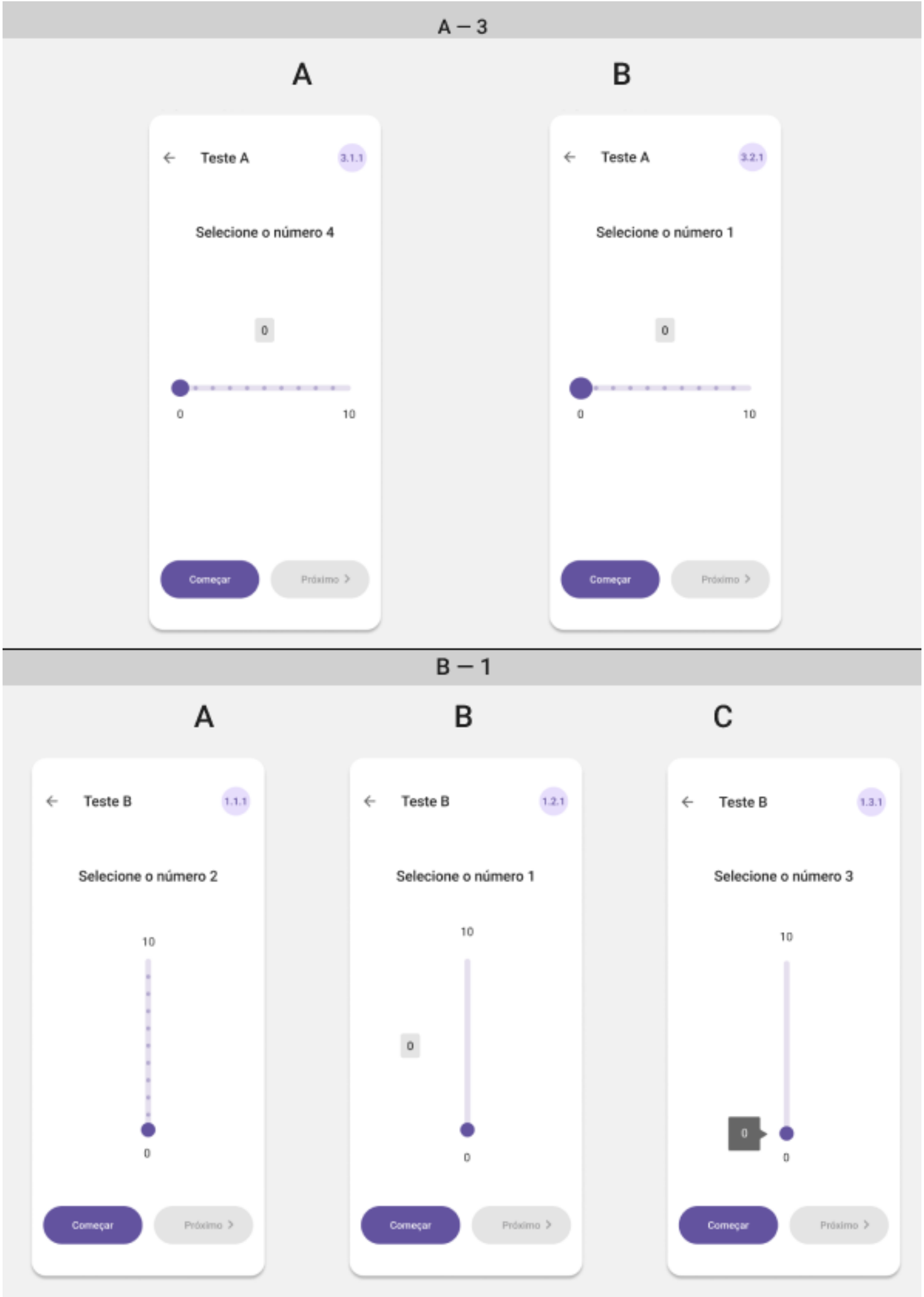


Figure D.2: Questionnaire options 2.

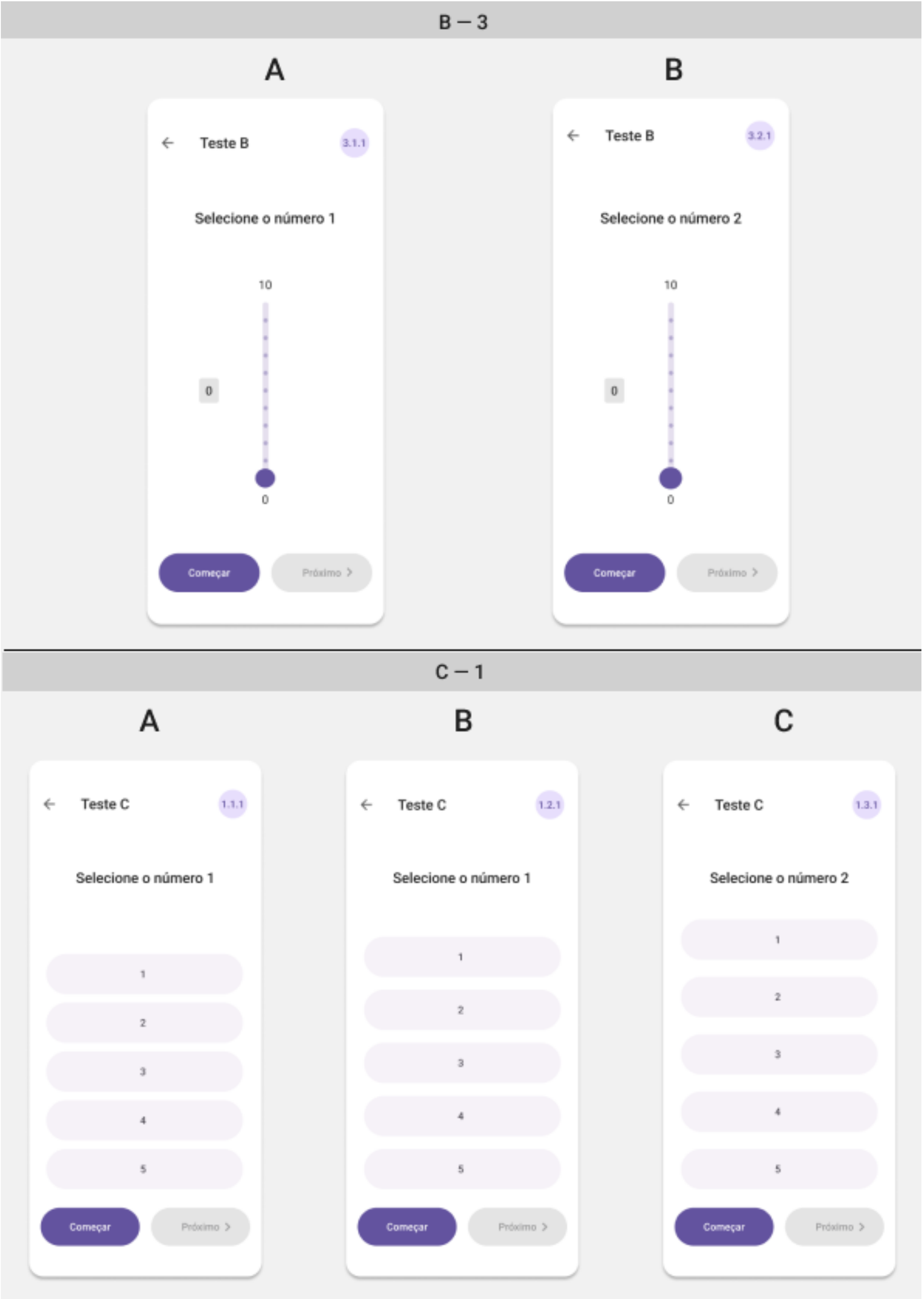


Figure D.3: Questionnaire options 3.

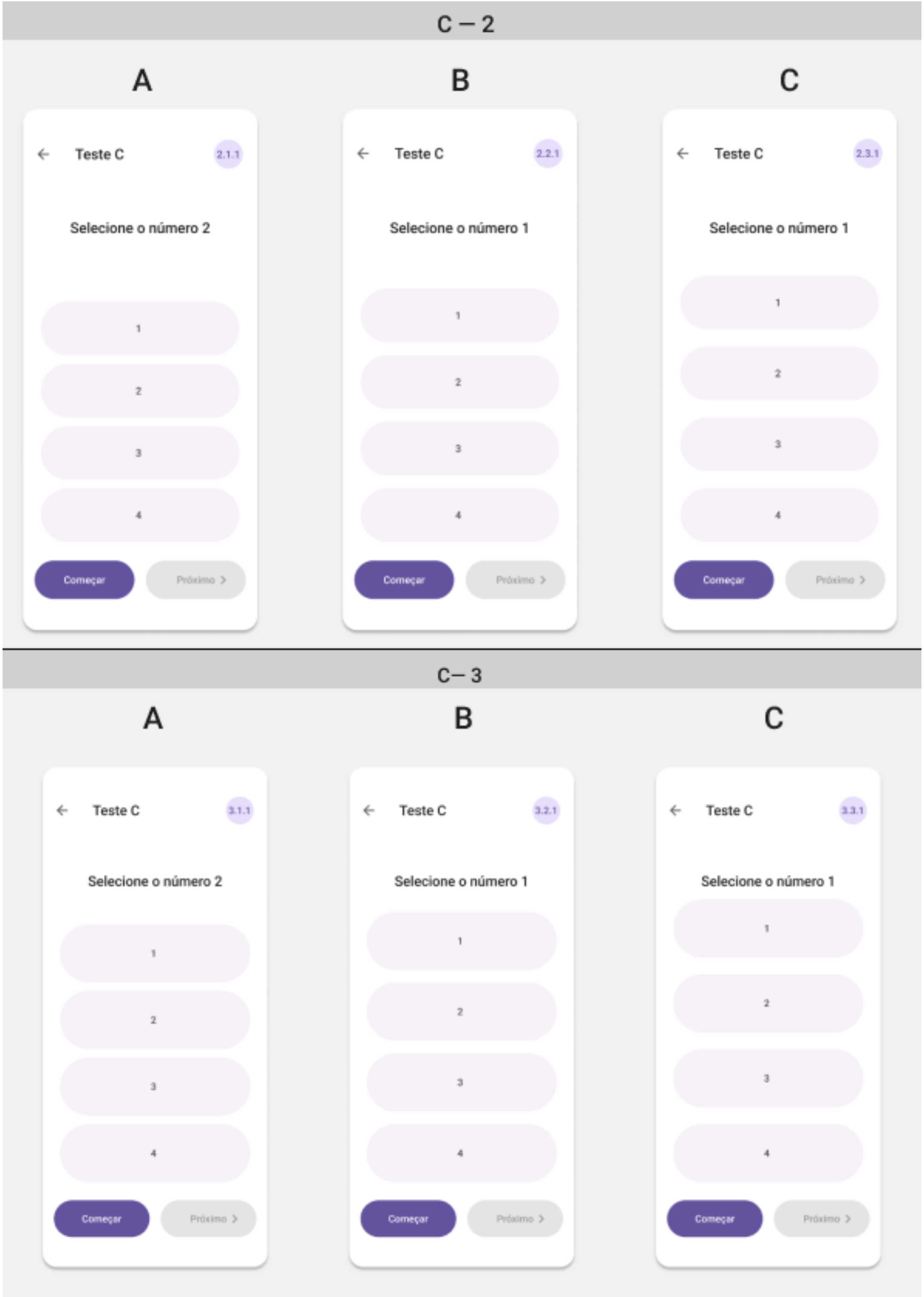


Figure D.4: Questionnaire options 4.

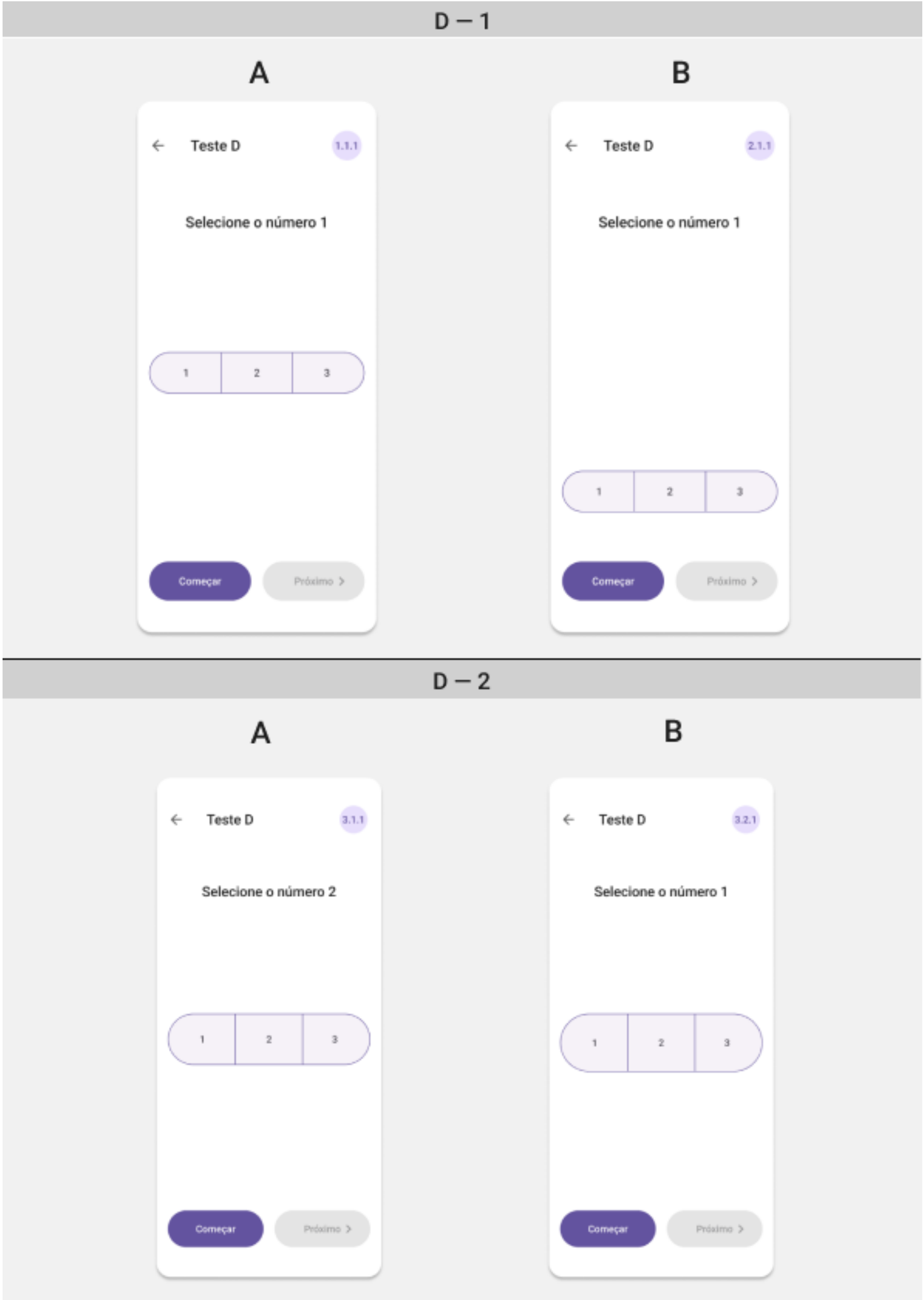


Figure D.5: Questionnaire options 5.

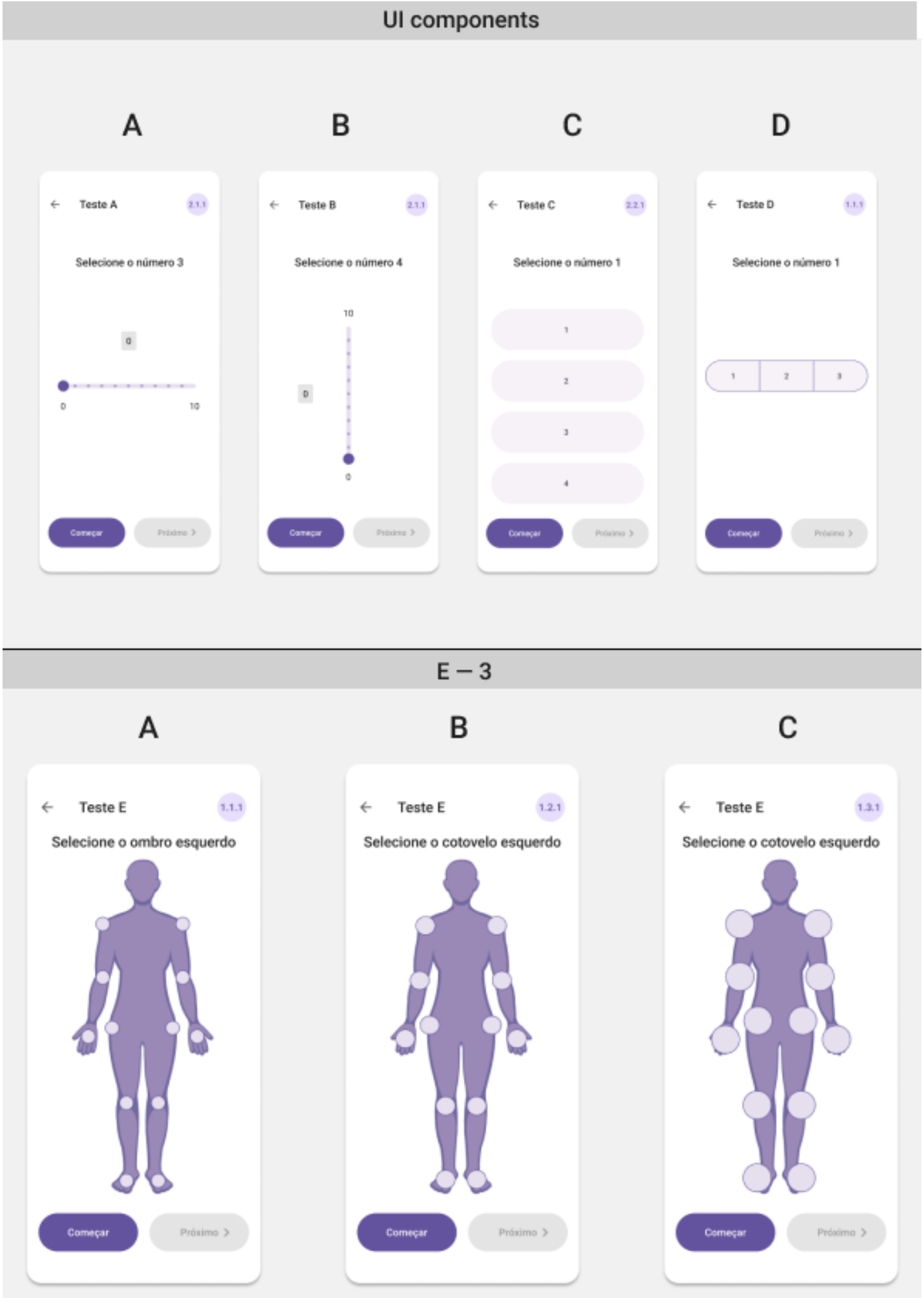


Figure D.6: Questionnaire options 6.