Politécnico
de Viseu

Escola Superior
de Tecnologia
e Gestão de Viseu

Guidelines for the Design of Smartwatch Interfaces for Older Adults

Mickaël Mota

Trabalho de Projeto
Mestrado em Engenharia Informática - Sistemas de Informação

Trabalho efetuado sob a orientação de
Professor Doutor Rui Pedro Monteiro Amaro Duarte
Professor Doutor Valter Nelson Noronha Alves

Janeiro de 2025

Politécnico
de Viseu

Escola Superior
de Tecnologia
e Gestão de Viseu

Guidelines for the Design of Smartwatch Interfaces for Older Adults

Mickaël Mota

Trabalho de Projeto

Mestrado em Engenharia Informática - Sistemas de Informação

Trabalho efetuado sob a orientação de

Professor Doutor Rui Pedro Monteiro Amaro Duarte
Professor Doutor Valter Nelson Noronha Alves

Janeiro de 2025

Acknowledgements

I would like to express my sincere gratitude to my supervisors, Professor Rui Pedro Monteiro Amaro Duarte and Professor Valter Nelson Noronha Alves. Their invaluable advice, support, insightful feedback, and enthusiasm were instrumental in the development of this thesis. I am also grateful to my family and friends for their encouragement and unconditional support throughout this arduous undertaking.

Abstract

As individuals age, they encounter many difficulties that can hinder their interaction with interfaces, compromising the user experience and potentially leading to the rejection of technology. Consequently, it is imperative to consider the needs associated with these challenges to design appropriate interfaces for this audience. For this purpose, various studies have proposed guidelines for designing interfaces for several types of devices. However, limited research has been undertaken to explore this topic within the context of smartwatches, resulting in a deficit of suitable smartwatch interfaces for older adults despite the potential utility of such devices, which have recently gained popularity as a non-intrusive solution for monitoring activities of daily living or health.

This study proposes a set of guidelines for designing smartwatch interfaces for older adults. The guidelines are adapted from existing recommendations originally developed for other devices. To achieve this, a thorough review of age-related challenges was conducted, followed by the systematic extraction of 175 design guidelines from the literature.

Finally, particular features of smartwatches were identified, followed by a comprehensive analysis of the collected guidelines. This process included preparation, filtering, classification, and synthesis, culminating in 21 proposed design guidelines and their respective profile sheets. A design system was developed to enhance the practical application and understanding of these guidelines, featuring examples of implementation and reusable components that can support future research. This study is intended to serve as a foundation for researchers aiming to create more suitable smartwatch interfaces for older adults.

Keywords: Design guidelines; Older adults; Smartwatch interfaces; Design system.

Resumo

À medida que envelhecem, os indivíduos deparam-se com muitas dificuldades que podem dificultar a sua interação com as interfaces, comprometendo a experiência de utilização e levando potencialmente à rejeição da tecnologia. Consequentemente, é imperativo ter em conta as necessidades associadas a estes desafios para conceber interfaces adequadas a este público. Para o efeito, vários estudos propuseram orientações para a conceção de interfaces para diversos tipos de dispositivos. No entanto, a investigação no contexto dos relógios inteligentes é limitada, o que resulta numa escassez de interfaces adequadas para adultos mais velhos, apesar da potencial utilidade destes dispositivos, que recentemente ganharam popularidade como uma solução não intrusiva para a monitorização das actividades da vida diária ou da saúde.

Este estudo propõe um conjunto de diretrizes para a conceção de interfaces de relógios inteligentes para adultos mais velhos. As diretrizes são adaptadas de recomendações existentes originalmente desenvolvidas para outros tipos de dispositivos. Para tal, foi realizada uma análise exaustiva dos desafios relacionados com a idade, seguida da extração sistemática de 175 orientações de conceção, a partir da literatura.

De seguida, foram identificadas caraterísticas específicas dos relógios inteligentes e foi feita uma análise exaustiva das diretrizes extraídas. Este processo incluiu preparação, filtragem, classificação e síntese, culminando numa proposta de 21 diretrizes de design e respectivas fichas de perfil. Para melhorar a sua aplicação prática e compreensão, foi desenvolvido um sistema de design, com exemplos de implementação e componentes reutilizáveis que podem apoiar a investigação futura. Pertende-se que este estudo possa constituir uma base para os investigadores que pretendem criar interfaces para relógios inteligentes mais adequadas para adultos mais velhos.

Palavras-Chave: Diretrizes de design; Adultos mais velhos; Relógios inteligentes; Interfaces; Sistema de design.

Contents

List of Tables

List of Figures

List of Acronyms

PG	*Proposed guideline*
RG	*Reference guideline*
UI	*User Interface*
UX	*User Experience*

Chapter 1

Introduction

This chapter presents the general context of the work, covering the theme and problem to be studied, the theoretical framework, and the work's objectives, methodology, and structure.

1.1 Motivation

Aging makes learning and using new technologies more complex and is accompanied by changes in vision, hearing, coordination, and memory [Farage et al., 2012]. In addition, currently, most older people have little experience and familiarity with digital interfaces and the design elements that make them up [Iancu and Iancu, 2020]. Based on these challenges, it is relevant that interface design meets the needs of this target public and enables their inclusion.

The complexity of the usability of portable devices is a significant issue that leads to many older people's rejection of these technologies [Farivar et al., 2020]. To address this problem, guidelines are already available in the literature, particularly for mobile applications and websites [Gomez-Hernandez et al., 2023, Patsoule and Koutsabasis, 2014, Iancu and Iancu, 2020]. However, this topic has received limited attention within the context of smartwatch interface design for older adults. Smartwatches have the potential to be relevant to older people since they are wearable devices that can collect data on the user's activity, such as sleep and heart rate, offering older adults monitoring and immediate feedback on vital signs, providing

real-time health information and support in healthcare assistance. Hence, smartwatches could be breakthrough devices that would help older adults to live better [Thorpe et al., 2016, Vilarinho et al., 2015, Lima et al., 2022, Aldeer et al., 2018]. Thus, it is essential to propose guidance for designing smartwatch applications focusing on older adults to improve their user experience.

1.2 Contextualisation

Smartwatches are computerised wristwatches with functions that go beyond simply displaying the time. They are equipped with touch screens and numerous sensors to give the user valuable information. Since these devices are watches, their size is limited, meaning that users have to interact with small screens. This constraint imposes a rigorous and careful use of the space available on the interface. Standard screen sizes on these devices are between 1 and 2 (25,4mm and 50,8mm) inches in diagonal. For example, Apple Watch Series 6, 44mm (1.73", i.e., 44mm, in case height) is 1.78" (45.2mm) in diagonal; Galaxy Watch 7, 40mm (1.57", i.e. 40mm, in case height) is 1.31" (33.3mm) in diagonal; and Garmin Venu 2, 45mm (1.77", i.e., 45mm in case height) is 1.30" (33mm) in diagonal. By way of comparison, some of today's standard smartphone screen sizes are between 6.1 and 6.7 inches (e.g., iPhone 15: 6.1" (154.9mm), Samsung Galaxy S24: 6.2" (157.5mm), Google Pixel 8 Pro: 6.7" (170.2mm)). Figure 1.1 shows a comparison in screen size between some of these devices.

Smartwatches have recently become increasingly popular as non-intrusive devices for monitoring daily activities. Their widespread adoption has facilitated the development of various remote health monitoring applications, primarily focusing on supporting independent living at home [Vilarinho et al., 2015, Mauldin et al., 2018, Thorpe et al., 2016].

They can provide several essential functionalities that could save lives, such as detecting a fall, enabling real-time monitoring of vital signs (e.g., heart rate or body temperature), and locating the wearer, which can be very important in the case of a person with cognitive impairment [King and Sarrafzadeh, 2018, Mauldin et al., 2018, Vilarinho et al., 2015, Lima et al., 2022, Himi et al., 2023, Bhanvadia et al., 2022, Kostopoulos et al., 2015, Han et al., 2023]. This device can also be very effective as a reminder to take medication or keep appointments [LiveConnect24, 2023, AccessibleHomeCare, 2022, Kalantarian et al., 2015]. Smartwatches possess numerous advantages over conventional monitoring devices. Their compact size allows for comfortable, all-day wear without causing any inconvenience [King and Sarrafzadeh, 2018]. Smartwatches are well-suited for older adults who may prefer to avoid bulky or cumbersome devices. Their portability makes them an option for monitoring activities of daily living, especially for older adults who travel or

Figure 1.1: Comparison of some typical screen sizes of smartphones and smartwatches.

move frequently. Additionally, smartwatches are user-friendly and do not require specialised clothing or accessories, allowing them to be worn like a traditional watch without interfering with daily routines. Notably, these devices are less likely to be perceived as intrusive, as this demographic is familiar with or has previously used conventional watches [Manini et al., 2019, Vargemidis et al., 2021]. As a result, they could be seamlessly integrated into everyday life without tethering the user to a monitoring device, making them an ideal solution for people who prefer not to feel constantly being monitored [Ding et al., 2022].

One of the key factors in the acceptance of technology is the usability of its interface. The complexity of an interface often leads to rejection, which is also the case with older people [Iancu and Iancu, 2020, Kuerbis et al., 2017]. Usability sets are compromised by different factors, one of which is age. Indeed, the difficulties associated with age are numerous, including those related to sensory issues. The most affected senses are audition, vision, and touch. Estimations indicate that around 40% of individuals experience hearing loss significant enough to impede social interaction and environmental safety by age 65. In addition, loss of sensitivity to high-frequencies in sound is a common occurrence in auditory decline [Fisk et al., 2020]. Moreover, visual impairments are also more pronounced in older adults, especially regarding dark adaptation, the extent of the visual field, visual processing speed, and perceptual flexibility [Farage et al., 2012]. Movement control is also

affected by aging due to illnesses: seniors need more time to respond to tasks since their moves are less precise [Lewis and Neider, 2017]. At the cognition level, the difficulties encountered include loss of attention and memory problems [Charness and Boot, 2009, Farage et al., 2012].

According to the United Nations Organisation [Organisation, 2023], the global population aged 65 years or older worldwide is projected to more than double by 2050, rising from 761 million (2021) to 1.6 billion. It is predicted that by that date, one in six people in the world will be over age 65 [Organisation, 2024]. It is, therefore, essential to ensure that this population group is included in using new technologies. Furthermore, many older adults are less familiar with new technologies than other user groups, limiting their ability to navigate interfaces using prior knowledge when faced with unfamiliar systems. Consequently, interaction designers must account for these challenges and develop solutions that enable positive and intuitive user experiences. In this document, the term "older adults" refers to individuals aged 65 and above, although other studies may define this group differently [Betts et al., 2019, Wildenbos et al., 2019].

Interaction design concerns how people interact with technology, creating user experiences [Sharp et al., 2023]. Designers and developers need to focus on the user and not the system. Two concepts are important to consider in interface design: *User Interface* (UI) and *User Experience* (UX). Users interact with applications through the UI. UX relates to users' perceptions of interacting with a product. They can be diverse, and the aim of measuring UX includes usability components and the emotional impact on the user. A positive impact allows the user to accept the interface better and be fault-tolerant, while a negative impact tends to determine that the interface is not used. This encompasses all the components that enable users to carry out tasks that cover the user's requirements in the context of use. Metaphors created with conceptual models are important, as they allow users to learn by analogy and draw on their existing knowledge to act in an unfamiliar domain [Helander, 2014].

1.3 Problem definition

To design interfaces adapted to the needs of older adults on smartwatches, in this study, a set of *proposed guidelines* (PGs) are being developed to propose guidance for application design for those specific devices. This work examines older adults' needs and challenges when interacting with digital interfaces. It then identifies existing design guidelines tailored to this demographic for other devices and considers the unique characteristics of smartwatches in this context. The objective is to integrate these insights to propose design guidelines suited explicitly for older adults, ensuring their practical applicability to smartwatches. By addressing a current gap

in the literature, this study aims to facilitate the development of interfaces that accommodate the needs of older adults, thereby enhancing their ability to use these devices effectively.

With this in mind, three main research questions are defined:

- *(RQ1)*: What specific challenges and impediments do older adults encounter when engaging with digital interfaces, particularly on smartwatches?
- *(RQ2)*: How do existing interface design guidelines tailored for older adults, originally developed for alternate devices, align with the design prerequisites and usability considerations inherent to smartwatches?
- *(RQ3)*: How can the PGs be illustrated in a way that addresses different contexts of application and facilitates their use in future work?

1.4 Objectives

The main objective of this work is to propose a set of guidelines for designing smartwatch interfaces for older users to improve their experience with these interfaces. The challenge is to address the difficulties associated with this target audience by considering design guidelines for other devices and synthesising them into design guidelines for smartwatch interfaces for older adults. Finally, these guidelines should be translated into interface examples and components grouped into a design system. A design system is a collection of standards, guidelines, and reusable design elements enabling organisations to ensure consistency, efficiency, and scalability when designing digital products, aiming at enhancing user experience [Perez-Cruz, 2019, Bergman, 2024].

The general objective can be divided into specific objectives as follows:

- *(O1)*: Conduct a comprehensive examination of the challenges and obstacles older adults face when interacting with digital interfaces, particularly on smartwatches, to gain insights into their specific needs and preferences. This objective relates to *RQ1*.
- *(O2)*: Examine the utilisation and functionalities of smartwatches to identify their particular features. This objective relates to *RQ2*.
- *(O3)*: Review and analyse existing interface design guidelines for older adults, originally developed for other devices, to assess their applicability and suitability for implementation on smartwatches. This objective relates to *RQ2*.
- *(O4)*: Propose guidelines for developing smartwatch applications for older adults, considering their needs and the particular characteristics of these devices. This objective relates to *RQ2*.

- *(O5)*: Develop a design system in line with the guidelines to optimise interface design for smartwatches, focusing on balancing simplicity and usability while accommodating a diverse range of functionalities focused on the needs of older adults. This objective relates to *RQ3*.

1.5 Expected results

Considering the objectives identified in the previous section, the following results are expected:

- A set of guidelines for designing smartwatch interfaces for older adults, based on indicators from a literature review of existing guidelines created for other devices. This result refers to objectives *O1*, *O2*, *O3*, *O4*;
- A design system for the design of smartwatch applications focused on the target audience, integrating the PGs. This result refers to objective *O5*.

1.6 Work plan

To achieve the objectives and the anticipated results, this work was developed through the following macro stages:

- Research into the main restrictions associated with older adults;
- Search for existing guidelines for older adults in different domains;
- Identification of the specific characteristics of smartwatches;
- Proposal of guidelines for the design of smartwatch interfaces for older adults;
- Creation of the design system based on the proposed guidelines.

Figure 1.2 shows the work plan resulting from these macro stages, including the document's writing process.

1.7 Thesis structure

This document is organised into six chapters. After this introductory chapter, Chapter 2 presents the state-of-the-art review and analysis of related work. Chapter 3 describes the methodology used for bibliographical research, the design of the proposed guidelines, and the design system. Chapter 4 explains the process for obtaining the proposed guidelines. Chapter 5 presents the creation of the design system. Finally, Chapter 6 presents conclusions, discusses the limitations of this study, and provides insights into future work.

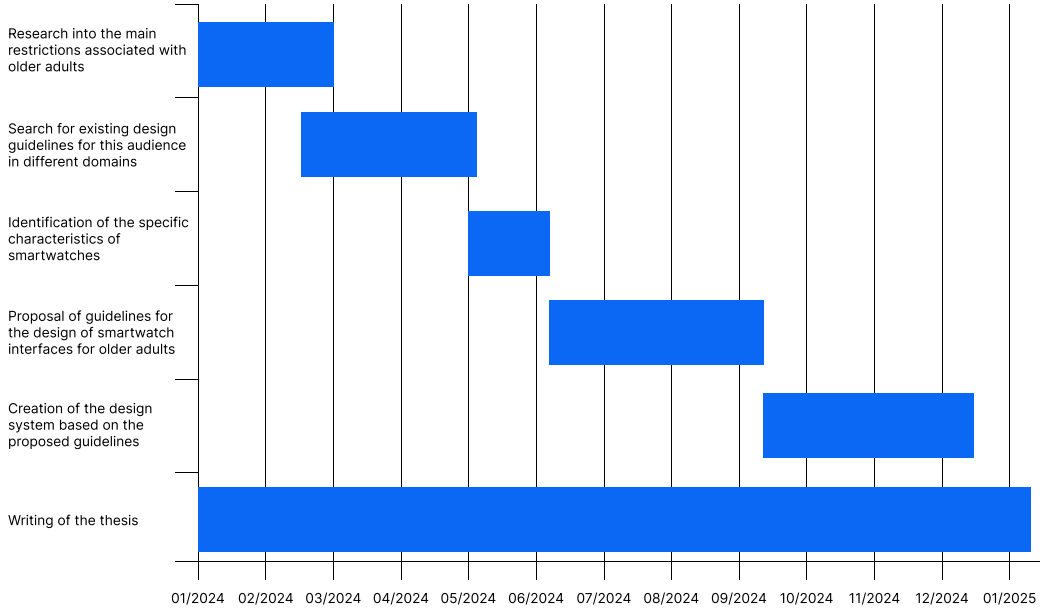

Figure 1.2: Gantt chart depicting the progression of this study.

Chapter 2

Literature Review

This chapter presents the theoretical framework of the study. The first section gathers relevant information on concepts associated with the related work, followed by a presentation and analysis of previous work relevant to the scope of this work.

2.1 Main concepts

Interaction design aims to create products that enable users to achieve their objectives in the best possible way. It focuses on the dialogue between users and technology, optimising interaction to improve the interface or product's appeal and usability. Interaction design is essential for shaping the user experience during interaction, so it is a practice that influences not only the effectiveness and ease of use of a product but also user satisfaction and emotion. The role of interaction designers is to define the architecture, functionalities, and interactions of digital devices, taking into account users' emotional and cognitive aspects and the context of the environment in which users interact. They aim to create a harmonious relationship with users by creating simple and meaningful experiences [Sharp et al., 2023, Huang, 2009, Foundation, 2024].

As referred in Chapter 1, users interact with applications through the **UI**. This includes all the components that enable users to carry out tasks that cover the user's requirements in the context of use. The primary objective of a user interface is to allow efficient and easy interaction between the user and the system [Miraz et al., 2021, Geeksforgeeks, 2024a, Indeed, 2024]. Also, **UX** pertains to how users

perceive a product, encompassing a variety of perspectives. The measurement of UX focuses on both the usability elements and the emotional impact on the user during interface interactions. A positive impact fosters user acceptance and tolerance for faults, whereas a negative impact indicates that the interface is unlikely to be utilised [Rusu et al., 2015, Norman and Nielsen, 1998].

Design guidelines are recommendations to guarantee consistency and best practices when designing products, applications, or websites (which will be referred to as "Domains" in this thesis). Guidelines provide designers with a structured framework to ensure the final product is user-friendly and easy to use. They can encompass various aspects such as typography, colours, navigation, and layout. Design guidelines can support designers in avoiding common mistakes, enhancing usability, ensuring consistency, and creating designs that effectively address users' accessibility requirements [Hartson, 2012, Geeksforgeeks, 2024b].

2.2 Related work

The design of smartwatch interfaces for older adults has received very little attention in the literature. To the best of our knowledge, the work of [Samaddar and Petrie, 2023] is the only one that refers to this subject. It aimed to develop a user-centered smartwatch application that enhances independent living, providing a range of supportive functionalities considering older users' opinions and design concerns. To this end, the authors designed a high-fidelity application prototype and tested it by asking 32 older users to carry out tasks. This allowed them to explore older adults' attitudes towards smartwatch technology for independent living, including their perceptions of usability and ease of interaction with a smartwatch application designed for them. In contrast to our work, which used existing guidelines for other devices, these authors developed guidelines based on the information obtained from older users' experiences during this test phase. Finally, the smartwatch application was developed based on these guidelines and evaluated with older users, providing valuable feedback for refining their guidelines. The guidelines proposed in this study are as follows: G1. Do not assume all users know how to use touch interfaces and gestures; G2. Accept multiple types of tapping. Consider increasing the input time for a tapping gesture to allow for older users with limited mobility or reduced dexterity; G3. Interactive elements should either have sufficient space between them or be big enough to account for inaccuracies in tapping gestures; G4. Keep swiping gestures to a minimum; G5. Use high contrast between text and background colour; G6. Use different colours to increase memorability and learnability for older users who cannot read the text and do not wish to use icons. Consider that older users may prefer text labels to icons; G7. Use text size as large as possible. (Font sizes

differ across devices and operating systems. For reference, 14px should be the minimum size used); G8. Where possible, avoid icons unless these are acceptable and understandable to the target user group.

Meanwhile, several sets of guidance for designing applications for older adults but focused on other devices (e.g., mobile applications, websites) have been proposed in the literature. Researchers presented a theoretical review of solutions for mobile technology design for older adults, which is motivated by the assumption that an improvement at the design level can bring a higher acceptance and use of technology for older adults [Iancu and Iancu, 2020]. This review begins by considering the cognitive and physical characteristics of older adults. It emphasises key factors that should be considered when designing technology for older adults and the main elements a device intended for this demographic should possess. Furthermore, it provides insights into the current offerings in the market. This study brings several contributions. First, it aims to comprehensively discuss the role of design within the technology acceptance process. Secondly, it sheds light on older adults' technological and personal profiles, highlighting the challenges and issues they face as they age. Thirdly, it develops an orderly approach to how technology can confute these issues through design. Lastly, it addresses the existing technology offered to older adults.

Other authors [Gomez-Hernandez et al., 2023] systematically reviewed the scientific literature that provided recommendations for the design of mobile applications based on usability testing with older adults and organised such recommendations into a meaningful set of design guidelines. Their approach involved a systematic literature review encompassing articles published between 2010 and 2021. Studies that conducted usability tests with individuals aged over 60 and provided guidelines for mobile application design were included in the analysis. This led to a compilation of 27 interface design guidelines. Among the derived guidelines, two key principles emerged as particularly significant: simplifying the design and increasing the size and spacing of interactive controls. The remaining guidelines were categorised into five distinct groups with corresponding subcategories. Those guidelines support the design of mobile applications that cater to the needs of older adults.

Moreover, Patsoule and Koutsabasis [Patsoule and Koutsabasis, 2014] presented a case study of redesigning a website to better suit the needs of older adults. During the redesign process, the authors, first identified a set of 45 guidelines for web design for older adults. Secondly, they conducted a heuristic evaluation of the original website based on the identified guidelines. Thirdly, they redesigned the website using an interactive online prototype. Finally, a comparative usability evaluation of the two websites was performed involving 12 older users and post hoc interviews and questionnaires. The results showed that the redesigned website was significantly more usable and acceptable than the original.

Furthermore, a study on mobile health applications designed for older adults

has been carried out [Morey et al., 2019]. Due to the lack of existing guidelines for designing these applications, specifically for older adults, they aimed to derive guidelines from usability tests, enabling designers to create health applications that could be used successfully by one of their primary target user populations. First, three healthcare applications were evaluated using cognitive walkthroughs, heuristic analysis, and user testing to achieve this objective. Based on these evaluations, several design problems were identified that may limit usability by older adults, such as poor navigation, small button sizes, and inadequate data visualisations. Then, based on those findings, a list of guidelines was provided to facilitate mobile health application usability for older users. Nine guidelines were found to provide solutions to address older adults' cognitive, perceptual, physical, and motivational needs.

Other researchers [De Barros et al., 2014] presented the design and evaluation process of a mobile application user interface designed to promote exercise and prevent falls among older adults. Several interfaces were designed iteratively based on feedback from usability tests. Each usability test session brought to light the users' difficulties, which led to improvements that were subsequently tested to achieve a more user-friendly interface. Then, once the three iterations of design and testing had been completed, the authors proposed general recommendations for designing a mobile interface targeted at older adults based on the results obtained.

In addition, Nurgalieva et al. [Nurgalieva et al., 2019] presented a systematic literature review of research-derived design guidelines indicated for older adults to discover, classify, and evaluate the work carried out in the field of touchscreen design guidelines. This review includes an analysis of 52 research articles, resulting in several research-derived design guidelines for touchscreen applications. Then, guidelines derived from the literature were analysed using taxonomy and formed a list, which could be used while developing inclusive touchscreen applications.

Researchers conducted a literature review on mobile health applications to examine barriers and identify gaps in knowledge that require further research to improve the accessibility of mobile health use among older adults [Li et al., 2021]. Considering that older adults are increasingly adopting mobile devices and that these mobile applications represent an innovative approach to delivering health information but often have design flaws that may limit their use by older users, the authors were motivated by the fact that it is necessary to ensure that older adults can effectively utilise these applications. In this work, the authors summarise common barriers to older adults' adoption of mobile health apps and recapitulate design considerations for interfaces tailored to these applications and users.

Other authors analysed the literature to present design guidelines focusing on older adults [Farage et al., 2012]. Firstly, the authors gave a detailed description of age-related changes and their impact on daily life. They classified these changes into

five categories: visual function, hearing, touch and temperature perception, mobility and balance, and memory and cognition. For each category, the authors proposed several design guidelines to respond to the age-related changes described, focusing on the design of products, communication materials, and physical environments. These guidelines should enable design professionals to take account of these changes and better meet the needs of older people.

Finally, researchers have proposed recommendations for the design of wearable devices for the older population [Lewis and Neider, 2017], with the motivation that digital wearable technology can aid everyday life, helping to alleviate age-related challenges in many areas such as health and well-being. The wearable devices concerned in this work can be worn on the wrist, on the head, or attached to clothing, with which users can interact without needing to hold it. Firstly, the authors assessed the audience regarding cognitive, physical, and sensory abilities, outlining age-related problems and their consequences. They then proposed 23 recommendations for the design of wearable devices based on the public's assessment.

The aforementioned studies offer numerous guidelines to help designers consider the difficulties associated with older adults during the design process. However, while some of these guidelines are usable on smartwatches (e.g., provide high contrast between foreground and background colour), others could be challenging to apply. Indeed, smartwatches are very different from traditional smartphones, tablets, or computers. These are much smaller devices, which means a much smaller touch screen. This feature calls for rigorous space management in the interface to facilitate easy reading and understanding. Some guidelines seem, therefore, difficult to apply, such as "Use simple and static menus"; "Avoid locating controls close to the edge of the screen", and "Designers should avoid scrolling". Thus, the significant differences between the devices make the work of previous authors not directly applicable to the subject of this study.

2.3 Smartwatches

A smartwatch is a wearable device that merges the functions of a traditional watch with advanced features akin to those found in smartphones and other digital devices. Essentially, it is a tiny wearable computer designed to resemble and fit the size of a wristwatch. Like a smartphone, a smartwatch uses a touch screen, often supplemented by a few side buttons. They primarily function as satellite devices, collecting valuable data from paired smartphones via wireless Bluetooth connections. These devices can also be equipped with Wi-Fi connectivity for an Internet connection without relying on the smartphone. They can also include Long Term Evolution (LTE) cellular connectivity, enabling the smartwatch to connect to mobile networks autonomously without needing a smartphone nearby to make calls, send

messages, or use applications. Those devices provide more convenient, quicker, and alternative access to information, particularly in cases where using a smartphone is impractical or impossible [Kim and Shin, 2015]. It shares similarities with smartphones regarding hardware and software, particularly in working memory, storage memory, processor, and operating system. The most commonly used operating systems for smartwatches are Android Wear and Apple Watch OS. They also feature wireless connectivity via Bluetooth or WiFi. Most devices have an LCD or OLED touchscreen and are usually powered by a rechargeable Lithium-ion battery, such as smartphones [Dehghani and Kim, 2019]. They are designed to be lightweight, thanks to their small size and the materials used, such as polymer, aluminum, and titanium [Luo, 2023]. This lightness means they can be worn all day and avoid feeling too bulky on the wrist.

Manufacturers are offering a range of essential functions, such as weather, SMS, phone calls, audio and video playback, FM radio reception, e-mail, calendar, timer, alarm and wake-up call, calculator, Bluetooth connectivity, display notifications from a paired smartphone, measurement of the wearer's physical activity, and a voice assistant for dictating text messages and taking advantage of assistance functions. Health applications take advantage of the sensors installed on these devices to collect data previously reserved for medical or sports equipment, such as sleep, blood oxygen saturation, and heart rate monitoring [Ben Lutkevich, 2022, SamsungGroup, 2024b, Islam et al., 2020]. The device's small size complicates conventional text input using a keyboard. However, smartwatch manufacturers generally promote other means of input that avoid using a keyboard. In particular, they can dictate a message or respond using answers suggested by artificial intelligence, as Samsung does on the Galaxy Watch 7 [SamsungGroup, 2024a].

Smartwatches may include sensors such as a GPS sensor for geolocation, essential for certain functionalities (e.g., weather, assisted navigation), movement sensors such as a gyroscope and an accelerometer, critical for energy savings (e.g., automatically turning the screen on or off), pedometer for monitoring physical activity such as measuring steps and routes. Other sensors are designed for specific applications, such as barometers and thermometers for displaying the weather, and NFC for contactless payments. More recent sensors focus on health: infrared sensors for pulse and blood oxygen levels and electrical sensors for electrocardiograms [Design, 2024, King and Sarrafzadeh, 2018, Kamišalić et al., 2018].

Studies have highlighted the use of these devices in various fields, such as fall detection [Mauldin et al., 2018, Vilarinho et al., 2015, Kostopoulos et al., 2015, Casilari and Oviedo-Jiménez, 2015], real-time activity monitoring [Kheirkhahan et al., 2019, King and Sarrafzadeh, 2018], or analysis of health data concerning, for example, the cardiovascular system, blood pressure [Lima et al., 2022, Himi et al., 2023, Bhanvadia et al., 2022, Han et al., 2023], user's stress level [Siirtola, 2019],

or posture analysis [Erdem et al., 2019]. These devices can also be used for daily assistance, for example, in the field of medication adherence [Kalantarian et al., 2015, Aldeer et al., 2018], or regarding people suffering from cognitive difficulties [Thorpe et al., 2016].

Smartwatches exhibit specific characteristics compared to commonly used devices like smartphones, tablets, or computers. They include their small screen size, lightweight design, minimal or absent physical buttons, alternatives to keyboard input, resemblance to conventional watches, and the integration of diverse sensors. In particular, the compact screens, wrist-worn nature, and lightweight design contribute to their portability and convenience. Finally, their resemblance to standard watches makes them discreet and unobtrusive.

2.4 Challenges for older adults

As individuals age, they experience various changes affecting their physical, cognitive, emotional, and perceptual abilities. These age-related transformations can influence their daily activities, health, and overall quality of life. Understanding these changes is essential for designing interfaces that effectively address the unique needs of older adults, thereby enhancing usability and supporting their well-being.

2.4.1 Visual

Near-focus impairment is one of the earliest signs of aging, known as presbyopia. This condition occurs as the eye's crystalline lens becomes stiffer and less flexible, hindering its ability to focus on close objects and resulting in blurred vision [Cota et al., 2015]. Presbyopia typically becomes noticeable around age 40 and progressively worsens over time. It can be effectively managed with corrective lenses, such as reading glasses, which compensate for the reduced flexibility of the lens and help restore near vision [Iancu and Iancu, 2020, Lewis and Neider, 2017, Farage et al., 2012, Wildenbos et al., 2018]. Another prevalent age-related visual change is a decline in visual acuity or the sharpness of vision. This condition reduces the clarity of objects, making them appear less distinct. A common cause is cataracts, characterised by the opacification of the eye's natural lens, resulting in blurred or hazy vision. Additional causes include retinal diseases such as macular degeneration, which impairs the perception of fine details and may cause objects to appear distorted or blurred, and diabetes-related eye complications. Furthermore, visual field narrowing is another issue affecting older adults, leading to reduced peripheral vision and compromising their ability to detect objects or movements outside their central field of vision [Farage et al., 2012, Wildenbos et al., 2018].

Age-related changes in the lens and retina can naturally lead to a decline in colour perception. Specifically, sensitivity to colours within the violet-blue-green range of

the spectrum tends to diminish, while colours in the yellow-orange-red range remain more easily distinguishable. Consequently, older individuals generally find it easier to perceive and differentiate bright, warm colours compared to cooler tones [Farage et al., 2012, Wildenbos et al., 2018]. In addition, the ability to detect contrast often diminishes with age. This decline can be attributed to various factors, including changes in the eye lens, retina, and visual processing pathways. Thus, older adults may have difficulty distinguishing objects from their background, especially in low-light conditions or environments with poor contrast. There is, therefore, a need to increase contrast to make it easier to distinguish between elements [Cota et al., 2015, Farage et al., 2012, Wildenbos et al., 2018, Li et al., 2021].

Older adults adapt more slowly to changes in illumination, particularly when transitioning to darker environments. This is primarily due to a decrease in the number of photoreceptor rods in the eye, which reduces light perception. For instance, individuals with this limitation may require more time to adjust when moving from bright to dimly lit surroundings. As a result, higher levels of illumination and enhanced contrast are necessary to improve visual clarity [Iancu and Iancu, 2020, Farage et al., 2012, Wildenbos et al., 2018]. Additionally, the pupil becomes smaller with age, allowing less light to enter the eye and increasing the need for brighter lighting to achieve sharp vision. A 60-year-old, for example, requires approximately twice as much light as a younger person to see clearly. Older adults also exhibit heightened sensitivity to glare, where direct or reflected light impairs vision. This issue may be exacerbated by changes to the vitreous humour or the presence of cataracts, which scatter light within the eye. Consequently, providing adequate lighting is crucial to minimise glare and optimise visual clarity for older adults [Iancu and Iancu, 2020, Farage et al., 2012, Wildenbos et al., 2018].

2.4.2 Hearing

Auditory sharpness frequently diminishes as a natural part of the ageing process. In fact, during ageing, cellular atrophy occurs in the cochlea, which is the primary detector of incoming auditory signals of the hearing sensory system. [Lewis and Neider, 2017]. This decline, known as presbycusis, usually includes progressive hearing loss deteriorating over time, difficulty hearing high-frequency sounds, and ringing or whistling in the ears commonly known as tinnitus [Fisk et al., 2020, Iancu and Iancu, 2020, Lewis and Neider, 2017, Farage et al., 2012]. As a result, sound perception and voice recognition are significantly impaired, particularly for low-intensity sounds, which appear to be muffled.

In addition, older adults have difficulty identifying the location of a sound, stimuli to one ear can, therefore, cause disorientation [Farage et al., 2012].

Regarding auditory attention, older adults have difficulty disregarding competing information that reaches the ears. This difficulty affects the differentiation of speech

from background noise and speech recognition. Furthermore, understanding distinct sounds at fast rates is an additional difficulty, as recall diminishes as the rate of speech increases. This decline can also affect performance in multitask environments [Iancu and Iancu, 2020, Lewis and Neider, 2017, Farage et al., 2012, Wildenbos et al., 2018].

2.4.3 Motor-control

Throughout the ageing process, there is a reduction in grey matter volume within the brain structures involved in movement coordination. Parkinson's disease, Huntington's disease, multiple sclerosis, and arthritis can worsen the decline in motor function, resulting in restricted movement and discomfort due to inflammation and pain. These changes have many consequences for the behaviour of older adults. In particular, synchronisation and precision are impacted, which means that movements made by older adults may take longer and be less precise [Fisk et al., 2020, Iancu and Iancu, 2020, Chen et al., 2013]. This results in a decreased ability to handle buttons, for example, when typing on a keyboard [Lewis and Neider, 2017, Farage et al., 2012, Chen et al., 2013]. Additionally, the ability to perceive touch-based stimuli, which can be important when interacting with an interface, is diminished [Fisk et al., 2020]. This decrease becomes noticeable around the fifth decade and is more visible from the age of 65 or 70 [Farage et al., 2012]. Decreased sensitivity to pressure can make it harder to perceive contact with a surface or button press.

In addition, joint pain and stiffness caused by certain conditions, such as arthritis or rheumatoid arthritis, can make it difficult to grip and hold objects, especially with just one hand [Wildenbos et al., 2018, Seidler et al., 2010]. Finally, the ability to time and execute movement in a coordinated way is reduced. Hence, actions such as double clicking a computer mouse, and drag and drop, pose a challenge for older adults [Farage et al., 2012, Seidler et al., 2010].

2.4.4 Cognition/Memory changes

Cognitive ageing losses are related to a reduced capacity for executive functions such as attention, memory, decision-making, comprehension, and spatial cognition. At the neural level, these changes are linked to the fact that the prefrontal cortex, a brain region associated with executive function, experiences a significant reduction in tissue volume with advancing age compared to many other brain structures [Lewis and Neider, 2017].

The decrease in attention, the capacity to maintain focus on a particular stimulus, implies that it takes longer to shift attention, and older adults may struggle to suppress irrelevant information. Understanding information quickly, making timely

decisions, and managing several tasks simultaneously are a challenge [Iancu and Iancu, 2020, Farage et al., 2012, Li et al., 2021, Cota et al., 2015].

Challenges with working memory – the active memory used to process and retain information currently being perceived or considered – may not significantly affect simple tasks. Still, they can impair the ability to recall multiple instructions or pieces of information. Older adults are particularly susceptible to information overload and difficulty multitasking, as their capacity to retain large amounts of information in working memory diminishes with age [Cota et al., 2015, Iancu and Iancu, 2020, Farage et al., 2012, Wildenbos et al., 2018]. In the context of prospective memory – the ability to recall planned actions or tasks scheduled for specific times – older adults may find remembering time-based tasks more challenging than event-based ones. For instance, remembering to take medication at a particular time may be more complex than recalling a task prompted by an external cue, such as a sound or visual reminder [Lewis and Neider, 2017, Farage et al., 2012].

Procedural memory refers to the ability to retain skills and tasks acquired in the past, including well-practiced routines performed almost unconsciously, such as driving. This type of memory generally remains well-preserved in older adults. Although older individuals can transfer existing skills to new contexts and acquire new skills, the learning process may take longer and benefit from a slower pace, along with increased opportunities for practice and repetition to achieve proficiency [Farage et al., 2012].

Language comprehension is also affected as individuals age, making it more challenging for older adults to understand verbal and written information and make inferences. Specifically, subtlety, irony, and unfamiliar context can hinder understanding [Farage et al., 2012, Federmeier et al., 2010].

Finally, spatial cognition, which involves the mental manipulation of spatial information, becomes increasingly challenging with age. This decline can adversely affect performance in computer-based tasks and the ability to orient themselves. Additionally, a reduced capacity for executive functions such as attention, memory, decision-making, comprehension, and spatial cognition can significantly impact older adults' effectiveness and ease of interface use [Iancu and Iancu, 2020, Wildenbos et al., 2018].

2.4.5 Motivation

Confidence is critical in influencing the willingness to adopt new technologies [Berkowsky et al., 2017]. Barriers such as limited digital skills, negative experiences with previous technology failures, and computer anxiety significantly can impede the adoption and effective use of digital technologies [Wildenbos et al., 2019]. A lack of familiarity with technology and anxiety related to its use can diminish users' perceptions of its ease of use and usefulness, reducing their motivation to engage

with it [Ferreira-Brito et al., 2024, Berkowsky et al., 2017]. Low confidence, in particular, can be a substantial obstacle to the effective use of technology and the initial willingness to attempt using it [Siren and Knudsen, 2017, Li et al., 2021].

2.5 Technology adoption among older adults

Numerous technologies have the potential to significantly improve the quality of life for older adults in various domains, including health monitoring, home automation, social connectivity, cognitive and mental support, and mobility. Technological advances can benefit older adults by promoting their independence and improving their daily lives despite the difficulties associated with ageing. There is a disparity in technology adoption rates between older and younger populations, with older adults less likely to adopt new technologies [Friemel, 2016, Anderson and Perrin, 2017]; this prevents them from taking advantage of the potential benefits. This might suggest that this audience has little interest in using technology. Still, studies have been carried out on the acceptability and use of technology by older adults, concluding that older adults can be interested in learning how to use it. Participants in these studies came from various social and geographical backgrounds and had different cognitive abilities and knowledge of technology. These disparities did not impact the results obtained by the researchers, regardless of the technology tested. Participants expressed a strong interest in using mobile applications to track their health observations and symptoms. They emphasised the benefits of mobile health apps that offer enhanced interactivity, individualised health monitoring, and personalised medication information [Park et al., 2020]. Older adults also expressed an interest in using a communication application [Neves and Mead, 2021]. As other research indicates, they recognised the benefits of digital technology, and most were keen to learn how to use it effectively [Barbosa Neves et al., 2019, Betts et al., 2019]. Overall, older adults can be motivated by learning to use new technologies that can help them improve their quality of life and maintain their independence [Heinz et al., 2013].

Older adults can not only be interested in technology, but can also adopt it and use it on a daily basis. Many areas and devices have been reviewed by researchers, such as technology-based exercise, which had a reasonable utilisation rate [Valenzuela et al., 2018]. Concerning the use of mobile technologies for medication adherence, older adults can be committed users, as mobile applications are perceived as useful tools for taking medication [Park et al., 2020]. In addition, a device such as a wristwatch enabling monitoring health conditions can also have a high take-up rate and be adopted for long periods of time [Evans et al., 2016]. Finally, it should be noted that in these studies, the personal situation of the participants had no significant impact on their willingness to learn to use the technology. However, it was

noted that preconceived ideas about ageing and technology could negatively affect their confidence and motivation.

Several factors significantly influence the decision to adopt new technologies. Notably, perceived value and impact on quality of life [Peek et al., 2014, Moxley et al., 2022]. The fact that technology is deemed useful and can positively impact daily life is a factor contributing to its adoption. Evidence for a direct link between perceived usefulness and technology adoption has been found across various technologies [Lee and Coughlin, 2015].

Support and training before and during the use of technology are also important factors to consider. Older adults are often less familiar with and confident about new technologies than younger people. Thus, proper training and appropriate support could be important [Lee and Coughlin, 2015]. Older users prefer to be trained before using a new technology. Training programmes, including written manuals and face-to-face training, can be more effective if designed to account for low technological literacy, lack of confidence in new technology, and age-related difficulties [Neves and Mead, 2021, Heinz et al., 2013, Lee and Coughlin, 2015]. In addition, individuals within the social circles of older adults, including family and friends, can play a crucial role in helping and motivating older users [Peek et al., 2014, Neves and Mead, 2021, Lee and Coughlin, 2015].

Personal privacy violations and data privacy concerns are also important in technology adoption. Older adults still have suspicions about new technology, even those accustomed to using computers or mobile phones [Park et al., 2020, Heinz et al., 2013, Li et al., 2021]. While privacy is a concern for older adults, they may be willing to compromise some privacy if the technology offers significant benefits [Peek et al., 2014], including remote monitoring and data sharing with healthcare professionals to identify emerging health issues [Evans et al., 2016].

Not surprisingly, a critical factor in technology adoption is ease of use. This characteristic refers to how users can use a technology effectively and satisfactorily. That implies enabling users to perform their tasks accurately in a reasonable time, making learning and understanding the technology easier and minimising errors and, therefore, user frustration. Older adults can be apprehensive about technology because of concerns and frustrations about ease of use, which may inhibit their desire to adopt it. In this context, usability can be the source of user satisfaction [Hawley-Hague et al., 2014]. This audience, therefore, generally chooses to adopt the technology that is easiest for them to use [Evans et al., 2016, Neves and Mead, 2021, Lee and Coughlin, 2015]. Thus, older adults who find an application both beneficial and easy to use are more likely to adopt and integrate it into their daily lives [Neves and Mead, 2021].

Technology should be designed with emotional considerations in mind. A product's ability to connect the users to something they feel is a significant part of its

appeal [Lee and Coughlin, 2015]. Those affective benefits should also be evident to our target audience. For example, devices that enhance communication and family interaction, or features that allow for personalisation with meaningful characteristics (e.g., using a voice message from a loved person), may imply greater motivation on the part of this audience [Rodríguez et al., 2009].

The desire for independence significantly influences technology adoption among older adults [Peek et al., 2014]. Technologies that help older adults to remain independent, enabling them to manage their daily activities and health, and that do not emphasise ageing or frailty are more likely to be adopted by this audience [Lee and Coughlin, 2015]. Smartwatches, for example, seem to meet this need. They offer many features that can be useful for this audience, while at the same time being commonly used devices [Manini et al., 2019, Ding et al., 2022, Thorpe et al., 2016, Vargemidis et al., 2021].

Chapter 3

Methodology

This chapter presents the methodology used during the development of this work. Firstly, it addresses the bibliographical research and the topics and areas of research. Secondly, it presents the project implementation process.

3.1 Bibliographical research

The bibliographical research was carried out using a four-stage procedure, described in Figure 3.1. The first stage consisted of searching for works related to this project's subject using appropriate keywords. Searches were carried out using various sources of information, such as the scientific literature from Google Scholar and b-On resources. They included keywords associated with Interaction design, guidelines, smartwatches, and older adults, such as Design guidelines, Design recommendations, Design principles, usability, smartwatches, smartwatch applications, technology adoption, technology use, older adults, elderly, elders, seniors, aging, age-related changes, universal design, aging barriers. These keywords make reaching for scientific literature on human-machine interaction, guidance, health, and technology feasible. The second stage consisted of selecting potentially interesting works by examining their titles, and then their abstracts, introductions, and conclusions. By taking into account these important sections, the aim was to determine whether those research subjects were compatible with this work. As for the identification of existing guidelines, we did not consider research providing design guidelines that were not relevant to our target audience.

The third stage aimed to select quality works; it was based on a complete reading of the works selected in the previous step, analysing them in detail, in terms of the work carried out and other factors such as the number of citations, language, year of publication and the indexing of the journals in which they are published. Only scientific literature written in English with several citations and published in Scopus or Web of Science-indexed journals were considered. The period covered by the bibliographic sources regarding interface design guidelines extends from 2012 to 2024, with recent sources. The final stage involved synthesising the relevant articles and extracting information of interest. In particular, if it was a work proposing guidelines, they were extracted to list them.

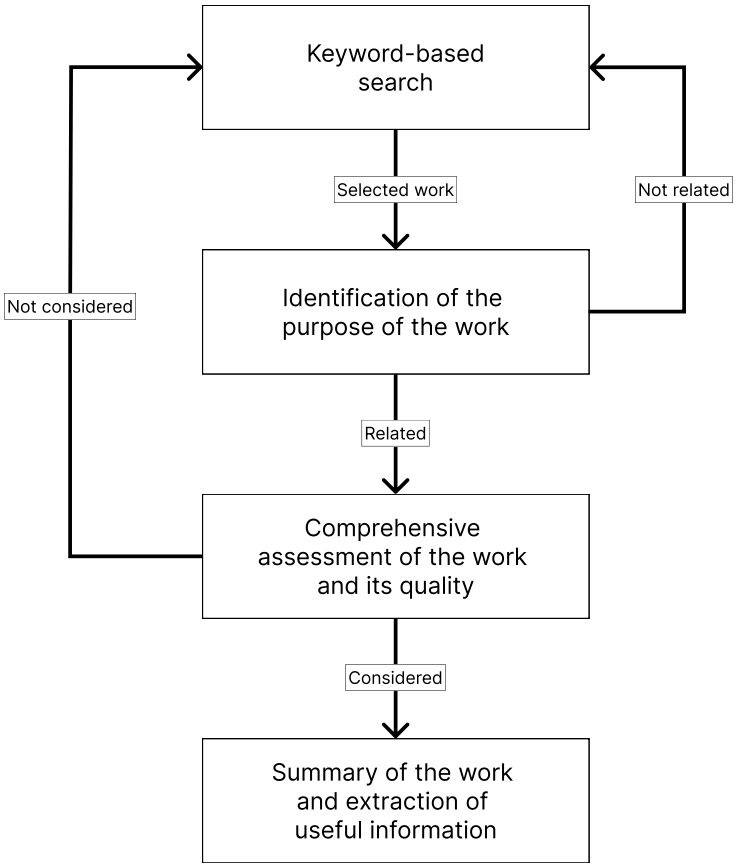

Figure 3.1: Bibliographical research methodology.

3.2 Implementation process

Several steps must be taken to develop interface design guidelines for smartwatch applications that support older adults. The process workflow is summarised in Figure 3.2.

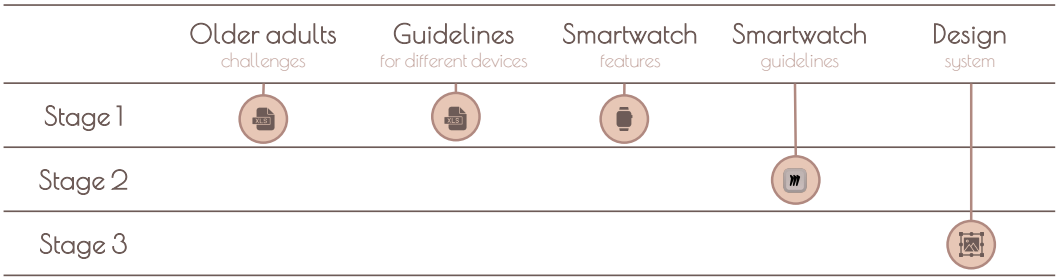

Figure 3.2: Process workflow.

A review of the existing scientific literature is required to carry out the proposed work in this thesis. Firstly, it is crucial to understand the difficulties older adults face since age-related changes in visual, auditory, perceptual, motor, and cognitive abilities (as referred in Chapter 2), coupled with a lack of experience with digital interfaces, are key factors in understanding the needs of older adults and adapting interfaces accordingly. Secondly, it is necessary to analyse the guidelines for designing interfaces for older adults geared toward different devices to establish common points between them, which will provide important indicators for the proposal of guidelines in the case of smartwatch interfaces. As part of this project, it is necessary to extract and group the guidelines found in the literature into a list to satisfy the previous point. Finally, the identification of the peculiar features of smartwatches, through an examination of their utilisation and functionalities, is important to evaluate the applicability of the extracted guidelines.

The methodology used to arrive at the PGs consists of eight stages, described chronologically in Figure 3.3.

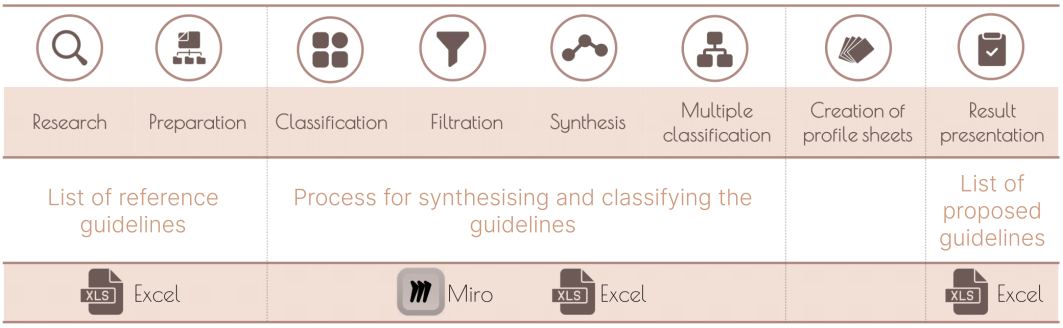

Figure 3.3: Stages of the process leading to the proposal of the guidelines.

Once the search had been conducted under the above-mentioned conditions, 175 guidelines from 8 different studies were obtained. In this work, we have called these guidelines, derived from the research results, *reference guidelines* (RGs). Those guidelines were listed using an Excel table called *List of reference guidelines*. Secondly, several RGs with different formats were prepared to be compatible with the

other guidelines for the following stages of the work.

Thirdly, a Miro file named *Process for synthesising and classifying the guidelines* was created. Miro is a collaborative platform used to facilitate communication and the visual presentation of projects. The RGs were classified and sorted into subcategories based on similarity. Then, the classified RGs were analysed according to the constraints imposed by the identified particular features of smartwatches and were compared with each other to identify any potential contradictions. This step led to their filtration concerning their compatibility with smartwatches and their contradictions. Subsequently, the study of the similarities between the prepared and filtered RGs enabled their synthesis into the PGs. Finally, as the initial classification, using one class per guideline was not considered appropriate for this project; a switch was made to a multiple criteria classification with several classes per guideline. Figure 3.4 shows the stages involved in the *Process for synthesising and classifying the guidelines*.

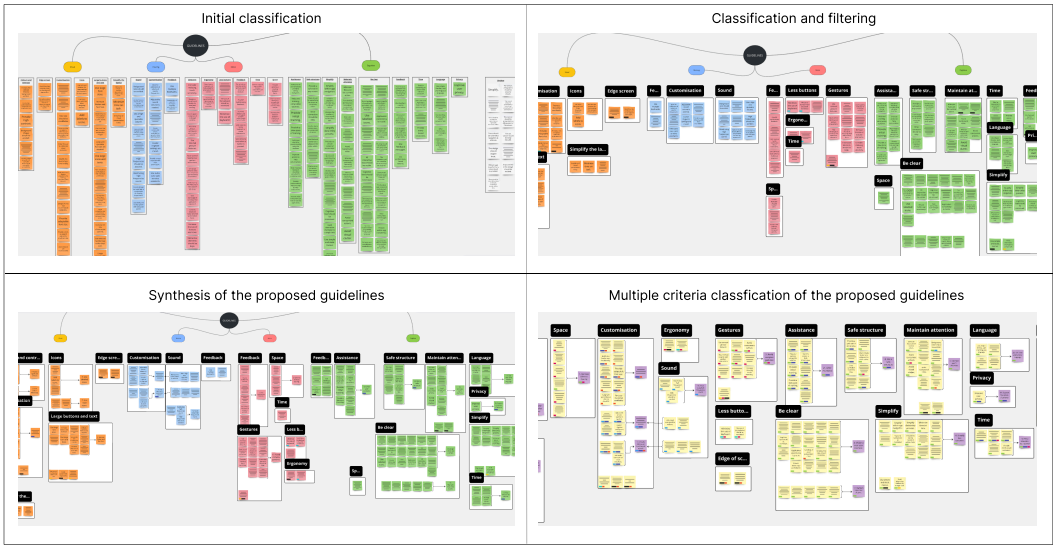

Figure 3.4: Synthesis and classification of the PGs based on the research (non-visible information is presented for illustration purposes).

Once the PGs had been determined, profile sheets summarising their information were produced for each, making it possible to study them quickly and easily. Also, two new worksheets were added to the Excel file. The first, called *Guidelines overview*, summarises the results of the analysis and synthesis for each RG, allowing to quickly see which RGs led to which PGs or to see which RGs have been filtered. The second, is called *List of proposed guidelines* and contains the PGs detailing their domains of origin, titles, synopsis, explanation, and classification.

The previous step provides a framework for developing a design system using Figma software, comprising generic components and suggesting concrete examples of applying the PGs. This set of design elements could make it easier to understand

Figure 3.5: Stages involved in the design system creation.

and use these guidelines in other works involving the design of smartwatch interfaces for this target audience. The stages in the development of this part of the work are described in Figure 3.5. Firstly, we considered possible examples of concrete cases for which the guidelines could be used. Following this stage, several examples were chosen to illustrate the use of the guidelines. Next, we designed the components in the interfaces idealised in the previous stage, such as buttons and lists. Finally, we designed the suggested interfaces applying the PGs using these components.

Chapter 4

Guidelines

This chapter presents, in detail, the work carried out to propose smartwatch interface design guidelines for older adults.

4.1 Preparation and filtering

As introduced in Chapter 3, we created a *List of reference guidelines* enumerating the guidelines from the literature. This list was initially composed of 4 columns: "Number", "Author", "Domain", and "Guideline". The Number column contains the identification index allocated to each RG; the Author column describes the name of the authors to recognise the origin of the guideline easily; the Domain column reveals the scope or type of device for which the RG was proposed, and finally; the Guideline column lists the original title of the RGs, or if it does not have a title, a portion of text from which these guidelines were extracted. Eventually, we added a fifth column, "Explanation", as shown in Table 4.1, to host a more precise description of the guidelines. We have researched and extracted the authors' explanations from their original works for each RG. If a RG has no text explaining how it works, the corresponding cell in this column has been left empty.

Once the RGs had been listed, their analysis could begin. During our research, specific guidance concerning the design of interfaces for our target audience was described as "guidelines" but were in the form of texts. We have, therefore, extracted these texts and placed them in the "Explanation" column. We have isolated their

Table 4.1: Examples of the initial analysis for the *list of reference guidelines*.

RG	Author	Domain	Guideline	Explanation
1	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	The screens should be large enough to incorporate icons of at least 9.6 millimeters diagonally (or 11 millimeters if a mouse is used).	—
2	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	Font sizes bigger than 16 pixels and adjustable.	—
3	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	Space between interface elements that function in a sequence manner should be around 0.2 cm, and the space between unrelated buttons should be around 1 cm apart in the diagonal.	—
...	...	...	...	...
25	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	—	While having a minimum display items, task-relevant information only, and no parallel information at the same time.
...	...	...	...	...
56	Gomez-Hernandez et al.[Gomez-Hernandez et al., 2023]	Mobile	Provide multisensory feedback.	Because older users may experience perception limitations, multisensory feedback will increase the probability that messages will get to users correctly. In this manner, we provide multiple options to users with limitations in hearing or vision.
57	Gomez-Hernandez et al.[Gomez-Hernandez et al., 2023]	Mobile	Show clear feedback after control tapping, as subtle feedback might not be noticed.	Limitations in perception may lead the user to miss subtle feedback; therefore, feedback should be clear and always provided to respond to an explicit user action, such as control tapping. Older users may not notice subtle changes in the color of a pressed button and have a higher risk of tapping outside the target. Therefore, provide bolder interaction feedback anytime the tap has occurred so that the user is aware of having tapped a control.
58	Gomez-Hernandez et al.[Gomez-Hernandez et al., 2023]	Mobile	Do not rely on vibration as the primary way of providing feedback.	Designers should not consider vibration and tactile feedback as the only means of conveying information because older users may not notice it.
59	Gomez-Hernandez et al.[Gomez-Hernandez et al., 2023]	Mobile	Increase response time for feedback information, and time-outs.	Long time-outs in input interaction modes allow users time to interpret the screen and decide on their next action. In this regard, the time for feedback information on the screen should be long enough for users to process, such as in the case of pop-up messages.
...	...	...	...	...
116	De Barros et al. [De Barros et al., 2014]	Mobile	Use the back button as a safeguard for older adults.	After learning how to use the back buttons, either on their own or after a demonstration from the test facilitator, participants were able to use these to navigate through the application structure. Also, participants seemed to use the back button when disoriented. Therefore, test results lead us to believe that the back button is important as a fall-back mechanism that older adults rely on when they do not know how to solve a given problem.
117	De Barros et al. [De Barros et al., 2014]	Mobile	Take advantage of scrolling if the application requires it.	Our results suggest that, after being taught how to do it, older adults can perform a swipe gesture to navigate an interface. Given that swiping to scroll might not be an issue for older adults, it could be possible to make use of it without additional visual aids, such as arrows on the screen.
...	...	...	...	...
126	Lewis & Neider [Lewis and Neider, 2017]	Wearable	Tasks requiring fine-motor control should allow for easy recovery from errors.	Designers should nearly always account for some difficulty in movement when considering older adult users. Given that many devices require fine, coordinated motor actions, such as gesture or button selection for interaction, this change warrants particular consideration.
127	Lewis & Neider [Lewis and Neider, 2017]	Wearable	Guard against activation of nontarget controls.	—
128	Lewis & Neider [Lewis and Neider, 2017]	Wearable	Limit need for tactile feedback in device interactions.	Additionally, older adults are less sensitive to tactile feedback or touch-based stimuli, which are imperative for interacting with technology. An alternative to using interfaces that require fine motor control is using voice-commanded technology.
...	...	...	...	...

messages to resume them in short sentences, which will be used as titles of those RGs so that they are compatible with the other guidelines.

For example, RG25 is based on the following sentence, "While having a minimum display item, task-relevant information only, and no parallel information at the same time", and it has been reformulated into "Use minimum display items, task-relevant information only, and avoid parallel information at the same time". The same applies to guidelines that include measures specific to other devices, such as recommended sizes for icons, fonts, and spacing, since the dimensions recommended by the authors for much larger devices may not be appropriate for smartwatches. For example, RG3, "Space between interface elements that function in a sequence manner should be around 0.2 cm, the space between unrelated buttons should be around 1 cm apart in the diagonal", describes the spacing proposed for mobile applications and websites. As the precise spacing proposed in this guideline may not be suitable for small devices such as smartwatches, this RG has been reworded while retaining its primary objective, which is that interface elements that are more related should be closer together. In contrast, unrelated elements should be more spaced. The beige cells of the "Reformulated Guideline" column in the *List of reference guidelines* describe the new titles resulting from the reformulation of the original texts.

During the analysis of the guidelines, other modifications were made. Some guidelines were composed of several parts dealing with different subjects, so dividing them to have one clear objective per RG was preferable. As shown in Table 4.2, the RG6, "Need for use of text and pictures for representing the functions of the buttons. And increased visibility for frequent and important actions", has been split into two separate guidelines: "Need for use of text and pictures for representing the functions of the buttons" and "Frequent and important actions should have increased visibility". The blue cells in the *List of reference guidelines* represent this type of intervention. In total, 10 RGs were decomposed, giving rise to 23 new guidelines.

Table 4.2: Split of RGs from the *list of reference guidelines*. The light grey represents the group of guidelines created from the dark grey guideline.

RG	Author	Domain	Guideline	Explanation	Reformulated guideline
1	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	The screens should be large enough to incorporate icons of at least 9.6 millimeters diagonally (or 11 millimeters diagonally if a mouse is used).	—	Large screen with large icons.
2	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	Font sizes bigger than 16 pixels and adjustable.	—	Large and adjustable font sizes are required.
3	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	Space between interface elements that function in a sequence manner should be around 0,2 cm, the space between unrelated buttons should be around 1 cm apart in the diagonal.	—	Interface elements that function sequentially should have a smaller spacing than buttons that are not linked.
—	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	—	Need for use of text and pictures for representing the functions of the buttons. And increased visibility for frequent and important actions.	—
4	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	—	Need for use of text and pictures for representing the functions of the button.	Use text and pictures for representing the functions of the buttons.
5	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	—	Increased visibility for frequent and important actions.	Frequent and important actions should have increased visibility.
—	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	—	The need for proper illumination in dim light and adjustable light and increased and adjustable contrast between the background and the text.	—
6	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	—	The need for increased contrast between the background and the text.	Increase the contrast between background and text.
7	Iancu & Iancu [Iancu and Iancu, 2020]	Mobile	—	The need for proper illumination in dim light and adjustable light and adjustable contrast between the background and the text.	Adequate lighting is required in low light conditions, as well as adjustable brightness and contrast between background and text.
...	...	...	...	...	

In addition, in some cases, we merged RGs that suggested the same kind of intervention in different contexts. For example, Patsoule and Koutsabasis's guidelines "Assistance should be provided in the execution of an operation", "Assistance should be provided while performing an incorrect action", "Assistance should be provided while searching", and "Assistance should be provided while completing forms" (numbered as 93, 94, 95, and 96), were merged into "Assistance should be provided while using the interface", which replaces the previous guidelines. This guideline merger operation is represented by the green lines in the *List of reference guidelines*, as shown in Table 4.3, and involved 11 RGs grouped into 2.

In addition, the RGs whose titles did not allow a clear understanding of their objectives and which had no explanatory text were considered "Unclear" and were not used for the rest of the work. They are grouped in a cluster called "Unclear" in the *Process for synthesising and classifying the guidelines* – carried out on Miro – and are coloured orange in the *List of reference guidelines*, as shown in Figure 4.1.

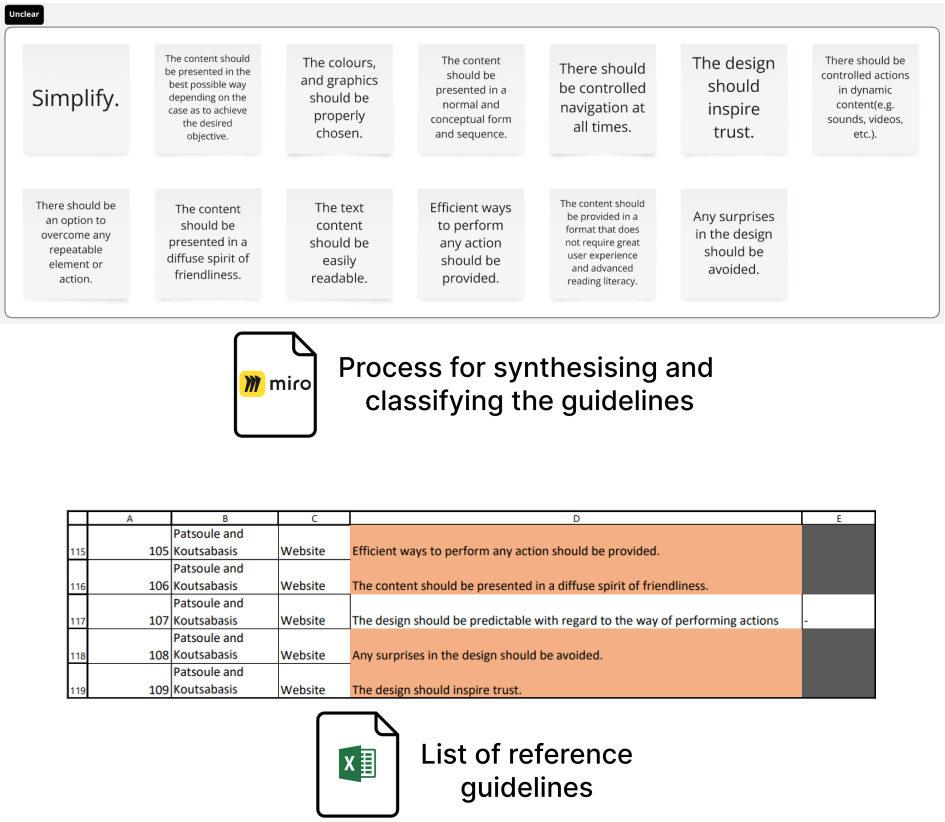

Figure 4.1: Unclear guidelines in Miro (top) and in Excel (bottom).

Table 4.3: Merge of RGs from the *list of reference guidelines*. Light green represents the group of guidelines merged into the dark green guideline.

RG	Author	Domain	Guideline	Explanation	Reformulated guideline
...	...	...	...	...	...
92	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	There should be an option to select ways of searching content according to user preferences.	-	There should be an option to select ways of searching content according to user preferences.
93	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	Assistance should be provided in the execution of an operation.	-	Assistance should be provided to the user while using the application.
94	Patsoule& Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	Assistance should be provided while performing an incorrect action.	-	
95	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	Assistance should be provided while searching.	-	
96	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	Assistance should be provided while completing forms.	-	
97	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	Major helping elements should be provided for inexperienced.	-	Major helping elements should be provided for inexperienced.
98	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	All elements of the site should be consistently displayed.	-	Application consistency is crucial.
99	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	There should be a layout consistency.	-	
100	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	The conceptual organization of information should be consistent.	-	
101	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	There should be navigation consistency.	-	
102	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	The actions required should be consistent.	-	
103	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	The design style and format should be consistent.	-	
104	Patsoule & Koutsabasis [Patsoule and Koutsabasis, 2014]	Web	There should be terminology consistency.	-	
...	...	...	...	...	...

The preparation phase includes the steps of reformulating guidelines, dividing a guideline into several if the original one covers several subjects, grouping very similar guidelines from the same work, and identifying those that are unclear and excluding them. After these steps, the *List of reference guidelines* became prepared to be added to the *Process for synthesising and classifying the guidelines* on Miro; this allowed us to group them and analyse their commonalities while also presenting them in a simpler and more flexible and more intuitive way.

Similarly to some authors who have presented their guidelines divided into classes concerning the challenges faced by older adults [Iancu and Iancu, 2020, Gomez-Hernandez et al., 2023, Lewis and Neider, 2017, Farage et al., 2012], we also opted for grouping guidelines in such classes. At the beginning of our work, we considered four classes in line with what most authors presented: Visual, Hearing, Motor, and Cognition. Figure 4.2 shows the first representation of the classification of RGs, using the Visual, Hearing, and Motor classes as examples. Within each class, sub-categories have been created to group guidelines by theme, as also visible in the figure. A colour code was used to easily distinguish the 4 classes: Visual class in orange, Hearing in blue, Motor in pink, and Cognitive in green.

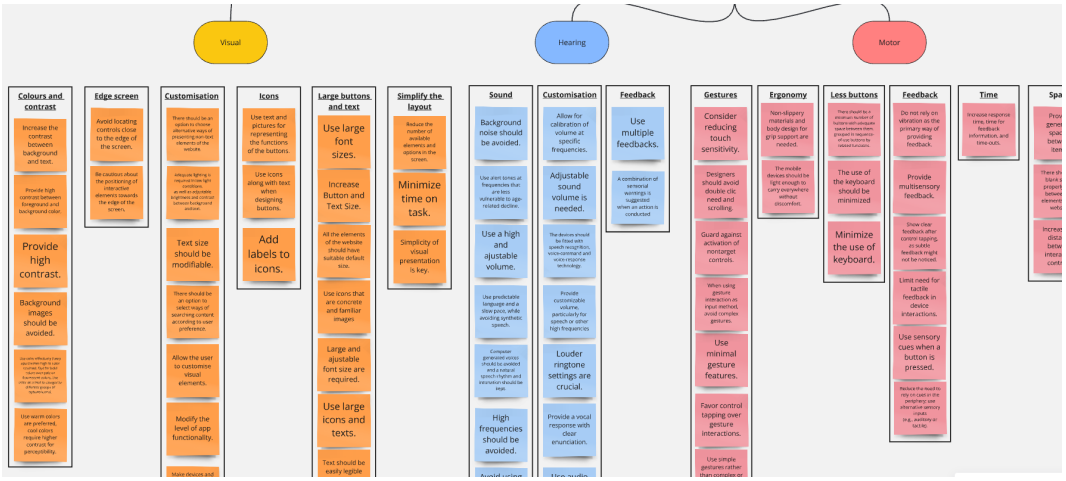

Figure 4.2: First classification of the references guidelines carried out on Miro.

After classifying the prepared RGs, we began evaluating their applicability to smartwatch interfaces. This involved filtering the guidelines based on this specific criterion. As a result, we found that some RGs, while relevant to our target audience on other devices, did not apply to smartwatches. This outcome marked eleven RGs as *"Not applicable"* as shown in Table 4.4.

RG1, from the mobile application and website domains, describes the need for a large screen in which icons also need to be large. However, smartwatch screens are small, so this guideline cannot be applied. RG21, which describes the ergonomic requirements for a good grip on the device, is also not applicable to smartwatches

Table 4.4: Not applicable guidelines.

RG	Title	Reason
1	Large screen with large icons.	Small screen size of smartwatches.
19	Designers should avoid double clic need and scrolling.	Small screen size of smartwatches.
21	Non-slippery materials and body design for grip support are needed.	Smartwatches are designed to be worn.
27	Indicate a permanent indication of the current position within the information space and task.	Small screen size of smartwatches.
31	Use simple and static menus.	Small screen size of smartwatches.
41	Avoid locating controls close to the edge of the screen.	Small screen size of smartwatches.
122	Be cautious about the positioning of interactive elements towards the edge of the screen.	Small screen size of smartwatches.
135	Make devices and displays adaptable to the user (e.g., adjustable display location).	Small screen size of smartwatches.
141	Provide the user with the status of the steps or goals within broader tasks, such as showing the user the next action.	Small screen size of smartwatches.
180	Zoom features are recommended.	Small screen size of smartwatches.
185	Use performance-based rewards.	Small screen size of smartwatches.

since they are worn on the wrist and do not need to be held in the hand. Regarding RG19, while the use of double clicks is not even common in smartwatch interfaces, it seems very difficult to avoid scrolling given the small screen size of these devices. The same applies to RG31, where the small screen size means that static menus can be difficult to use or involve a limited number of functions. For RG27 and RG141, the screen's small size could make it difficult to exhibit the position or purpose of the task to the user. RG41 and RG122 were also dismissed because interactive elements need to be located close to the edges of a small screen to take advantage of maximum space. Finally, it seems very difficult to allow the user to adjust the location of the display (RG135), as well as to provide a zoom feature (RG180), or to display congratulatory messages after completing a task (RG185) on such small screens.

We also concluded that some RGs are already ensured by the specificities of smartwatches, namely those referred to in Section 2.3. We tagged those guidelines as "Covered" and left them without further consideration. That happened to four RGs, presented in table 4.5, relating to features compatible with smartwatches, such as the need for a lightweight device (e.g., RG23) and reduced use of keyboards (e.g., RG54 and RG118), since these devices are lightweight and mobile and very rarely offer the use of a keyboard (e.g., calculator application). In addition, since smartwatches are compatible with and can be used by people who wear eyeglasses, RG136 was also tagged as such.

Table 4.5: Covered guidelines.

RG	**Title**	**Reason**
23	The mobile devices should be light enough to carry everywhere without discomfort.	Smartwatches are lightweight devices.
54	Minimize the use of keyboard.	Smartwatches provide alternative input options.
118	The use of the keyboard should be minimized.	Smartwatches provide alternative input options.
136	Design devices that accommodate eyeglasses.	Smartwatches are compatible with eyeglasses.

Finally, some RGs have been identified as conflicting with others, as shown in Table 4.6. These include RG19, which suggests avoiding scrolling, whereas RG117 recommends its use. Since RG19 had already been tagged as "Not applicable", it

was not retained for further work. RG29 suggests not providing alternative paths for a single task, such as being able to make calls from contacts and call history. This could contradict the principle of RG26, RG134, RG140, and RG146, which advocated reducing the number of steps for user tasks. In some cases, not designing alternative paths can lead to an increase in the number of steps for certain tasks. For example, if a user is in call history and wants to call a number in this list but can only do so from the contact application, the task the user wants to perform will take longer and will include more steps than if an alternative path had been devised from the initial interface. RG32 recommends using text and numbers rather than icons. However, RG4, RG44, RG121, and RG160 recommend combining icons and text. We have chosen to consider these latter and mark RG32 with the "conflict" label. Finally, RG181 suggests the use of sans serif typefaces. Conversely, RG8 and RG150 propose using certain serif typefaces (e.g., Times New Roman, Bookman). We have decided to focus on these guidelines and mark RG180 with the "conflict" label. Conflicts between RGs are signaled in the corresponding PG profile sheet.

Table 4.6: Guidelines in conflict.

RG	**Title**	**RGs with which it conflicts**
19	Designers should avoid double click need and scrolling.	117
29	Avoid alternative methods for a single task.	26, 134, 140, 146
32	Use Text and number key rather than icons.	4, 44, 121, 160
181	The use of sans serif typeface is recommended.	8, 150

This filtering phase of the RGs carried out in the *Process for synthesising and classifying the guidelines*, is represented by labels of different colours, placed in the bottom-left corner of the respective guidelines, as shown in Figure 4.3: black for "Not applicable"; blue for "Covered", and yellow for "Conflict".

Figure 4.3: Use of labels in Miro.

4.2 Synthesis and multicriteria classification

Once the RGs had been prepared, classified and filtered, the aim was to study their similarities to synthesise them into PGs. As shown in figure 4.4, the RGs were synthesised in each sub-category to produce several PGs. Each RG contributed to the synthesis of one or more PGs. The brackets (1) identify the RGs, which served as inputs to the synthesis, while the arrows (2) point to the resulting PG (3).

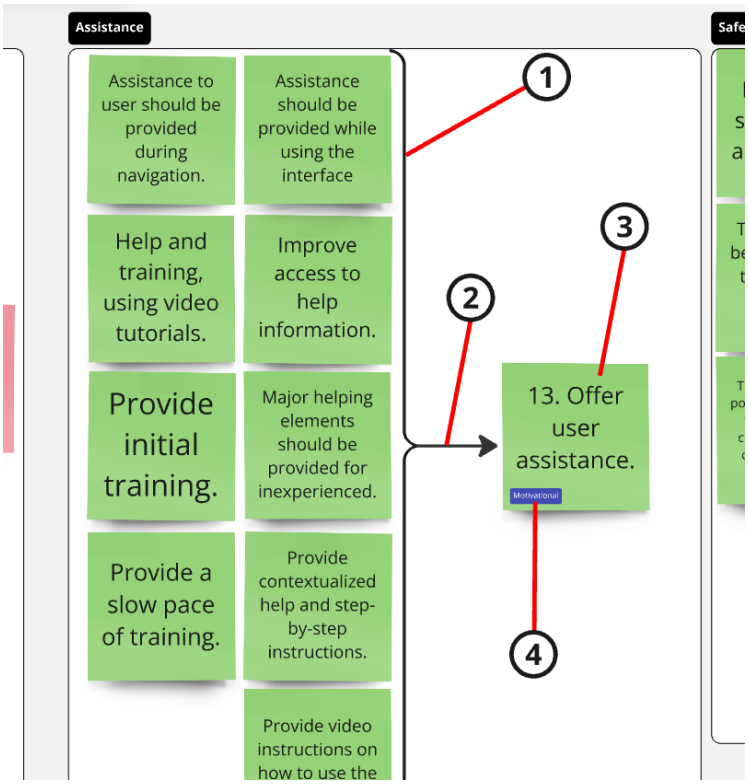

Figure 4.4: Determining the PGs.

An identification number has been allocated to each PG. Initially, this was simply a means of identification so as not to have to remember the title of the PGs. Still, the numbers were subsequently revised to account for the perceived (subjective) order of importance of the guidelines. The order of importance may be relevant if readers of this work do not look at the entire list. So the first guidelines on the list should be among the most important ones. A "Motivational" label has been introduced to indicate when a guideline could positively impact user motivation, considering the information gathered in Chapter 2. It is symbolised by the blue "Motivational" label on the *Process for synthesising and classifying the guidelines*, which can be seen in figure 4.4, at the level of the PG "Offer user assistance" (4).

During the synthesis of the PGs, a problem was identified. Although the *"Visual"*, *"Hearing"*, *"Motor"*, and *"Cognitive"* classes, which have been taken from other studies, have been used since the beginning of this work, it was noticed that

certain guidelines could fall into several of these classes instead of being restricted to a single class as proposed in those works. For example, RG47, "Clearly show which elements are touchable", describes the need to visually differentiate the interactive elements from other interface elements and make it easier for the user to recognise and understand their function. Therefore, it is a guideline in both the cognitive and visual classes. Also, PG13, "Avoid time-based interactions", was initially classified as *"Cognitive"* because users may need more time to interpret the interface. Still, it can also be classified as *"Motor"*, particularly because movement control can become slower and less precise with age, so more time might also be needed for gestural interaction.

In addition, certain sub-categories were repeated in several classes, notably, as shown in Figure 4.5, the *"Feedback"* sub-categories in the *"Hearing"*, *"Motor"*, and *"Cognitive"* classes, as well as the *"Customisation"* sub-categories in the *"Visual"* and *"Hearing"* classes. This repetition of sub-categories in different classes prevented the grouping of RGs dealing with the same themes since they had been classified in different classes. This was the case, for example, for RG13, entitled "A combination of sensorial warnings is suggested when an action is conducted", which was located in the *"Feedback"* subcategory of the *"Motor"* class, and for RG69 entitled "There should be an appropriate form of feedback with a clear indication of any change that may happen", located in the "Feedback" sub-category but in the *"Cognitive"* class.

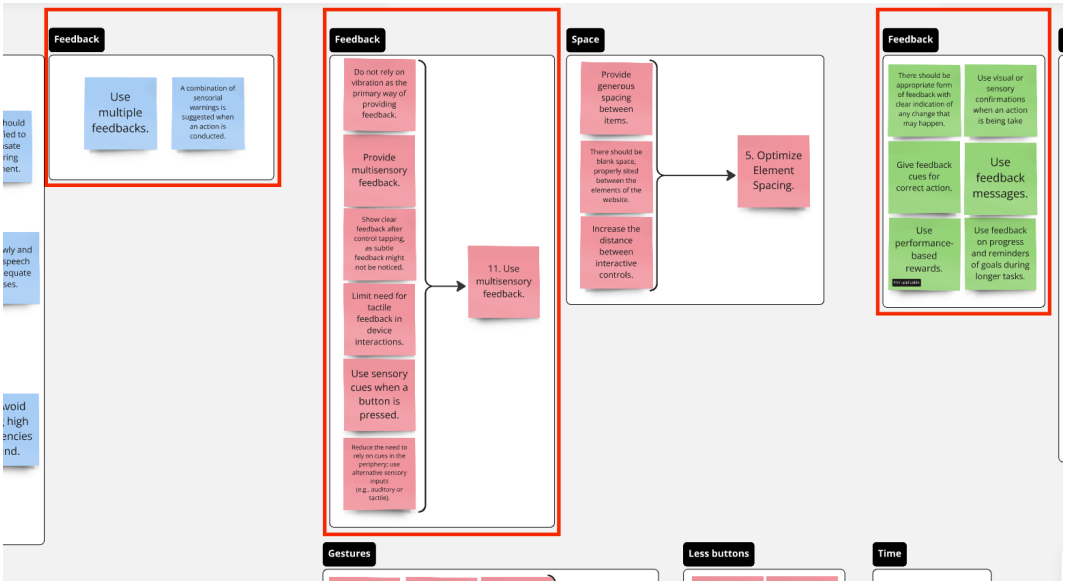

Figure 4.5: Repetition of the Feedback sub-category (framed in red) in the Hearing, Motor, and Cognitive classes.

Therefore, using one class per guideline, that classification prevented a proper synthesis of the RGs. Thus, the classification was revised based on a multicriteria classification, allowing the same guideline to be included in several classes. Also, our

first classification did not address the motivational barrier as a class. Instead, a label indicated a guideline that could address it. However, with this change regarding the classification, this barrier has been introduced as a fifth class. This underscores that motivation is no less important than the other challenges. Table 4.7 shows the changes in the classification of the PGs, made possible by the switch to multicriteria classification.

Table 4.7: Changes in the classification of the PGs after switching to a multicriteria classification.

PG	**Initial classification**	**Multicriteria classification**
1	Visual	Visual, Motor
2	Hearing	Hearing, Motivational
5	Motor	Motor, Cognitive
6	Motor	Motor, Cognitive
7	Motor	Motor, Cognitive, Hearing, Visual
8	Cognitive	Cognitive, Motivational
9	Visual	Visual, Cognitive
11	Visual	Visual, Motivational
13	Cognitive	Cognitive, Motor, Motivational
14	Hearing	Hearing, Visual, Motivational
18	Visual	Visual, Cognitive
19	Cognitive	Cognitive, Motivational
21	Cognitive	Cognitive, Motivational

The visual format used to indicate the classes of guidelines has also changed. Until then, the schema was divided into 4 main groups of guidelines, where the colour of the guideline indicated its class. The labels now signal this distinction by moving to a classification with several classes per guideline. Five classes were therefore considered from this stage onwards: **Visual**, **Hearing**, **Motor**, **Cognitive**, and **Motivational**. Figure 4.6 shows the "Feedback" sub-category, which now contains guidelines with several classes. These changes in the Miro working file dictated the need to adopt other colours to the posts containing the guidelines to allow proper contrast with the superimposed labels. The RGs become yellow, and the PGs are purple.

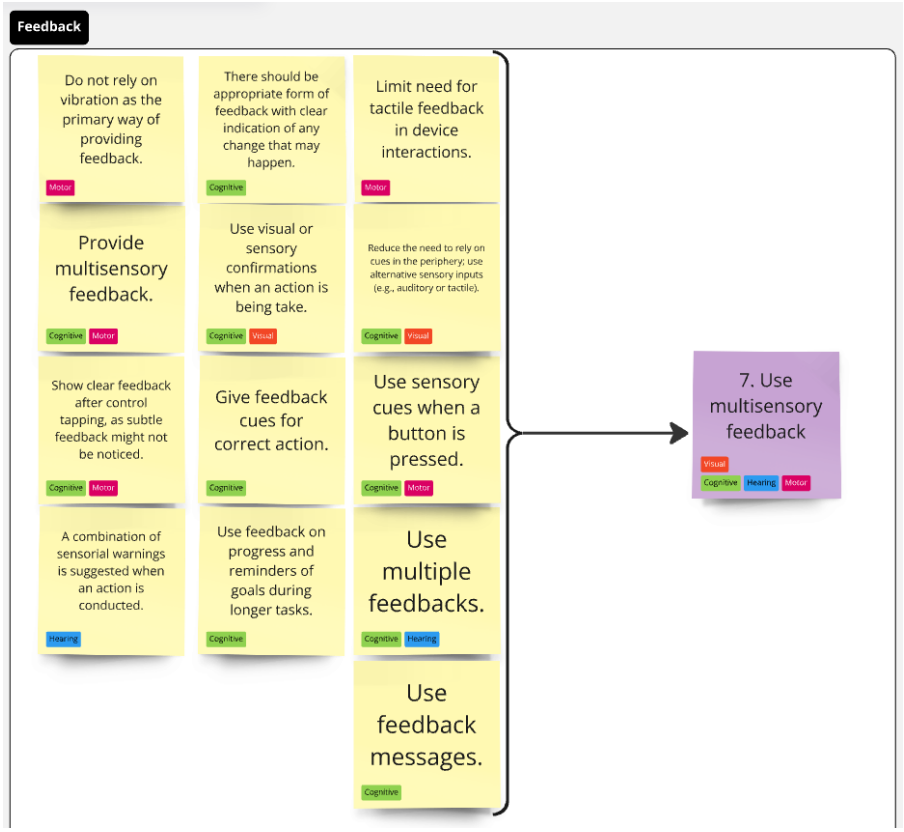

Figure 4.6: Multicriteria classification represented by labels for the feedback domain.

Subsequently, the titles of the PGs have been optimised to be clearer, more concise, and easier to remember. In addition, a profile sheet has been created for each of these guidelines to make them easier to use and understand. These profiles, available in Appendix A, make it possible to study the guidelines proposed in this work independently, as they include all of each guideline's information, allowing anyone wishing to use them to do so without depending on this full report. Figure 4.7 shows an example of the profile sheet corresponding to PG9. Each sheet is made up of several elements: first, the PG number (1) next to its title (2), followed by a synopsis (3) explaining it in a short text. It also includes an explanatory text (4) describing the corresponding guideline. Then, the classes (5) assigned to this guideline and the domains of origin (6) of the RGs that gave rise to this PG. Finally, the related PGs (7), and the potential conflicts (8) with RGs.

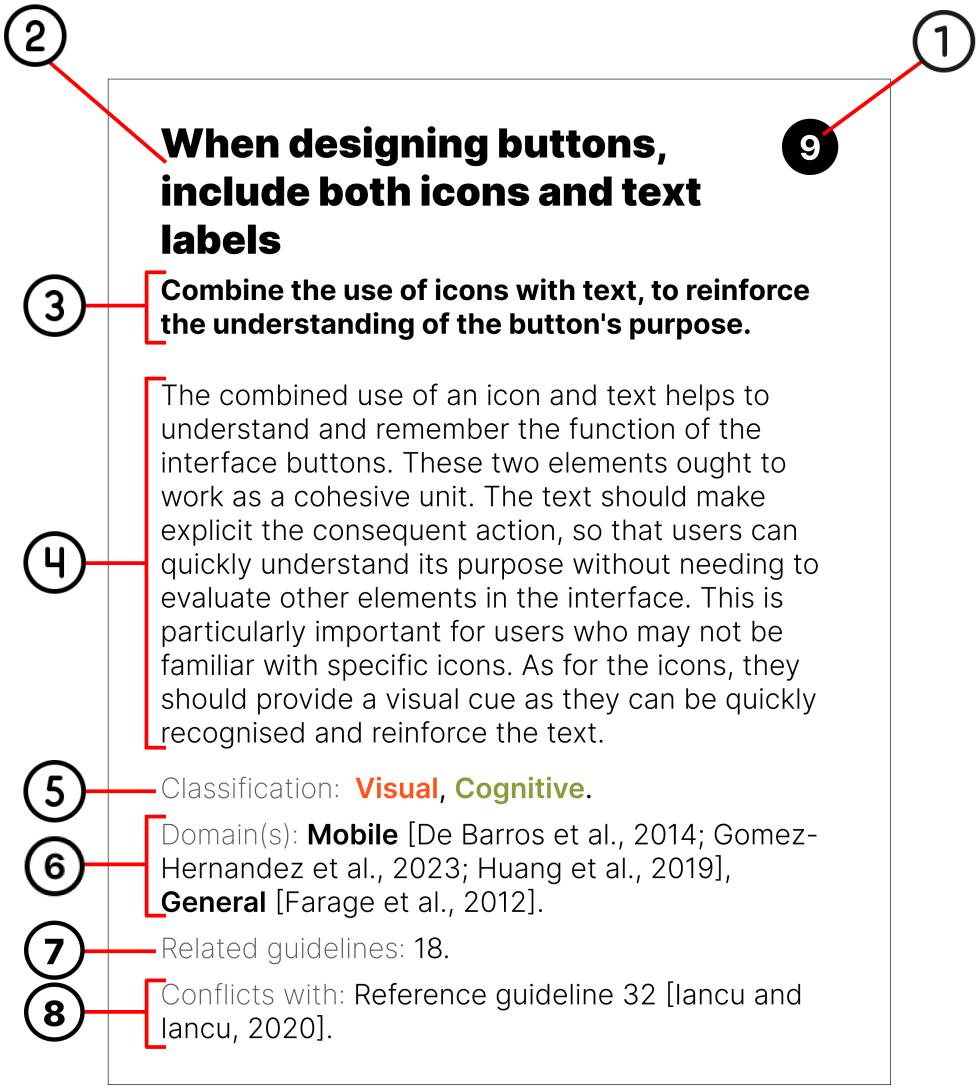

Figure 4.7: Example of a proposed guideline profile sheet.

Afterwards, two new lists were created using Excel software. The first, entitled *List of proposed guidelines*, summarises all the information found on the profile sheets, with the addition of the "First title", "Second title", and "Final title" columns, allowing to list the different versions of the titles attributed to the guidelines along the process. The second document, shown in Table 4.8, entitled *Guidelines overview*, describes the work carried out for each of the RGs, indicating which of them led to each of the PGs, as well as those that have been filtered, and also original RGs that were merged, or classified as "unclear" during the preparation phase. The *Guidelines overview* comprises four columns, the first being the number

and title of the RGs and the other two the number and title of the PGs. In the case of a filtered guideline, the last column indicates the corresponding filtering.

Table 4.8: Extract from the worksheet *guidelines overview*, showing examples of links between RGs and PGs.

RG	**RG title**	**PG**	**PG title**
2	Large and ajustable font size are required.	1	Provide large buttons and readable text.
8	Use large icons and texts.	1	Provide large buttons and readable text.
35	Increase the size of interactive controls.	1	Provide large buttons and readable text.
...	...	...	...
12	Adjustable sound volume is needed.	2	Favour loud but adjustable sound volume.
16	Louder ringtone settings are crucial.	2	Favour loud but adjustable sound volume.
...	...	...	...
18	Use minimal gesture features.	5	Avoid complex gestures.
52	Favor control tapping over gesture interactions.	5	Avoid complex gestures.
53	When using gesture interaction as input method, avoid complex gestures.	5	Avoid complex gestures.
...	...	...	...
28	Time for conducting an action must not be a constraint.	13	Avoid time-based interactions.
59	Increase response time, time for feedback information, and time-outs.	13	Avoid time-based interactions.
...	...	...	...
5	Frequent and important actions should have increased visibility.	17	Emphasise the most important information.
70	The most important content of the website should be visible and directly presented.	17	Emphasise the most important information.
...	...	...	...

Finally, a new column, “Resulting proposed guidelines or filtration”, has been added to the *List of reference guidelines*. As illustrated in Table 4.9, this column contains, for each RG, the number of the resulting PG or a label such as “Not applicable”, “Covered”, or “Conflict”, indicating that this RG has been filtered.

Table 4.9: Extract from the worksheet *list of reference guidelines*, showing the mapping into PGs or filtration.

RG	**Reformulated guideline**	**Resulting PG(s) or filtration**
1	Large screen with large icons.	Not applicable
2	Large and adjustable font size are required.	1, 11
3	Interface elements that function sequentially should have a smaller spacing than buttons that are not linked.	6
4	Use text and pictures for representing the functions of the buttons.	9
5	Frequent and important actions should have increased visibility.	17
...	...	...
9	Provide adaptable font size.	11
10	Background images should be avoided.	3
11	Background noise should be avoided.	12
12	Adjustable sound volume is needed.	2
13	A combination of sensorial warnings is suggested when an action is conducted.	7
14	The devices should be fitted with speech recognition, voice-command and voice-response technology.	14
15	Computer generated voices should be avoided and a natural speech rhythm and intonation should be kept.	14
16	Louder ringtone settings are crucial.	2
17	Avoid using high frequencies sound.	10
18	Use minimal gesture features.	5
19	Designers should avoid double clic need and scrolling.	Not applicable, conflict
20	There should be a minimum number of buttons with adequate space between them, grouped in sequence-of-use buttons by related functions.	6
...	...	...

The set of PGs produced during this study is described in Table 4.10, where the classification, domains, and related PG(s) for each guideline are presented. The full guidelines are presented in the profile sheets, available in Appendix A.

Table 4.10: Proposed guidelines.

PG	Title	Multicriteria Classification					Domain				Related PGs
		Visual	Hearing	Motor	Cognitive	Motivational	Mobile	Web	General	Wearable	
1	Provide large buttons and readable text	✓		✓			✓	✓	✓	✓	
2	Favour loud but adjustable sound volume		✓			✓	✓		✓	✓	10,11
3	Ensure high contrast	✓					✓		✓		16
4	Be objective				✓		✓	✓			12,15,17
5	Avoid complex gestures			✓	✓		✓		✓	✓	
6	Ensure distance between controls			✓	✓		✓	✓			
7	Use multisensory feedback	✓	✓	✓	✓		✓			✓	10,12
8	Support corrections				✓	✓	✓	✓	✓	✓	
9	When designing buttons, include both icons and text labels	✓			✓		✓		✓		18
10	When using sound, prefer low frequencies		✓				✓		✓	✓	2,7
11	Allow for customisations	✓				✓	✓	✓	✓	✓	
12	Declutter the interface				✓		✓	✓	✓	✓	4,15,17
13	Avoid time-based interactions			✓	✓	✓	✓		✓	✓	
14	Integrate speech to complement output/input	✓	✓			✓	✓		✓	✓	2,10,11
15	Simplify task execution				✓		✓		✓	✓	4,12
16	Use colour effectively	✓					✓		✓		3
17	Emphasise the most important information				✓		✓	✓			4
18	Use intuitive icons	✓			✓		✓		✓		9
19	Support the sense of privacy				✓	✓	✓				
20	Use plain language				✓		✓		✓		
21	Offer assistance				✓	✓	✓	✓			

4.3 Benchmarking

The following benchmark analysis evaluates the comprehensiveness of the smartwatch design guidelines (1 – 21) proposed in our work in addressing critical dimensions relevant to older adults, smartwatch-specific constraints, and general usability principles. This analysis builds on the limitations of the guidelines (G1 – G8) proposed by Samaddar et al. [Samaddar and Petrie, 2023] to identify key areas where the PGs provide broader and deeper coverage.

Table 4.11 evaluates how the PGs address the specific needs of older adults, including motor, visual, and hearing impairments, cognitive load, privacy concerns, and personalisation. Older adults often face challenges such as reduced dexterity, sensory limitations, and difficulty adapting to complex interfaces. The table highlights how the PGs provide enhanced support compared to Samaddar et al. [Samaddar and Petrie, 2023] guidelines by emphasising cognitive simplicity (4, 12, and 20), multisensory feedback (2 and 7), and customisation options (11). This ensures a user-centred design approach that aligns with the requirements of older adults.

Table 4.11: Comparison of guidelines based on the needs of older adults.

Criteria	**Samaddar and Petrie [Samaddar and Petrie, 2023] guidelines (G1 — G8)**	**PGs (PG1 – PG21)**	**Coverage analysis for the PGs**
Motor impairments	G2, G3	PG1, PG6, PG8	Provide stronger support through large buttons, error recovery, and spacing, which are crucial for motor impairments.
Visual impairments	G5, G7	PG1, PG3, PG16	Build on readability by refining colour usage, emphasising key information, and improving overall contrast and font size.
Hearing impairments	Not addressed	PG2, PG7, PG10	Explicitly address hearing needs, providing adjustable volume and multisensory feedback, absent in [Samaddar and Petrie, 2023].
Cognitive load	G4, G6	PG4, PG12, PG15, PG20	Comprehensively targets cognitive simplicity by reducing clutter, using objective designs, and offering task simplification, which was not emphasised in [Samaddar and Petrie, 2023].
Privacy concerns	Not addressed	PG19	Adds privacy considerations, critical for older adults managing health data or sensitive information.
Personalisation and adaptability	Not addressed	PG11	Introduces customisation options for fonts, themes, and controls, addressing a key gap in [Samaddar and Petrie, 2023].

Table 4.12 assesses how well the PGs accommodate smartwatch-specific constraints, such as small screens, limited input methods, reliance on gestures, multimodal feedback, and battery life considerations. The PGs demonstrate a detailed approach to addressing these challenges, particularly through features like large buttons (1), intuitive input alternatives (5, 9), and speech integration (14). The

guidelines also emphasise reducing gesture reliance (15), ensuring usability on compact devices with enhanced feedback mechanisms (2, 7), and supporting long-term use by considering battery-efficient features.

Table 4.12: Comparison of guidelines based on smartwatch characteristics.

Criteria	**Samaddar and Petrie [Samaddar and Petrie, 2023] guidelines (G1 — G8)**	**PGs (PG1 – PG21)**	**Coverage analysis for the PGs**
Small screen size	G3, G7	PG1, PG6	Explicitly address usability on small screens by including larger buttons, better control spacing, and improved font sizing.
Limited input methods	G1	PG5, PG9, PG13	Offers more comprehensive solutions for input, including reducing gesture complexity, providing text/icons combinations, and removing time-based interaction.
Reliance on gestures	G1, G4	PG5, PG15	Go beyond authors guidelines by reducing gesture reliance through simpler design, combining icon/text labels, and emphasising task simplicity.
Multimodal feedback	Not addressed	PG2, PG7, PG14	Explicitly introduce multimodal feedback to address both sensory limitations (visual, auditory), essential for older users and the smartwatch format.
Battery life considerations	Not addressed	PG14	Indirectly support battery efficiency by proposing speech integration to reduce reliance on visual touch-based input, thus saving power.

Table 4.13 benchmarks the guidelines against general design principles for older adults [Story, 2001], focusing on accessibility, error recovery, feedback mechanisms, navigation, task prioritisation, and privacy. The guidelines extend usability coverage by introducing explicit strategies for clarity (4), interface decluttering (12), and intuitive interaction through plain language (20). Additionally, they emphasise error recovery mechanisms (8, 21), privacy considerations (19), and efficient task prioritisation (16, 17). These features relate to universal design principles, ensuring usability for older adults.

In conclusion, the PGs (1 — 21) provide a detailed framework for designing smartwatch interfaces for older adults. They address previously overlooked dimensions such as hearing impairments, privacy, motivational aspects, multimodal feedback, and usability principles like error recovery and task prioritisation. They expand the coverage and depth of considerations and ensure a more inclusive, practical, and user-friendly approach to the interface design of smartwatch applications for older adults.

Table 4.13: Comparison of guidelines based on general design principles for older adults [Story, 2001].

Criteria	**Samaddar and Petrie [Samaddar and Petrie, 2023] guidelines (G1 — G8)**	**PGs (PG1 – PG21)**	**Coverage analysis for the PGs**
Accessibility	G5, G7	PG1, PG3, PG16, PG20	Improve upon accessibility by including enhanced readability, multimodal options, and better colour usage.
Error recovery	G2	PG8, PG21	Strengthen error recovery with explicit support, offering real-time assistance and feedback mechanisms to avoid user frustration.
Feedback and multimodality	Not addressed	PG2, PG7	Emphasise multisensory feedback, which is crucial for engaging users with different sensory impairments and providing diverse forms of feedback (sound, haptics, etc.).
Navigation and structure	G1	PG4, PG9, PG12, PG15	Introduce clearer navigation strategies, including more explicit icon/text labeling, better task prioritisation, and less reliance on gestures.
Task prioritization	G6	PG16, PG17	Provide refined prioritisation using colour, layout, and clear visual hierarchy to highlight important tasks.
Privacy and trust	Not addressed	PG19	Strongly addresses privacy concerns, especially for older adults, where trust in data handling is critical.

Chapter 5

Design system

This chapter details the design system created to provide tangible instantiations of the application of the PGs.

5.1 Preliminary information

As part of this project, to determine the screen size for the design system, we analysed the smartwatch models offered by some of the most well-known brands, such as Apple, Samsung, Huawei, and Google. A trend seems to be emerging, with these brands often offering their models in smaller sizes such as 38 *mm*, 40 *mm*, or 41 *mm* (Huawei Watch GT 4, Samsung Galaxy Watch 7, Fitbit Versa 4, Google Pixel Watch 2, Apple Watch Series 9), then in larger sizes such as 44 *mm* or 45 *mm* (also available for Huawei Watch GT 4, Samsung Galaxy Watch 7, Apple Watch Series 9). Finally, some brands offer a large model measuring 47 *mm* or more (Samsung Galaxy Watch Ultra LTE, Apple Watch Ultra 2). It is noticeable that in recent years, smartwatch manufacturers have tended to increase the size of their devices, with Apple, for example, presenting its first smartwatch in 2015 with 38 *mm* or 42 *mm* cases, but gradually increasing to 42 *mm* and 46 *mm* for their latest model. Bearing this in mind, and also that larger screen sizes can make it possible to present larger information and can be perceived as easier to control [Kim, 2017], we have therefore chosen to show the examples in the design system using frames corresponding to 44 *mm* smartwatch interfaces. We consider this size to be neither too big (larger screens can make the watch bulkier and less practical

to wear, which might not be appreciated by our target audience) nor too small (small screens can be harder to read and do not offer as much visual information as larger screens [Dehghani and Kim, 2019]). To gain a better understanding of the interfaces shown as examples of applications of the PGs, it is convenient to cover several of the shapes of smartwatches on the market today. Each interface example will, therefore, be shown in round (frequently encountered on Samsung, Huawei, and Google models), rectangular (used for Apple models), and square (often used for Fitbit models) formats.

We developed the design system on Figma, which is a well-established tool for interface design and prototyping[1].

5.2 Components

Several components have been created to provide consistent examples of interfaces. Components are reusable elements, helping to build coherent designs in projects. In Figma, designers create main components in which the respective properties are defined, and then those components are copied and used in the form of component instances. Instances are connected to the main component and are updated whenever the component changes [Figma, 2018]. Also, designers can define different variants for a same main component, allowing each instance to adopt one of those variants. This section presents the main components that we have created during this work. These components, along with their properties can be modified by future researchers. Moreover, we provided comprehensive documentation for all components, colour, and text styles, detailing their operation and application within the respective "descriptions" fields of their properties, in the Figma file.

5.2.1 Colour styles

Following PG3 and PG16, we have defined a limited colour palette with each colour serving a specific purpose, and presented pairs of foreground and background colours that ensure high contrast. For instance, we have paired a white background with black foreground elements (e.g., text, icons, buttons).

As shown in Table 5.1, we defined each colour as a "colour style" in the design system so that they are easily accessible during interface design. This practice also allows designers to easily modify the colours with a single operation, with immediate impact in all the objects using those styles in the projects. It should be noticed that this set of colours constitutes a theme that represents our options but can be modified, provided that principles such as contrast and perceived semantics are ensured. For instance, designers ought to make sure that users will be able to distinguish critical messages and confirmations from regular text.

[1] www.figma.com

Table 5.1: Colour styles used in the design system.

Colour style	**Colour(hex)**	**Use case**
Button dark	Black (#000000)	Standard buttons on white background
Warning actions	Red (#B60000)	Critical buttons on white background
Positive actions	Green (#0A4D0A)	Positive action buttons on white background
Help button	Brown (#844A00)	Help buttons on white background
Button light	White (#FFFFFF)	Pressed buttons on white background
Dark text	Black (#000000)	On white or beige backgrounds
White text	White (#FFFFFF)	On black or blue backgrounds
Lighter text	Dark grey (#585858)	Secondary information on white background
Button label light	White (#FFFFFF)	Unpressed button labels
Button label dark	Black (#000000)	Pressed button labels

Five colours have been defined specifically for buttons. The base colour is black (*Button dark*), which is used for standard buttons to strongly contrast the white screen background. The colour red (*Warning actions*) can be used in cases where the action performed by this button is critical (e.g., delete item), whereas green (*Positive actions*) can be used in the case of a positive action (e.g., answering a call). These colours also contrast with a white screen background: 7.03:1[2] and 10.10:1[3], respectively. The brown colour (*Help button*), resulting in a contrast of 7.09:1[4] with white, was used in this work to indicate the user help buttons, allowing them to be differentiated from other buttons, as recommended by PG21. Finally, we adopted white (*Button light*) for buttons while being pressed, to provide immediate visual feedback to the user.

Regarding text colours, we have defined a palette of three colours: black (*Dark text*) is used on light backgrounds; white (*White text*) is used against dark backgrounds; and grey (*Lighter text*) conveys secondary information on lighter backgrounds. Finally, two colours were used for button labels (i.e., the buttons' texts): white (*Button label light*) for unpressed buttons and black (*Button label dark*) for buttons being pressed.

5.2.2 Text styles

As presented in Table 5.2, we have defined several text styles to standardise text elements and ensure they are used consistently throughout the design system. In line with what was suggested in the literature review we adopt the typeface Arial [Iancu and Iancu, 2020, Farage et al., 2012]. Designers might for another typeface provided that it ensures good legibility and other typographical merits [Figma, 2024].

Large headline and *Headline* text styles refer to text displayed within interface headers. As they convey crucial information to the user, we have opted for a larger

[2] colourcontrast.cc/?background=fffff&foreground=B60000
[3] colourcontrast.cc/?background=fffff&foreground=0A4D0A
[4] colourcontrast.cc/?background=fffff&foreground=844A00

size. The *Body* text style characterises the main text of an interface, it is in regular font style with a smaller size than for the headlines. Also, given the importance of some data in specific contexts (e.g., user's heart rate in health tracking application), we created a text style with very large size and bold style (*Health data*). In some situations, it is relevant to include secondary information; thus, to maintain hierarchy in the contents, we defined a text style using a smaller size in combination with its specific colour *Secondary text*.

Concerning buttons, we have established various label types. To ensure button labels are large and highly legible, we have opted for a bold font style with the same dimensions of the *Body* text (*Button label*). To accommodate buttons with multiple text components and the need for a hierarchical relationship between them, we have specified the *Specific button label* text style. It retains the attributes of other button labels but features a larger font size.

Table 5.2: Text styles used in the design system.

Text styles	**Font**	**Size(px)**	**Use cases**
Large headline	Arial regular	24	Large interface header
Headline	Arial regular	20	Interface header
Body	Arial regular	18	Interface main text
Health data	Arial bold	52	Health data values (e.g., heart rate, blood pressure)
Secondary text	Arial regular	16	Secondary information
Data sharing indicator	Arial regular	15	Share indicator label
Button label	Arial bold	18	Button labels
Specific button label	Arial bold	20	Contact names in call directory buttons, and data names in sharing settings

5.2.3 Buttons

The interface button component, shown in Figure 5.1, is called *Buttons* and, as suggested by PG9, it consists of an icon and a text label. This component has several variants. Firstly, it has different sizes ("Large" and "Medium"), represented by the "Button size" property. We've set the height to ensure the buttons are large at 50 px. The width of the "large" buttons is 190 px so that they take up as much horizontal space as possible in the interface. The "medium" buttons are 170 px wide and can be used where large buttons would superimpose on other interface elements, typically on rectangular devices.

As previously seen, buttons also have different colours. They are selected using the "Colour" property of this component.

In addition, the buttons have two different states corresponding to the "State" property: either the button is pressed or it is not. In the first case, the colours

assume styles as presented in Subsection 5.2.1, and they get a large stroke during the action, to provide visual feedback to the user.

As an example of how to adapt the interface, as in the cases addressed by PG11, the size of the button icons can be adjusted using the “Icon size” property (“Small”, “Medium”, and “Large”).

Finally, to have button icons representing interfaces as those suggested in the design system, the “Icon” property of this component allows to choose among those available. Designers can have other variants to the buttons to include other icons alternatives. Additionally, it is possible to apply a custom icon to the “Custom” variant by swapping the component in place of the icon with their desired icon using an instance swap.

Figure 5.1: Button component and its variants.

5.2.4 List of buttons

As shown in Figure 5.2, the *List of buttons* component has been created to make the buttons available as a list. It also includes several variants: the “Number of buttons” property allows to choose the number of buttons within the list (2 to 5), with a fixed inter-button large spacing; the “Button size” property can be used to define the size of the buttons in the list (“Large” or “Medium”).

5.2.5 Data sharing indicator

To support the application of PG19, the component depicted in Figure 5.3 has been created, indicating the status of data sharing. We understood that the dimensions of its icon and text could be smaller than those of regular icons and text, and we envisaged its use bellow other elements in the interface, as will be illustrated in some of the following subsections. It has a property “isShared”, which is a Boolean

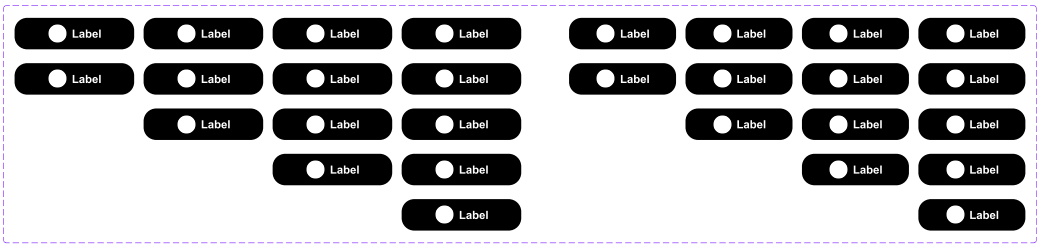

Figure 5.2: List of buttons component and its variants.

value that allows to set a variant according to the sharing status of the respective data, with the icon and label changing. It also has a property ("Colour") with which the most convenient colour style can be selected, namely according to the background.

Figure 5.3: Data sharing indicator component and its variants.

5.2.6 Sharing settings

The *Sharing settings* component has been used to create an interface for data-sharing parameters. As shown in Figure 5.4, this component consists of a large label indicating the name of the data, an instance of *Data sharing indicator* component presented in the former subsection, showing its sharing status, and finally, a button allowing the user to change that status. It has two properties: "Type of screen", which varies the width of this component to be used on the different device formats; "Share status", which determines the sharing status involving the component instance. This latter property can assume the values "Not sharing" in the case of data that is not being shared, or "Sharing" in the case of data that is being shared. In the first case, the button on this component will be labelled "Start sharing" to allow the user to share this data, and it uses the colour style *Warning actions* because this is a critical action. In the second case, the button is labelled "Stop sharing" to cease that sharing.

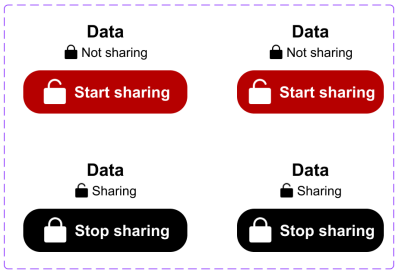

Figure 5.4: Sharing settings component and its variants.

5.2.7 Sharing settings list

Figure 5.5 shows the component that consists of a list of the components presented in the previous subsection. They are separated by a "Splitter" (which is also available as a component), to ease their delimitation. The list has two properties: "Number of items" (2 to 4) and "Type of screen" to select the appropriate size for the list according to smartwatch format ("Round/Square" or "Rectangular", corresponding to a larger or smaller width, respectively).

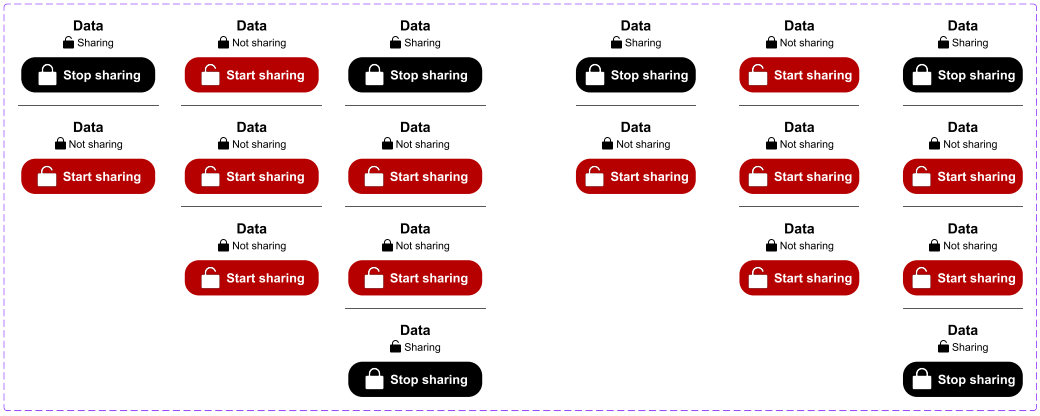

Figure 5.5: Sharing settings list component and its variants.

5.2.8 Call directory buttons

We have created a specific button, shown in Figure 5.6, for use in interfaces representing a call history. *Call directory buttons* are composed of three elements: a large text representing the name of the contact who called or was called, then an icon indicating the status of the call, and two secondary texts indicating the time and date. Their appearance is therefore similar to that of the *Buttons*, so that users can easily identify them as such. The component also includes three properties, one of which is the "Type of screen". Similar to the previous components, this property allows to adjust the button's width. As with the standard button, the width is

slightly reduced on devices with rectangular screen formats. The second property, "Call status", has three values that change the button icon (representing a missed call, busy line or declined call, and received call). Lastly, there is a "State" property as in regular buttons (either unpressed or pressed).

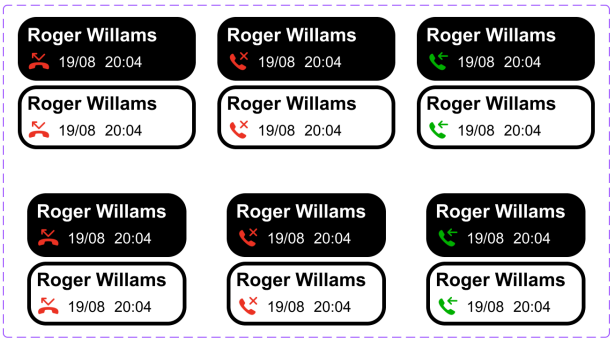

Figure 5.6: Call directory button component and its variants.

5.2.9 List of call directory buttons

As with other components, a list has been included, as evidenced in Figure 5.7. The spacing between the buttons has been reduced, as they are much wider the regular buttons. This component has two properties, equivalent to those presented in previous subsections: "Type of screen" and "Number of buttons".

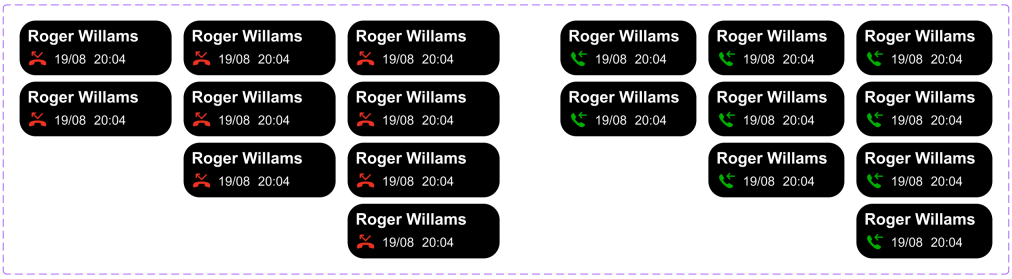

Figure 5.7: List of call directory buttons component and its variants.

5.2.10 Scroll indicator

We have created the component *Scroll indicator*, shown in Figure 5.8, to inform users of their possibility to scroll an interface and their position within it. We designed it to be placed, centered, on the right-hand edge of scrollable interfaces. It consists of an element sliding vertically over a longer base to indicate the position of the interface visible to the user. In this component, the property "Type of screen" indicates the type of device on which it will be used, with this component being

straight for square and rectangular devices, whereas it is curved for round devices. We also included a property ("Position") so that designers can emulate different scroll positions. Although it is a limited approach, as it does not cover all the possible positions, it is a widely used solution to circumvent the current restrictions of the design software (Figma).

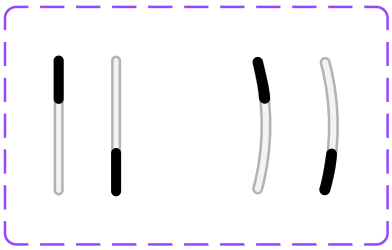

Figure 5.8: Scroll indicator component and its variants.

5.2.11 Sound volume indicator

The *Sound volume indicator* component, shown in Figure 5.9, allows to display and modify the sound volume level within the sound settings interface. It consists of two elements: a circular indicator where the dark grey section represents the current sound level; and the volume level displayed as a percentage. There is also a property ("Level") that allows designers to emulate for different volume levels.

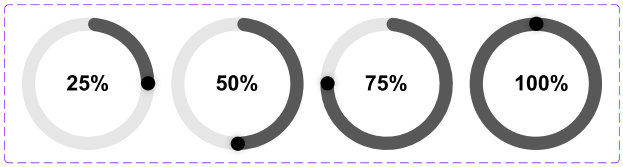

Figure 5.9: Sound volume indicator component and its variants.

5.2.12 Audio message indicator

To provide a visual cue for users during audio playback in applications featuring sound elements (e.g., sound notifications or audio messages), we created the *Audio message indicator*, shown in Figure 5.10. It allows users to visually track the progress of audio playback, providing an instant view of their current position within the audio, similar to a video progress bar. As in the previous indicators, there is also a property ("Progress") that allows designers to emulate three moments of the audio play.

Figure 5.10: Audio message indicator component and its variants.

5.2.13 Heart rate display

As illustrated in Figure 5.11, the *Heart rate display* component shows the user data relating to his heart rate, which might be useful, e.g. in health monitoring applications. The current heart rate is displayed in the centre. The minimum and maximum heart rates measured over a specific time period are shown to the left and right of the current heart rate, respectively. Both elements assume styles as presented in Subsections 5.2.1 and 5.2.2. The component has a "Type of screen" property that modifies the layout to adapt to different smartwatch formats, especially on rectangular devices where the minimum and maximum measurements are displayed below the current measurement so that the component takes up less space horizontally.

Figure 5.11: Heart rate display component and its variants.

5.2.14 Headers

Finally, to facilitate the presentation of diverse header styles, we designed the *Headers* component depicted in Figure 5.12. The header of an interface corresponds to its "title" and indicates the subject of the contents being displayed to the user. This element is typically found at the top. We propose a combination of text and icons to enhance their comprehensibility. The first property of this component is "NumLines", which allows to specify the desired number of lines of the text within the header. This can be a single line or two lines for a longer title that would not fit in a line (e.g., typically useful in round screen formats). Its second property is "Distance", specifying the spacing between the icon and the text ("Tighter", "Normal", and "Looser"). The "Layout" property determines whether headers are displayed inline, occupying more horizontal space, or stacked, occupying more vertical space. Finally, the "Size" property corresponds to the choice of the icon size, which can be "Normal" or "Large".

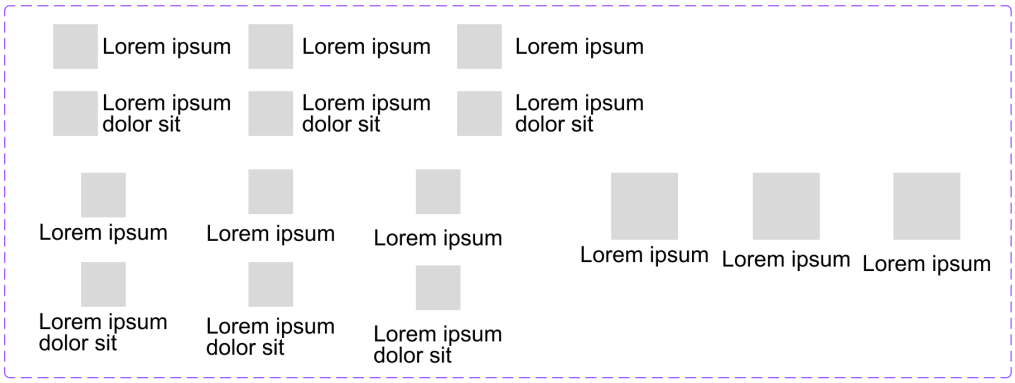

Figure 5.12: Header component and its variants.

5.3 Examples of applications of the proposed guidelines

5.3.1 PG1: Provide large buttons and readable text

Figure 5.13 shows two examples of applying PG1. *Example 1a* is a medication management application. Large buttons ensure they are visible and wide enough to prevent accidental pressing (1). On rectangular devices, the length of the buttons has been reduced so as not to superimpose the scroll indicator on the right of the interface (2).

Example 1b is a message application interface representing the reception of a text message sent by the "Mary" contact. It also includes the use of large buttons. Still, above all, it shows another text category, illustrated here by the message (3): the *Body* text style, referring to the main text of the page, which consists of a regular paragraph that conveys informative or descriptive content. We have chosen a large font size to make these texts easier to read. The text message can be easily distinguished from the header representing the contact's name because it is set lower, separated by a space, and does not include an icon. In both examples, the header text is large enough to be easily readable, well-spaced from other elements, and positioned at the top of the interface (4). The text on the button labels is also large, positioned in the centre of the button, and accompanied by an icon.

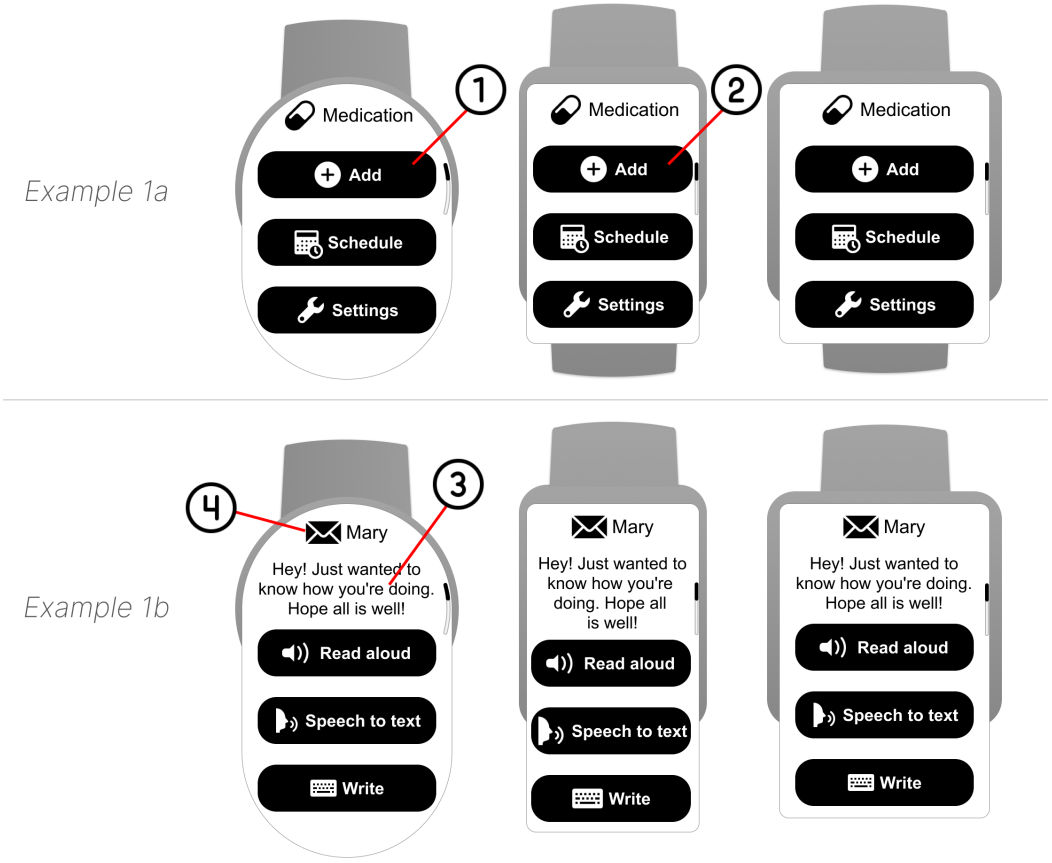

Figure 5.13: Examples of applications of PG1.

5.3.2 PG2: Favour loud but adjustable sound volume

The interface depicted in Figure 5.14 presents a possible design for a volume control interface. It comprises a header title (1) reminding the user that they are adjusting the volume, a circular indicator (2) that allows the user to modify the volume by tapping on it while providing a visual representation of the sound level, and finally, at the centre of this indicator, the sound level displayed as a percentage (3) to provide the user with a more exact display of the level.

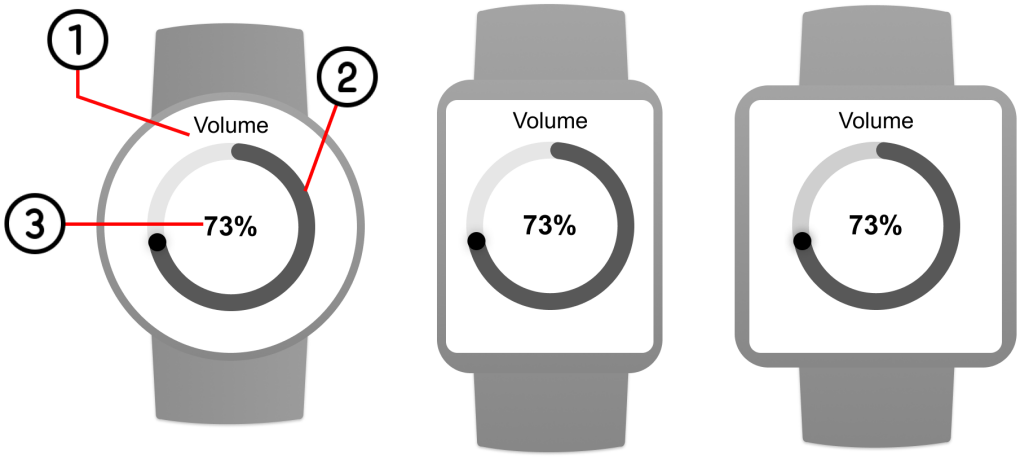

Figure 5.14: Example of application of PG2.

5.3.3 PG3: Ensure high contrast

Figure 5.15 shows two examples of the application of PG3. *Example 3a* shows an interface for a step count tracking application, showing the number of steps taken during the day. This interface uses the colour style *Light text* on a black background (1), allowing a very high contrast of 21:1. In addition, the light yellow icon (2), combined with a black background, also provides a high contrast of 20.16:1.

Example 3b shows the interface of a medication management application, in which using a white background with a black headline and black buttons, incorporating white labels, achieved a contrast of 21:1. In these examples, white and black colours correspond to the following colour styles: *Button dark* for the buttons, *Dark text* for the header, and *Button label light* for the button labels.

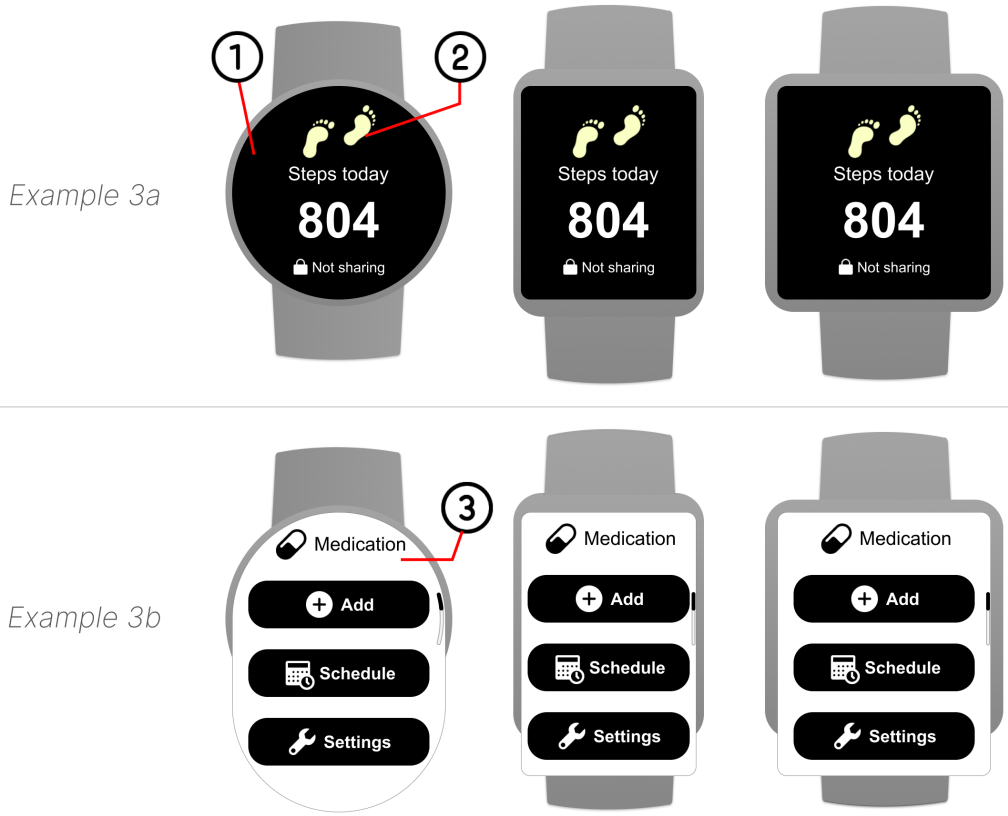

Figure 5.15: Examples of applications of PG3.

5.3.4 PG4: Be objective

As shown in Figure 5.16, two examples of PG4 application are given. *Example 4a* uses an interface based on the main menu of a sports activity tracking application. The headline is displayed centred at the top of the page, in a large size so that it is easily recognisable (1). In addition, the buttons assume the *Button dark* colour style to distinguish them from the rest of the interface and show that they are interactive elements (2). The white text (using the *White text* colour style) on the button and its icon make it easier to understand its function. Finally, the *Scroll indicator* on the right of the interface and the partial display of the last button in the list highlight that it is possible to scroll down (3).

Example 4b represents an alert notification after a fall of the user has been identified. The header is composed of an icon, and the text "Fall detected" (4) explicitly indicates to the user that this is an important notification that can be used to help them. The two buttons, positioned vertically to maximise the screen's width, aim to be easy to identify (5). They include a short sentence indicating their function and an icon. The help button assumes the *Warning actions* colour style,

symbolising urgency, so the interface element attracts the most attention from the user. No other elements have been added to keep the interface clear.

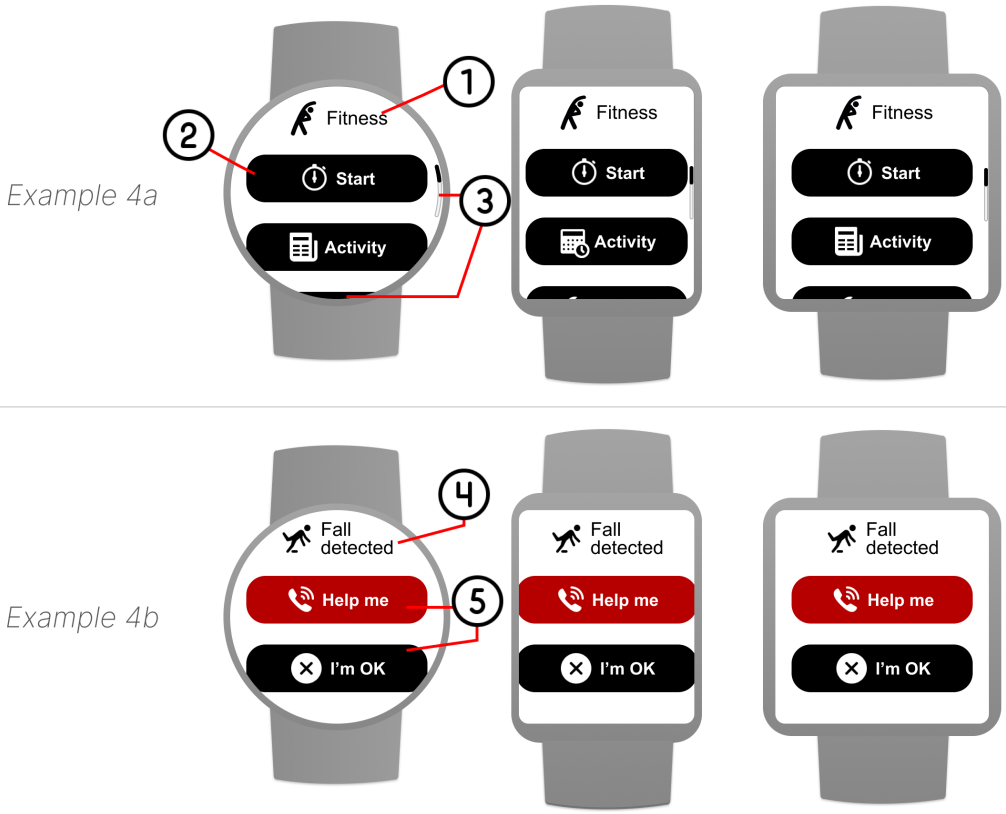

Figure 5.16: Examples of applications of PG4.

5.3.5 PG5: Avoid complex gestures

The single tap, represented in Figure 5.17, is a simple gesture and is undoubtedly the most commonly used way of interacting with a touch interface. This movement consists of placing the tip of the finger on an interactive zone. Scrolling is a slightly more complex gesture requiring a tap and a vertical finger movement, this operation seems essential for interacting on a smartwatch, since it is often the case that the contents don't fit the screen size.

In comparison, although swiping (horizontal scrolling) seems to imply the same level of motion complexity as scrolling but in a horizontal direction, it actually requires a more demanding movement of the finger and of the wrist. Consequently, it might be also considerable as usable by the target public, we suggest that it is avoided when other solutions are possible.

Also, while scrolling (vertically) typically occurs within a single page, swiping (horizontally) is also used in interface design as a way to transition between pages. We argue that the latter approach is even more challenging for inexperienced users.

A double tap involves a rapid succession of two taps within a very short time frame. This makes it a potentially challenging gesture. Furthermore, it contradicts PG13, which suggests avoiding time-based interactions. The pinch-to-zoom gesture necessitates a precise, coordinated movement of two fingers in a horizontal plane. This gesture may prove difficult for individuals with motor disabilities, including hand tremors.

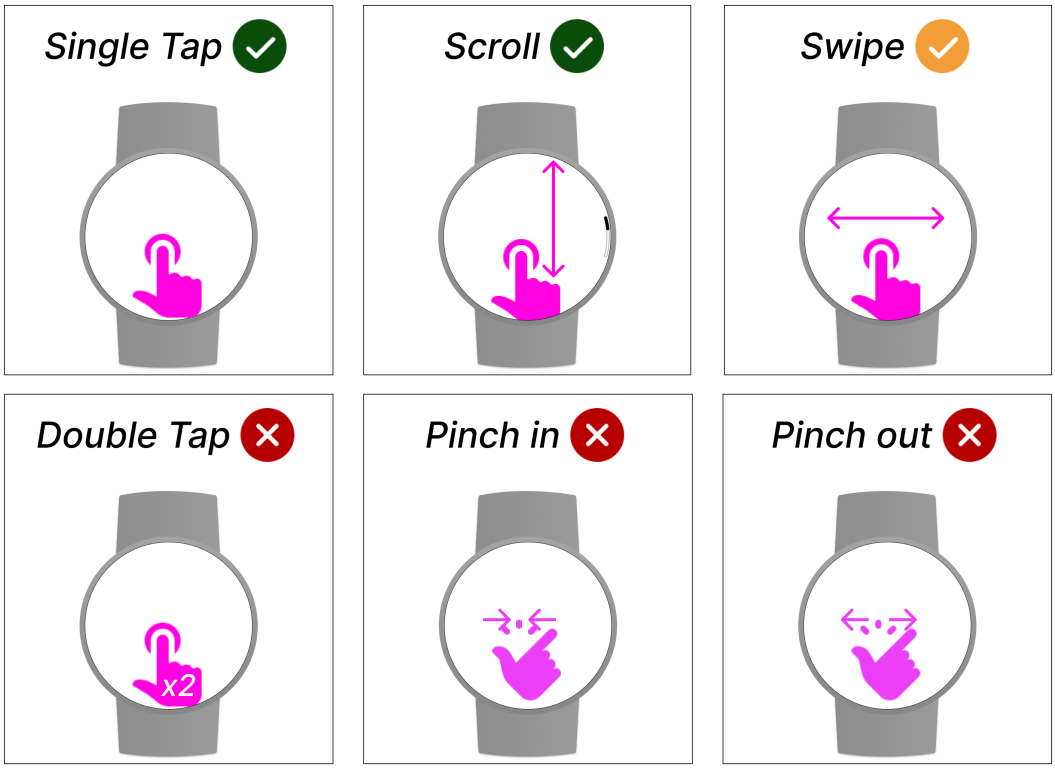

Figure 5.17: Examples of applications of PG5.

5.3.6 PG6: Ensure distance between controls

Figure 5.18 presents *Example 6a*, which takes the case of an activity tracking application to show the suggested spacing between the elements. Significant spacing has been taken into account: the space between the header and the button list is wider, to allow the title to be identified (1); The space between each button is less pronounced (2), to emphasise that they are related elements.

Also, *Example 6b* presents a suggested interface for receiving a voice call. Composed of a large headline representing the icon and the name of the calling contact and two large buttons for answering or hanging up the call. The space between the

icon and the name of the calling contact is close (3), so that the user can quickly relate the icon and the contact's name. The two decision buttons are positioned at the bottom, with a wider spacing between them and the header, to show that a decision has to be made (4). Finally, the two buttons are spaced far enough apart to avoid targeting errors (5). In the case of rectangular and square devices, the headers can be placed higher up to slightly increase the spacing, since the top of those screens is flat.

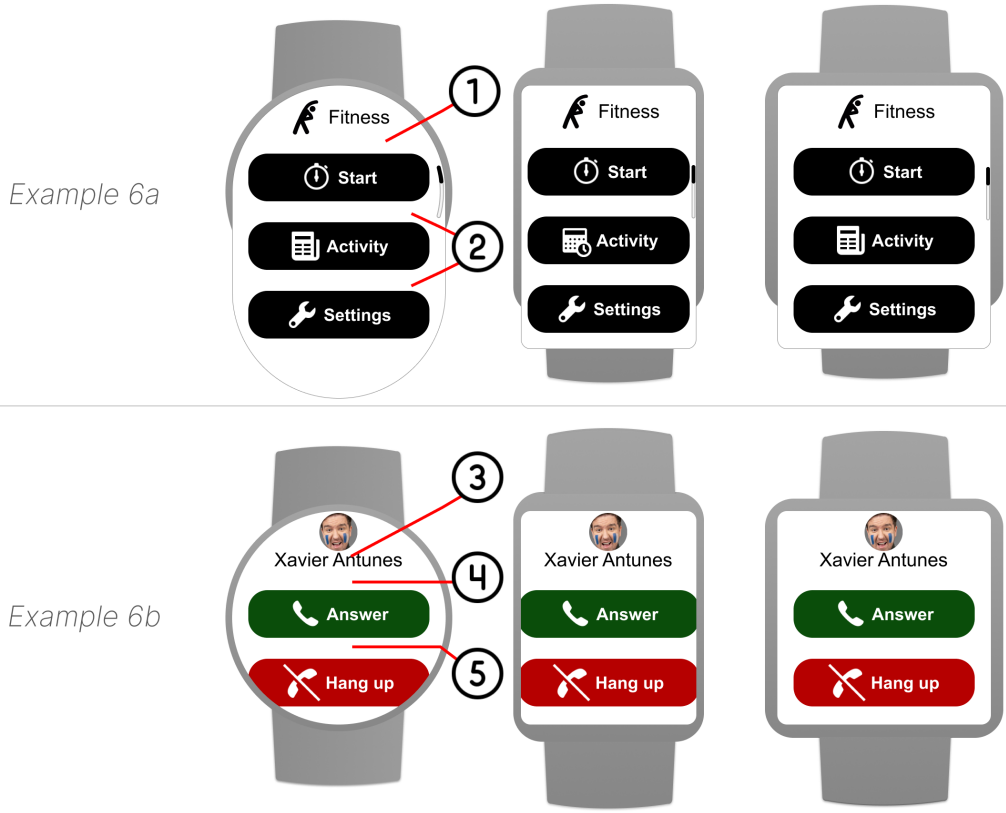

Figure 5.18: Examples of applications of PG6.

5.3.7 PG7: Use multisensory feedback

Suggestions regarding using PG7 can be found in Figure 5.19. *Example 7a* illustrates the feedback that can be used when a button has been pressed. The interface used represents the main menu of a health data tracking application. When a button is pressed, its colour changes, and its border is evidenced (1) to give visual feedback to the user so that they are aware of the action that has just been taken. To complement this, a sound is emitted (2), and vibrations are used as touch feedback (3).

Example 7b shows a use of feedback in the case of a notification from a medication reminder application. Here, a different background colour (4) (which still complies PG3) is used as visual feedback during the notification, drawing the user's attention to the screen. To complement this, sound (5) and vibrations are also emitted (6).

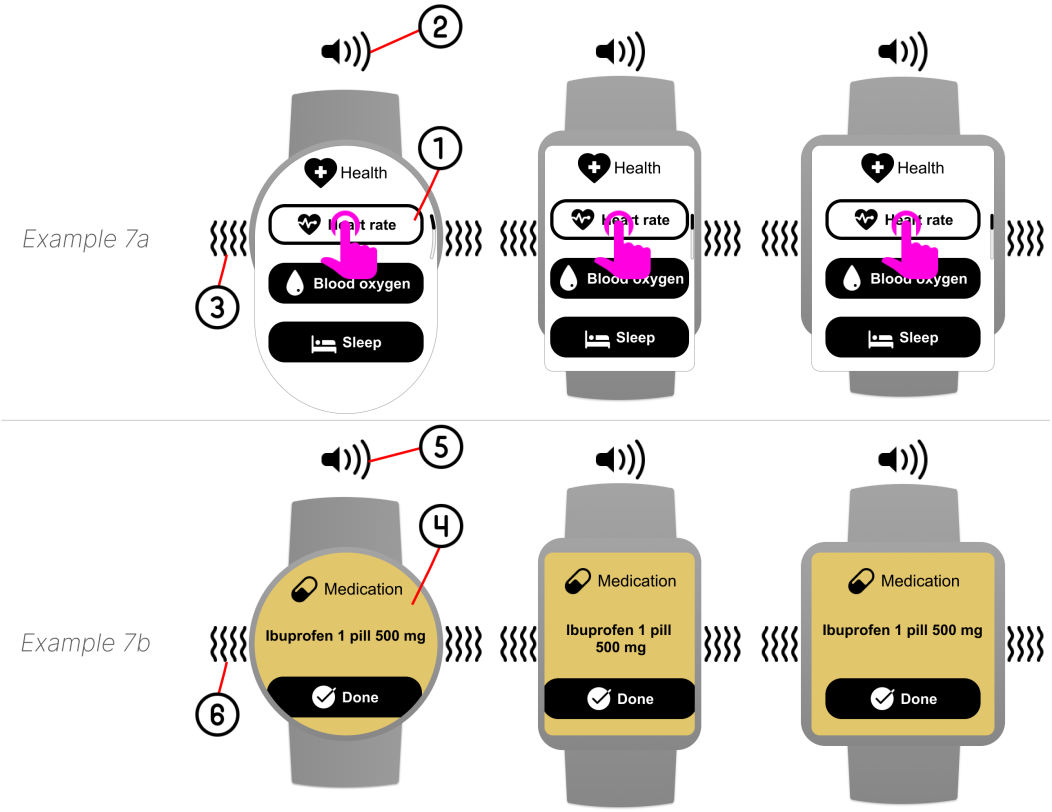

Figure 5.19: Examples of applications of PG7.

5.3.8 PG8: Support corrections

Figure 5.20 shows the suggested interfaces applying this PG. *Example 8a* refers to deleting a selected contact in a contact directory application. When the delete button is pressed (1), a confirmation page appears to allow the user to confirm or cancel this operation (2). The confirmation page can be scrolled down so that the full height of the "Cancel" button is visible, as not to hinder interaction. This is necessary to accommodate the wider header, which includes the contact's telephone number, for easy identification while keeping the spacing wide. Also, large buttons can be used for round or square smartwatches. In contrast, for rectangular ones, since both interfaces allow for scrolling, medium buttons were used to avoid superimposition with the scrolling indicator.

Example 8b shows a potential use case for a button to return to the application's main menu, which could be applied to smartwatches without a physical button to

perform this action. This is a page displaying the user's heart rate from a health-tracking application. When the back button is pressed (3), the user returns to the previous interface, which is, in this case, the main menu of the application (4).

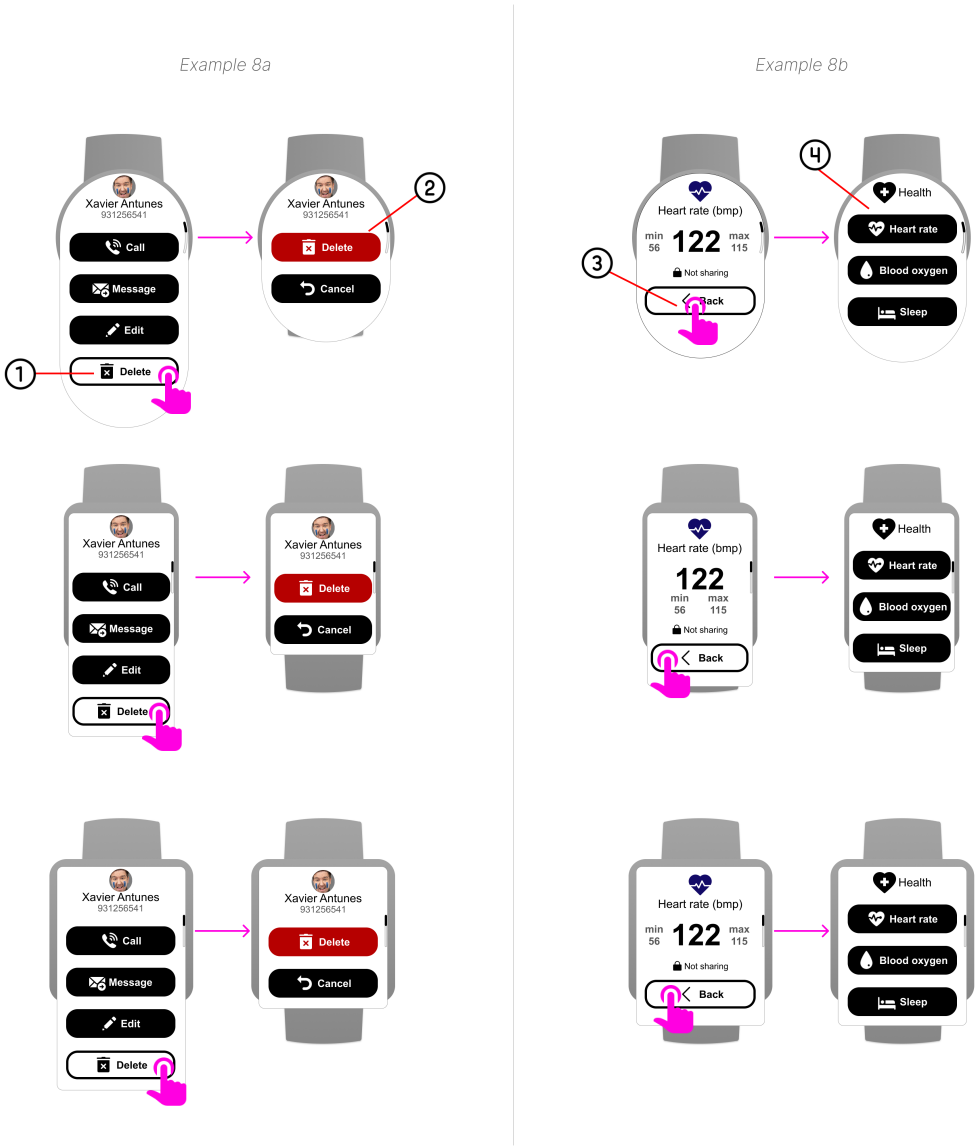

Figure 5.20: Examples of applications of PG8.

5.3.9 PG9: When designing buttons, include both icons and text labels

Figure 5.21 suggests two examples of applying this guideline. In *Example 9a*, the first button combines the use of the "Heart rate" label with an icon representing cardiac activity (1). The same applies to the second button, combining the "Blood

oxygen" label with an icon representing a drop (2), and for the third one using the "Sleep" label along with an icon representing a person lying in bed (3).

Example 9b presents a notification interface reminding the user to drink water to keep them hydrated. The button used to close this reminder also comprises a combination of an icon and a text label. It uses an "Ok" label and an icon representing a thumbs up (4) to indicate that this is a button for confirming the callback.

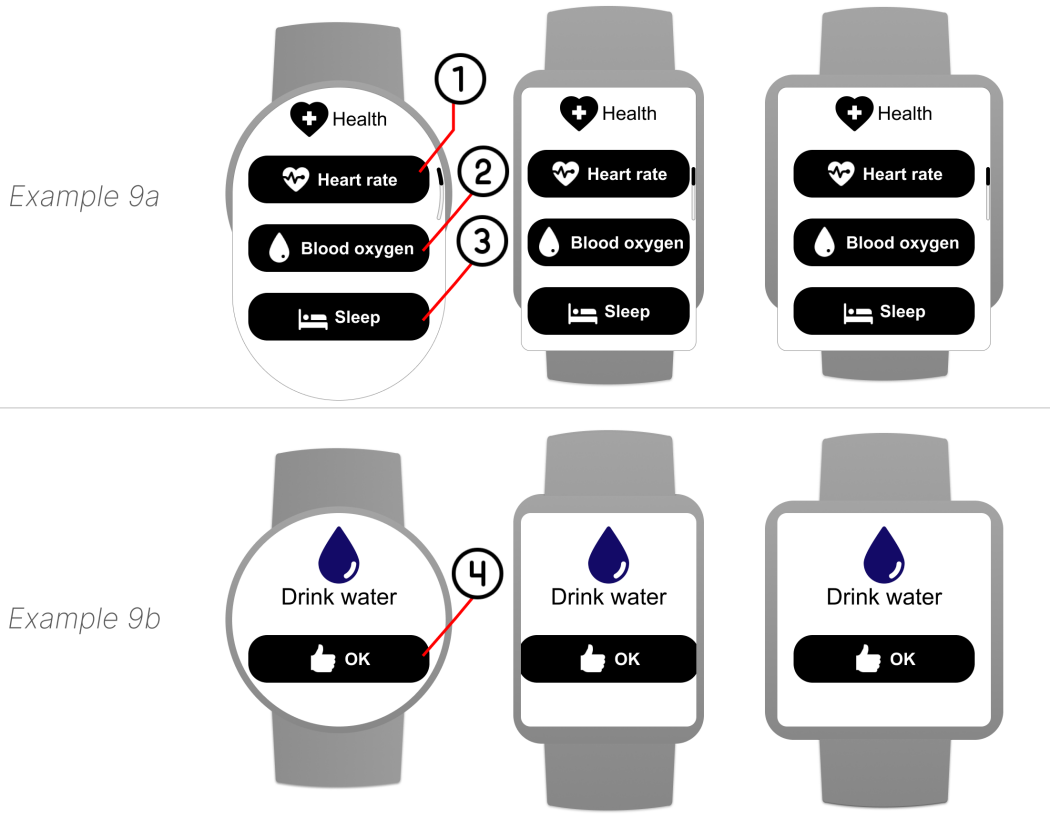

Figure 5.21: Examples of applications of PG9.

5.3.10 PG10: When using sound, prefer low frequencies

The interfaces shown in Figure 5.22 represents a medication reminder notification in the form of an audio message, recognisable by the *Audio message indicator* in the centre of the screen (1). This audio message should, therefore, have a frequency of less than 4000 Hz [Iancu and Iancu, 2020]. The same applies to the audible notification emitted by this reminder. In addition, multisensory feedback can be used to help the user perceive the notification (2).

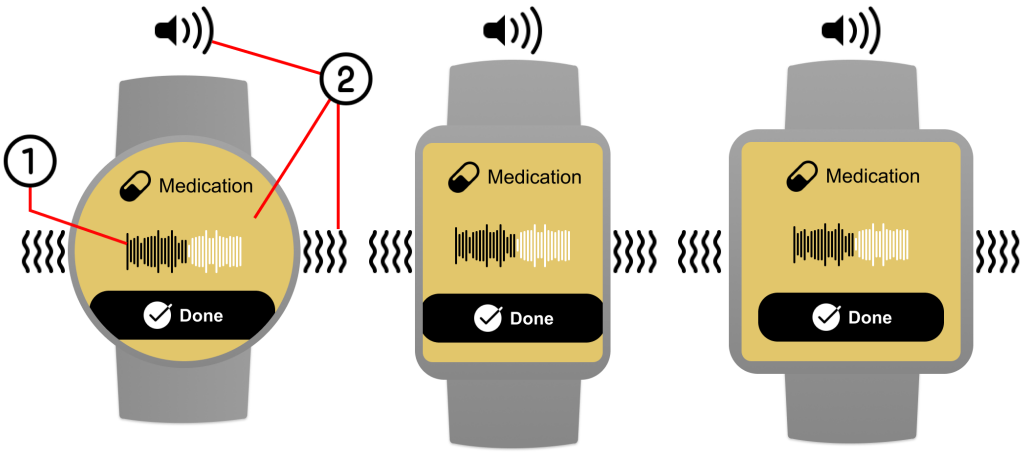

Figure 5.22: Example of application of PG10.

5.3.11 PG11: Allow for customisations

An example of the implementation of the user's ability to customise the interface is shown in Figure 5.23. These interfaces represent the parameters of an application, allowing the user to change display settings, such as the size of the button icons, shown here in this example. When the "Icon size" button is pressed in the display settings (1), a new page appears, allowing the user to choose three different button icon sizes. On this page, button icons are sized accordingly with the corresponding option, offering a visual representation to the user (2). After the user has chosen a size, for example, "Large", they automatically return to the previous page, where all the button icons have changed to large (3).

5.3.12 PG12: Declutter the interface

Example 12a, presented in Figure 5.24, uses the notification interface advising the user to hydrate. It consists of a large icon, representing a drop of water, positioned at the top of the interface, with a short sentence just below it indicating the precise purpose of the notification (1). Finally, the button representing the acknowledgment (2) is large and spaced further apart from the header to attract the user's attention.

Example 12b uses the interface showing the user's daily step count. As in the previous example, it consists of a large header at the top. Then, at the bottom, the number of steps taken and, finally, a *Data sharing indicator* showing if this data is being shared with a third party. The information that should mainly attract the user's attention is the number of steps, which uses the *Health data* text style (3). In these two examples, the interfaces are meant to be simple and include only useful elements, which could help users stay focused.

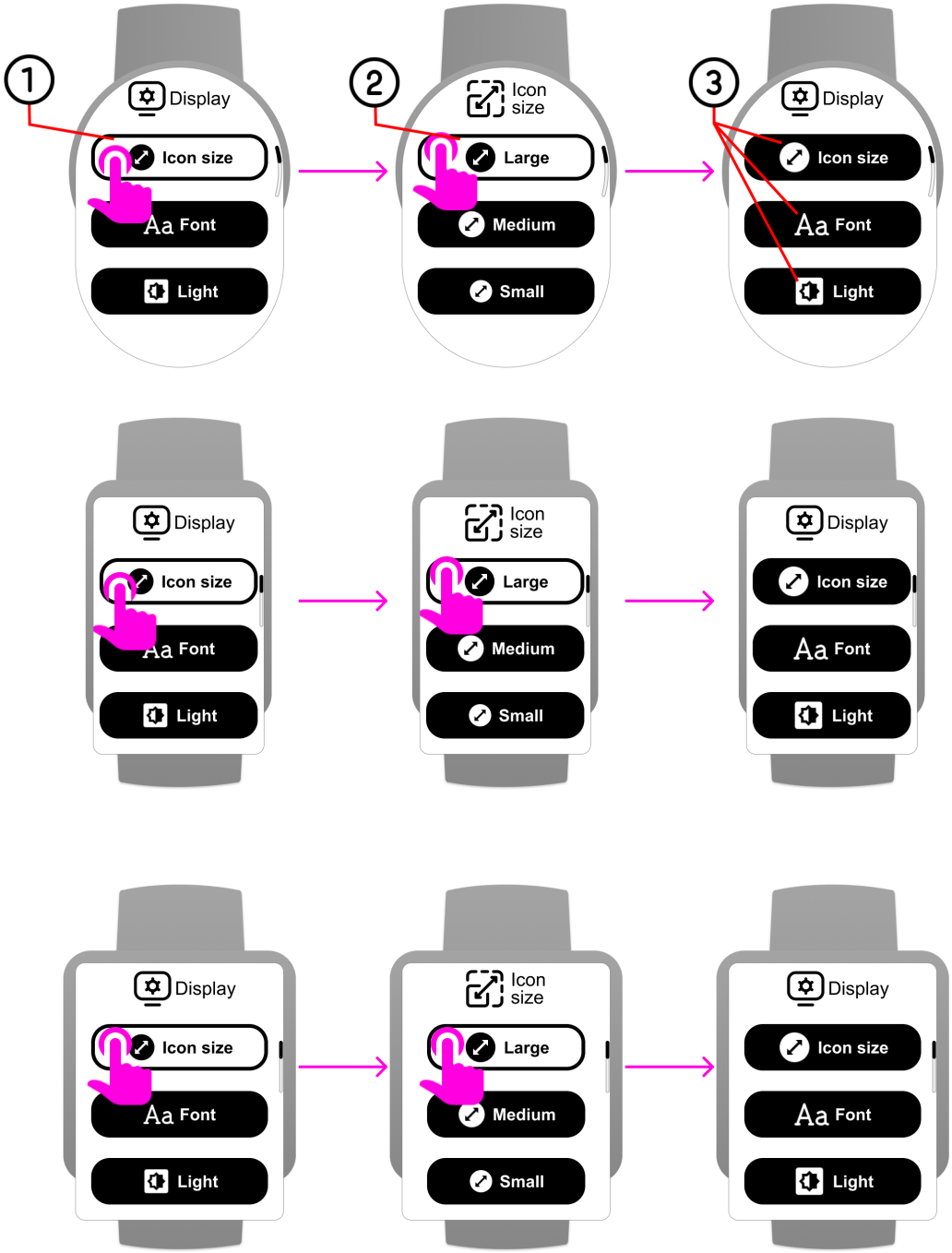

Figure 5.23: Example of application of PG11.

Figure 5.24: Examples of applications of PG12.

5.3.13 PG13: Avoid time-based interactions

Figure 5.25 presents the suggestions for applying PG13. *Example 13a* highlights that the medication reminder interface does not impose any time constraints on the user. It is a notification that does not disappear after a certain time-out since it uses the "Done" button to be closed (1), letting users read and understand the interface at their own pace.

In addition, as shown in *Example 13b*, the contact deletion confirmation page does not impose any time constraints as well, as it can only be closed by pressing either the confirm or cancel button. This interface could be more suitable than a pop-up (a small box that appears on the interface over its main content) because it typically closes after a time-out or by pressing either a button or outside it. As the space in a pop-up is very limited, and even more on a smartwatch, we decided not to consider that solution.

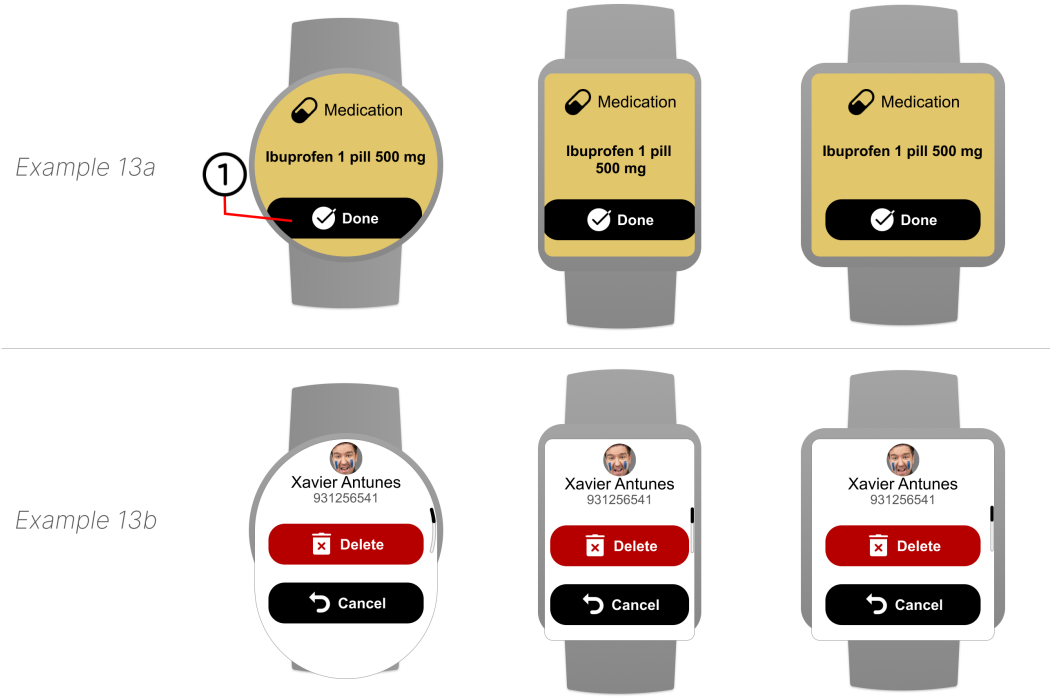

Figure 5.25: Examples of applications of PG13.

5.3.14 PG14: Integrate speech to complement output/input

Figure 5.26 shows the interface of a received message, proposing different input or output options. In this interface, the user can read the message received or it can be read aloud by pressing a button (1). In addition, to reply to the message, the user

can use a voice recognition mechanism to create a text message using speech after pressing the "Speech to text" button (2), or answer using a keyboard by pressing the "Write" button (3).

Figure 5.26: Example of application of PG14.

5.3.15 PG15: Simplify task execution

Two examples of applying PG15 are provided in Figure 5.27. *Example 15a* uses the interface showing a received message as seen for the previous guideline. Given that the user's goal is to reply to this message, using speech to write their reply (1) instead of writing it on a keyboard could reduce the time and effort needed to carry out the task.

Example 15b shows the interface for actions that can be carried out with a contact. This interface allows calling this contact directly by pressing the "Call" button (2). If the user is on this interface and decides to call the contact, pressing this button drastically reduces the number of steps involved, when compared to having to leave the contact list and find the calling application.

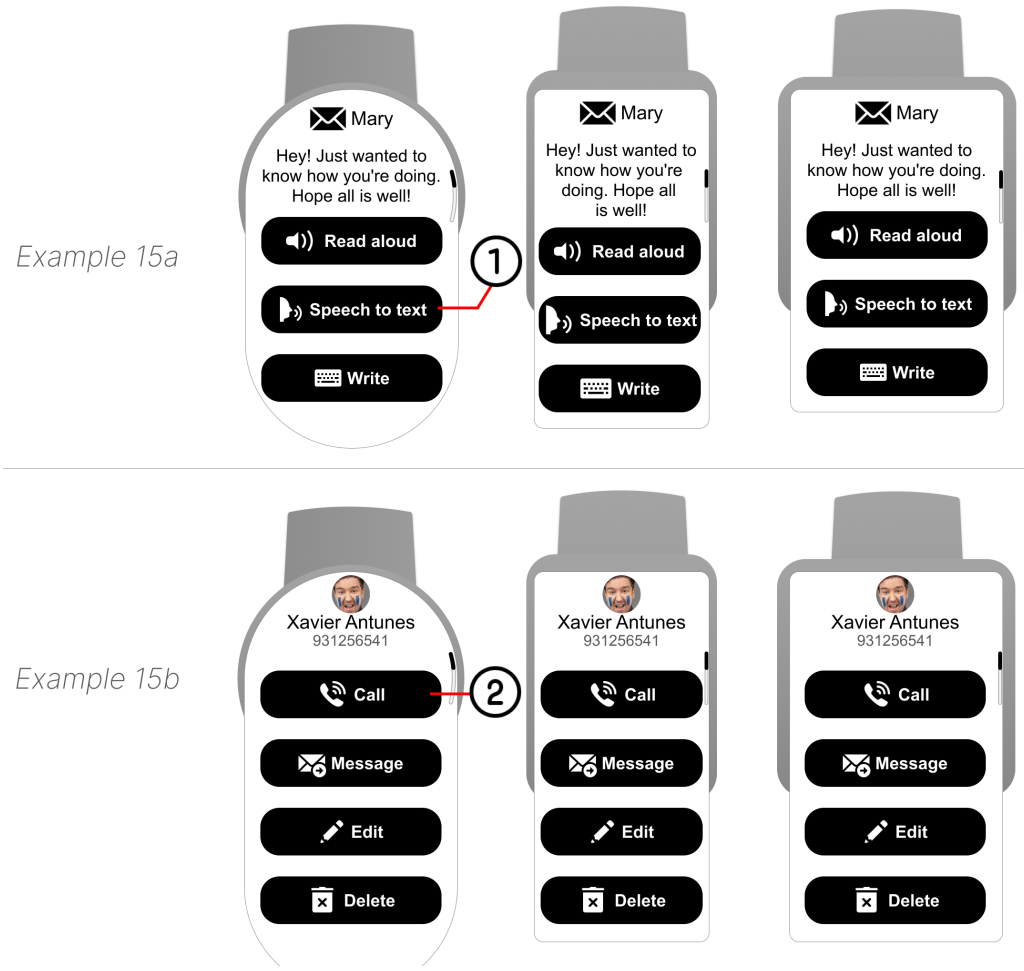

Figure 5.27: Examples of applications of PG15.

5.3.16 PG16: Use colour effectively

In the application for requesting help after a fall has been detected, shown in *Example 16a* in Figure 5.28, the *Warning actions* colour style, which is in the spectrum of "warm colour", is used to draw users' attention to the button (1), so that users are immediately drawn to the call for help [Farage et al., 2012].

In *Example 16b*, showing a weather application interface, blue, a "cool colour", is used in the background (2). However, it is combined with the *White text* colour style and a yellow icon to ensure a high contrast level of 16.58:1 and 15.34:1, respectively.

Figure 5.28: Examples of applications of PG16.

5.3.17 PG17: Emphasise the most important information

Figure 5.29 suggests two examples for applying PG17. *Example 17a* represents a voice call history consisting of a *list of call directory buttons*, each representing a call already made or received. The names of contacts (1) who have called or been called are written using the *Specific button label* text style at the top of the button. Under the contact's name is an icon (2) indicating the status of this call (e.g., missed, answered). Finally, other information, such as the date and time of the call (3), is displayed assuming the *Secondary text* text style, next to the icon and below the contact name.

Regarding *Example 17b*, using the activity tracking application interface, the most important information, the application header (4), is located at the top of the screen. Secondly, the buttons are easily identifiable from the background, and those representing the most frequently used actions are located at the top of the list to make them more accessible to the user (5). In this case, the button for starting a sports session is at the top of the list, followed by the button for viewing physical activities already completed. Finally, the settings button is at the bottom of the list.

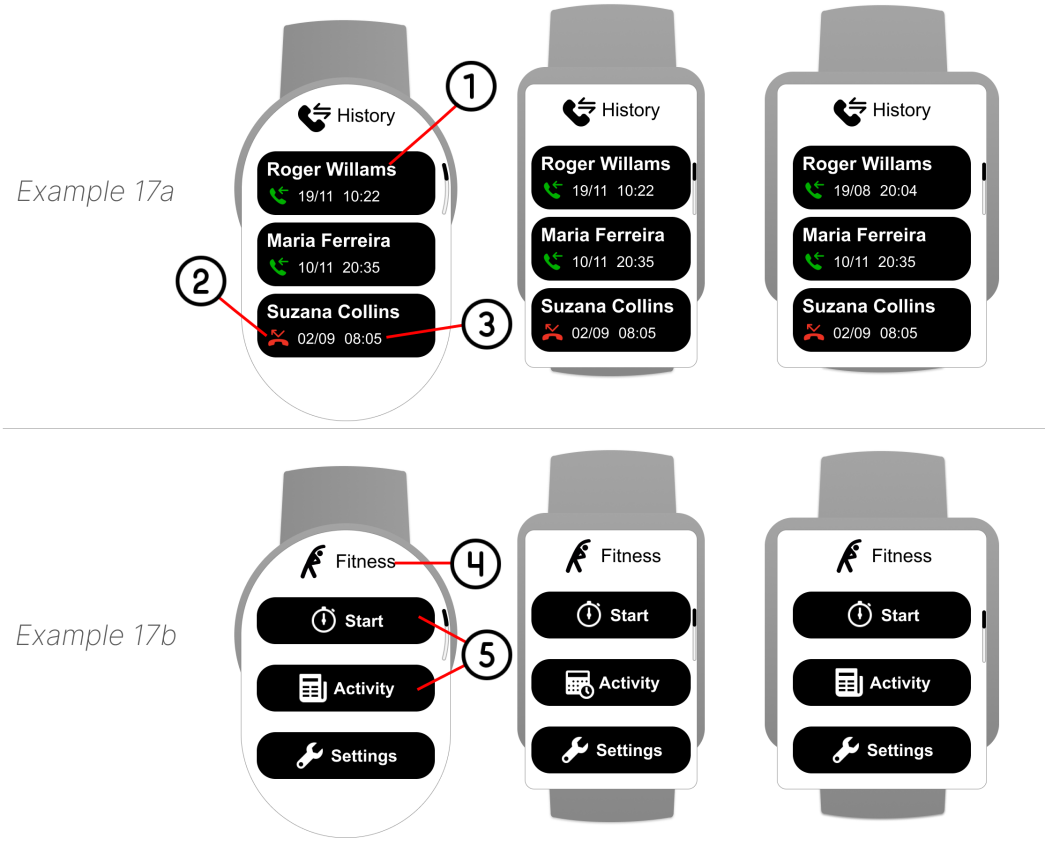

Figure 5.29: Examples of applications of PG17.

5.3.18 PG18: Use intuitive icons

Figure 5.30 shows two suggestions for applying this guideline. *Example 18a* uses the user fall detection interface, where each button has a simple icon representing its function. In the case of the help button, the icon used is a telephone indicating a call for help (1), and in the case of the button signifying that help is not required, a cross indicates refusal (2).

Regarding *Example 18b* using the menu of actions that can be carried out for a contact, a telephone icon is used for the call button (3), a letter icon for the button

allowing to send a message (4), a pencil symbolising the edit button (5), and a bin with a cross for the delete button (6).

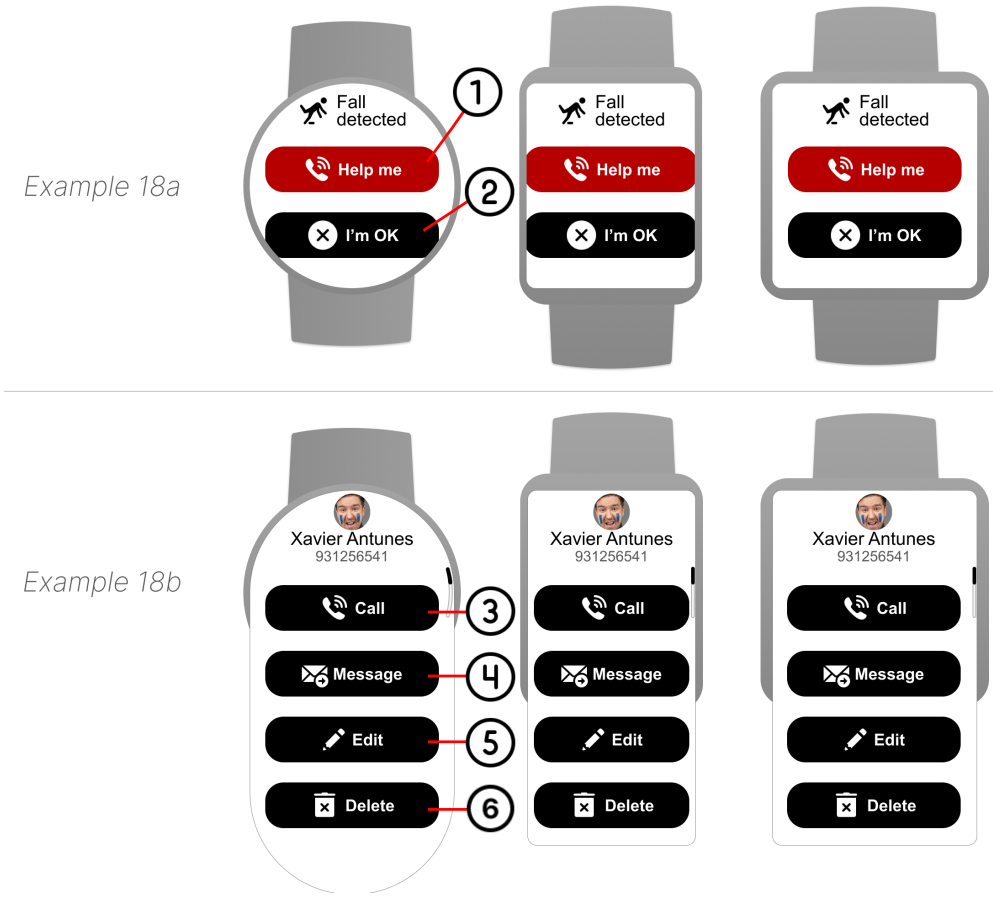

Figure 5.30: Examples of applications of PG18.

5.3.19 PG19: Support the sense of privacy

Two examples of implementation of PG19 are illustrated in Figure 5.31. *Example 19a* shows the change in data sharing parameters, for the case of heart rate. First, in the settings menu, the user selects the application for which they want to change these parameters (1). The next page, displaying a *Sharing settings list*, contains all the data that can be shared by the selected application. An indication of the sharing status and a button to change it are located below each data's name. If data sharing is not enabled, the indication is "Not sharing" (2), and the button is red and allows the user to enable it. If data sharing is enabled, the indication is "Sharing" (3), and the button allows to disable it. When a data sharing parameter changes, a confirmation screen ensures that the user is informed of the change (4). Using a rectangular or square smartwatch, the confirmation interface can be displayed without scrolling while preserving the spacing between interface elements (5).

Example 19b emphasises the distinction between private and public information within the application. Indeed, on the interface showing the user's heart rate, a visual element has been added to indicate that this data is not shared: the *Data sharing indicator*. As presented in Subsection 5.2.5, this component comprises a closed padlock icon and the label "Not sharing" (6).

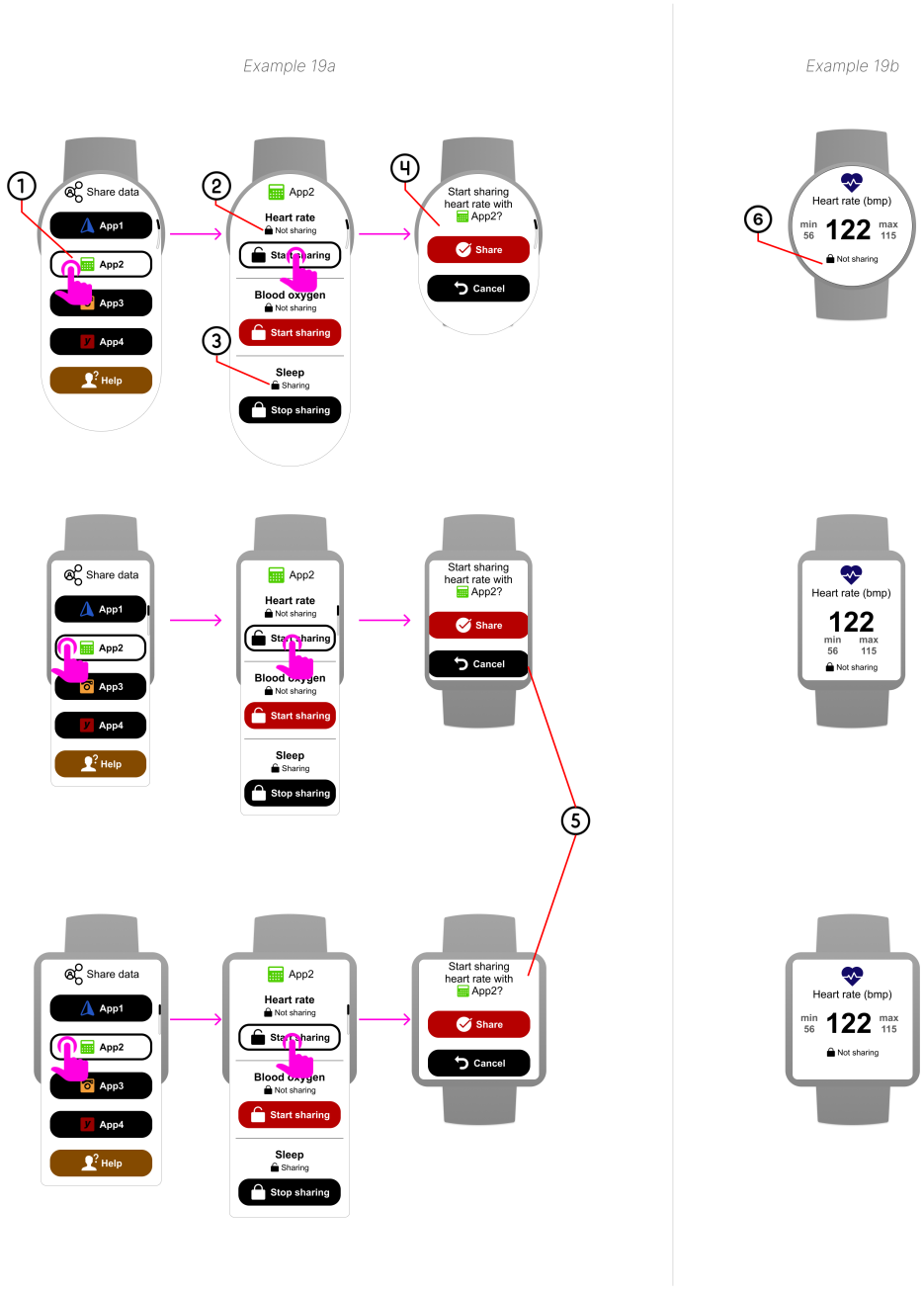

Figure 5.31: Examples of applications of PG19.

5.3.20 PG20: Use plain language

Figure 5.32 presents two interfaces using plain language. Regarding the notification of a detected fall (*Example 20a*), a very short, unambiguous message is presented at the top of the interface (1). In addition, the button labels describe the actions that would occur (2), as opposed to simple words such as "yes" and "no". This lets the user understand the button's function without depending on memorising the notification's header.

Example 20b shows the case of an interface requesting user authorisation for an application to use location. The subject of the notification is clearly expressed above the set of buttons, in a short sentence. In addition, the user is reminded of the application's name to use his location (3) to minimise the possibility mistakes. Finally, the two buttons used to respond to this request are labelled "Allow" or "Deny" (4) to link each button to the request mentioned in the interface header.

Figure 5.32: Examples of applications of PG20.

5.3.21 PG21: Offer assistance

A suggestion for applying PG21 is shown in Figure 5.33. This is the data-sharing settings menu, which includes a help button at the bottom of the list (1). This button might have a specific colour (we used the *Help button* colour style in this example), so it can be distinguished from the others through the application. If the user presses it, a page containing information about the screen appears to support the user (2). In this case, it is also included contact information (3), such as phone number and email, should the user require further help.

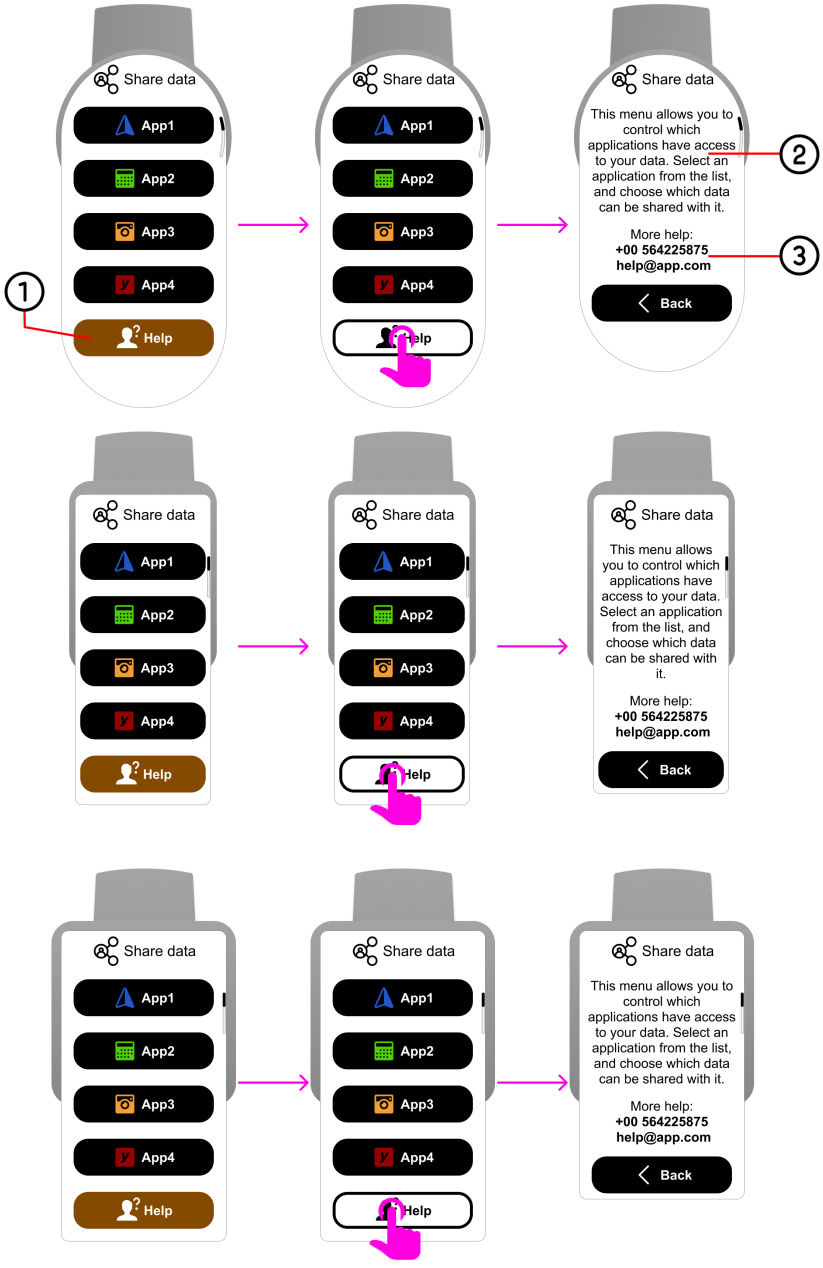

Figure 5.33: Example of application of PG21.

Chapter 6

Conclusion, limitations and future work

This chapter presents conclusions, discusses the limitations of this study, and provides insights into future work.

6.1 Conclusion

Age-related difficulties can hinder interactions with interfaces, compromising user experience and potentially leading to a negative perception and rejection of technology among older users. To address this issue, various studies have suggested guidelines for designing interfaces tailored to this target audience across different domains (e.g., mobile applications, Web, wearable devices). However, this subject has not been comprehensively investigated within the context of smartwatch interfaces despite the potential of such devices to be highly useful for older adults. In fact, smartwatches can provide several important functionalities that can save lives, such as detecting a fall and allowing real-time monitoring of vital signs (e.g., heart rate, body temperature). Furthermore, these devices possess numerous advantages when compared to conventional monitoring devices, as they are non-intrusive and highly portable, seamlessly integrating into daily life.

Our objective was, therefore, to fill this gap in the literature by proposing a set of design guidelines for smartwatch interfaces for older adults. In this study, we

reviewed the age-related challenges that can hinder interaction with interfaces, identifying five categories: visual impairments, hearing loss, motor difficulties, cognitive problems, and a possible loss of motivation, which can be linked to age-related challenges as well as to a poor or negative experience using technology (as addressed in our RQ1: "What specific challenges and impediments do older adults encounter when engaging with digital interfaces, particularly on smartwatches?"). Subsequently, we systematically extracted design guidelines focused on our target audience but related to other domains, resulting in 175 reference guidelines. Then, we identified peculiar features of smartwatches (e.g., small screen size, wrist-worn devices) in order to assess the potential applicability of the extracted guidelines initially designed for other devices. The analysis of these guidelines included a preparation and filtering phase, in which guidelines were identified as covered by some inherent characteristics of smartwatches, while others were considered not applicable to such devices when we could not find solutions for their implementation in smartwatch interfaces (which corresponds to our RQ2: "How do existing interface design guidelines tailored for older adults, originally developed for alternate devices, align with the design prerequisites and usability considerations inherent to smartwatches?"). Then, we classified the guidelines based on the five categories of challenges identified and distilled them into 21 guidelines that we propose for the design of smartwatch interfaces for older adults. Furthermore, we created profile sheets containing all relevant information for each guideline to allow future researchers to use this proposal independently without relying on this full report. Finally, to provide tangible instantiations of the application of the guidelines, we created a design system that includes examples and suggestions on the use of several components suitable for reuse in future studies and developments (according to our RQ3: "How can the PGs be illustrated in a way that addresses different contexts of application and facilitates their use in future work?"). Each example is presented and applied to representations of different smartwatch physical formats available on the market (round, rectangular, and square).

6.2 Limitations and future work

By proposing design guidelines for smartwatch interfaces for older adults, our work represents a contribution to the research and development in this domain. However, we acknowledge, as a main limitation, the fact that, due to time constraints, users were not involved in the process of evaluating the quality of the proposals. As such, our work should be regarded as a starting point, bearing in mind that the guidelines that we are presenting need to be further tested for future work. To achieve this, the components and interfaces of the design system, or others created in line with the set of guidelines, could be evaluated through usability tests. During those tests, researchers would assign specific tasks to participants and

observe their interactions, compiling a comprehensive record of all relevant information, such as errors, hesitations, misunderstandings, and successes. Furthermore, the tests could be recorded for subsequent analysis. The information gathered could provide insights for correcting, validating, or even proposing other guidelines and interface examples. In addition, future work might also provide recommendations on specific measures for component sizes and spacing, based on observations of the use of interfaces conceived according to the PGs. It would also be relevant to realise if there is a particular physical format of smartwatches that should be recommended for this target audience.

The research conducted as part of this master's thesis is being prepared for submission to a peer-reviewed scientific journal indexed in Scopus/World of Science. This includes refining the analysis, ensuring clarity and rigor in presenting the results, and aligning the manuscript with the specific requirements and standards of the target publication.

References

[AccessibleHomeCare, 2022] AccessibleHomeCare (2022). The benefits of smartwatches for seniors. visited on 2023-01-23. [Cited on page 2]

[Aldeer et al., 2018] Aldeer, M., Javanmard, M., and Martin, R. P. (2018). A review of medication adherence monitoring technologies. *Applied System Innovation*, 1(2):14. [Cited on pages 2 and 15]

[Anderson and Perrin, 2017] Anderson, M. and Perrin, A. (2017). Tech adoption climbs among older adults. [Cited on page 19]

[Barbosa Neves et al., 2019] Barbosa Neves, B., Franz, R., Judges, R., Beermann, C., and Baecker, R. (2019). Can digital technology enhance social connectedness among older adults? a feasibility study. *Journal of Applied Gerontology*, 38(1):49–72. [Cited on page 19]

[Ben Lutkevich, 2022] Ben Lutkevich, A. P. (2022). What is a smartwatch? visited on 2024-08-01. [Cited on page 14]

[Bergman, 2024] Bergman, C. (2024). Design systems 101: What is a design system? visited on 2024-12-08. [Cited on page 5]

[Berkowsky et al., 2017] Berkowsky, R. W., Sharit, J., and Czaja, S. J. (2017). Factors predicting decisions about technology adoption among older adults. *Innovation in aging*, 1(3):igy002. [Cited on pages 18 and 19]

[Betts et al., 2019] Betts, L. R., Hill, R., and Gardner, S. E. (2019). "there's not enough knowledge out there": Examining older adults' perceptions of digital technology use and digital inclusion classes. *Journal of Applied Gerontology*, 38(8):1147–1166. [Cited on pages 4 and 19]

[Bhanvadia et al., 2022] Bhanvadia, S. B., Brar, M. S., Delavar, A., Tavakoli, K., Radha Saseendrakumar, B., Weinreb, R. N., Zangwill, L. M., and Baxter, S. L. (2022). Assessing usability of smartwatch digital health devices for home blood pressure monitoring among glaucoma patients. *Informatics*, 9(4). [Cited on pages 2 and 14]

[Casilari and Oviedo-Jiménez, 2015] Casilari, E. and Oviedo-Jiménez, M. A. (2015). Automatic fall detection system based on the combined use of a smartphone and a smartwatch. *PloS one*, 10(11):e0140929. [Cited on page 14]

[Charness and Boot, 2009] Charness, N. and Boot, W. R. (2009). Aging and information technology use: Potential and barriers. *Current directions in psychological science*, 18(5):253–258. [Cited on page 4]

[Chen et al., 2013] Chen, K. B., Savage, A. B., Chourasia, A. O., Wiegmann, D. A., and Sesto, M. E. (2013). Touch screen performance by individuals with and without motor control disabilities. *Applied ergonomics*, 44(2):297–302. [Cited on page 17]

[Cota et al., 2015] Cota, T. T., Ishitani, L., and Vieira Jr, N. (2015). Mobile game design for the elderly: A study with focus on the motivation to play. *Computers in Human Behavior*, 51:96–105. [Cited on pages 15, 16, and 18]

[De Barros et al., 2014] De Barros, A. C., Leitão, R., and Ribeiro, J. (2014). Design and evaluation of a mobile user interface for older adults: navigation, interaction and visual design recommendations. *Procedia Computer Science*, 27:369–378. [Cited on pages 12 and 30]

[Dehghani and Kim, 2019] Dehghani, M. and Kim, K. J. (2019). The effects of design, size, and uniqueness of smartwatches: perspectives from current versus potential users. *Behaviour & Information Technology*, 38(11):1143–1153. [Cited on pages 14 and 52]

[Design, 2024] Design, E. P. (2024). Types of sensors in smartwatches, fitness trackers and bands. visited on 2024-08-02. [Cited on page 14]

[Ding et al., 2022] Ding, E. Y., CastañedaAvila, M., Tran, K.-V., Mehawej, J., Filippaios, A., Paul, T., Otabil, E. M., Noorishirazi, K., Han, D., Saczynski, J. S., et al. (2022). Usability of a smartwatch for atrial fibrillation detection in older adults after stroke. *Cardiovascular Digital Health Journal*, 3(3):126–135. [Cited on pages 3 and 21]

[Erdem et al., 2019] Erdem, N. S., Ersoy, C., and Tunca, C. (2019). Gait analysis using smartwatches. In *2019 IEEE 30th International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC Workshops)*, pages 1–6. [Cited on page 15]

[Evans et al., 2016] Evans, J., Papadopoulos, A., Silvers, C. T., Charness, N., Boot, W. R., Schlachta-Fairchild, L., Crump, C., Martinez, M., and Ent, C. B. (2016). Remote health monitoring for older adults and those with heart failure: adherence

and system usability. *Telemedicine and e-Health*, 22(6):480–488. [Cited on pages 19 and 20]

[Farage et al., 2012] Farage, M. A., Miller, K. W., Ajayi, F., and Hutchins, D. (2012). Design principles to accommodate older adults. *Global journal of health science*, 4(2):2. [Cited on pages 1, 3, 4, 12, 15, 16, 17, 18, 35, 53, and 77]

[Farivar et al., 2020] Farivar, S., Abouzahra, M., and Ghasemaghaei, M. (2020). Wearable device adoption among older adults: A mixed-methods study. *International Journal of Information Management*, 55:102209. [Cited on page 1]

[Federmeier et al., 2010] Federmeier, K. D., Kutas, M., and Schul, R. (2010). Age-related and individual differences in the use of prediction during language comprehension. *Brain and language*, 115(3):149–161. [Cited on page 18]

[Ferreira-Brito et al., 2024] Ferreira-Brito, F., Alves, S., Guerreiro, T., Santos, O., Caneiras, C., Carriço, L., and Verdelho, A. (2024). Digital health and patient adherence: A qualitative study in older adults. *Digital Health*, 10:20552076231223805. [Cited on page 19]

[Figma, 2018] Figma (2018). Guide to components in figma. visited on 2024-08-08. [Cited on page 52]

[Figma, 2024] Figma (2024). Typography in design. visited on 2024-12-02. [Cited on page 53]

[Fisk et al., 2020] Fisk, A. D., Czaja, S. J., Rogers, W. A., Charness, N., and Sharit, J. (2020). *Designing for older adults: Principles and creative human factors approaches*. CRC press. [Cited on pages 3, 16, and 17]

[Foundation, 2024] Foundation, I. D. (2024). What is interaction design (ixd)? visited on 2024-10-30. [Cited on page 9]

[Friemel, 2016] Friemel, T. N. (2016). The digital divide has grown old: Determinants of a digital divide among seniors. *New media & society*, 18(2):313–331. [Cited on page 19]

[Geeksforgeeks, 2024a] Geeksforgeeks (2024a). User interface (ui). visited on 2023-01-23. [Cited on page 9]

[Geeksforgeeks, 2024b] Geeksforgeeks (2024b). What are design guidelines? visited on 2024-10-30. [Cited on page 10]

[Gomez-Hernandez et al., 2023] Gomez-Hernandez, M., Ferre, X., Moral, C., and Villalba-Mora, E. (2023). Design guidelines of mobile apps for older adults: Systematic review and thematic analysis. *JMIR mHealth and uHealth*, 11:e43186. [Cited on pages 1, 11, 30, and 35]

[Han et al., 2023] Han, D., Ding, E. Y., Cho, C., Jung, H., Dickson, E. L., Mohagheghian, F., Peitzsch, A. G., DiMezza, D., Tran, K.-V., McManus, D. D., et al. (2023). A smartwatch system for continuous monitoring of atrial fibrillation in older adults after stroke or transient ischemic attack: application design study. *JMIR cardio*, 7:e41691. [Cited on pages 2 and 14]

[Hartson, 2012] Hartson, R. (2012). *The UX Book: Process and Guidelines for Ensuring a Quality User Experience*. Elsevier. [Cited on page 10]

[Hawley-Hague et al., 2014] Hawley-Hague, H., Boulton, E., Hall, A., Pfeiffer, K., and Todd, C. (2014). Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review. *International journal of medical informatics*, 83(6):416–426. [Cited on page 20]

[Heinz et al., 2013] Heinz, M., Martin, P., Margrett, J. A., Yearns, M., Franke, W., Yang, H.-I., Wong, J., and Chang, C. K. (2013). Perceptions of technology among older adults. *Journal of gerontological nursing*, 39(1):42–51. [Cited on pages 19 and 20]

[Helander, 2014] Helander, M. G. (2014). *Handbook of human-computer interaction*. Elsevier. [Cited on page 4]

[Himi et al., 2023] Himi, S. T., Monalisa, N. T., Whaiduzzaman, M., Barros, A., and Uddin, M. S. (2023). Medai: A smartwatch-based application framework for the prediction of common diseases using machine learning. *IEEE Access*, 11:12342–12359. [Cited on pages 2 and 14]

[Huang, 2009] Huang, K.-Y. (2009). Challenges in human-computer interaction design for mobile devices. In *Proceedings of the World Congress on Engineering and Computer Science*, volume 1, pages 1–6. San Francisco, USA. [Cited on page 9]

[Iancu and Iancu, 2020] Iancu, I. and Iancu, B. (2020). Designing mobile technology for elderly. a theoretical overview. *Technological Forecasting and Social Change*, 155:119977. [Cited on pages 1, 3, 11, 15, 16, 17, 18, 30, 32, 35, 53, and 70]

[Indeed, 2024] Indeed (2024). What is a user interface (ui)? visited on 2024-10-30. [Cited on page 9]

[Islam et al., 2020] Islam, A., Bezerianos, A., Lee, B., Blascheck, T., and Isenberg, P. (2020). Visualizing information on watch faces: A survey with smartwatch users. In *2020 IEEE Visualization Conference (VIS)*, pages 156–160. IEEE. [Cited on page 14]

[Kalantarian et al., 2015] Kalantarian, H., Alshurafa, N., Nemati, E., Le, T., and Sarrafzadeh, M. (2015). A smartwatch-based medication adherence system. In *2015 IEEE 12th International Conference on Wearable and Implantable Body Sensor Networks (BSN)*, pages 1–6. [Cited on pages 2 and 15]

[Kamišalić et al., 2018] Kamišalić, A., Fister Jr, I., Turkanović, M., and Karakatič, S. (2018). Sensors and functionalities of non-invasive wrist-wearable devices: A review. *Sensors*, 18(6):1714. [Cited on page 14]

[Kheirkhahan et al., 2019] Kheirkhahan, M., Nair, S., Davoudi, A., Rashidi, P., Wanigatunga, A. A., Corbett, D. B., Mendoza, T., Manini, T. M., and Ranka, S. (2019). A smartwatch-based framework for real-time and online assessment and mobility monitoring. *Journal of biomedical informatics*, 89:29–40. [Cited on page 14]

[Kim, 2017] Kim, K. J. (2017). Shape and size matter for smartwatches: Effects of screen shape, screen size, and presentation mode in wearable communication. *Journal of Computer-Mediated Communication*, 22(3):124–140. [Cited on page 51]

[Kim and Shin, 2015] Kim, K. J. and Shin, D.-H. (2015). An acceptance model for smart watches: Implications for the adoption of future wearable technology. *Internet Research*, 25(4):527–541. [Cited on page 14]

[King and Sarrafzadeh, 2018] King, C. E. and Sarrafzadeh, M. (2018). A survey of smartwatches in remote health monitoring. *Journal of healthcare informatics research*, 2:1–24. [Cited on pages 2 and 14]

[Kostopoulos et al., 2015] Kostopoulos, P., Nunes, T., Salvi, K., Deriaz, M., and Torrent, J. (2015). F2d: A fall detection system tested with real data from daily life of elderly people. In *2015 17th International Conference on E-health Networking, Application & Services (HealthCom)*, pages 397–403. IEEE. [Cited on pages 2 and 14]

[Kuerbis et al., 2017] Kuerbis, A., Mulliken, A., Muench, F., Moore, A. A., and Gardner, D. (2017). Older adults and mobile technology: Factors that enhance and inhibit utilization in the context of behavioral health. [Cited on page 3]

[Lee and Coughlin, 2015] Lee, C. and Coughlin, J. F. (2015). Perspective: Older adults' adoption of technology: an integrated approach to identifying determinants and barriers. *Journal of Product Innovation Management*, 32(5):747–759. [Cited on pages 20 and 21]

[Lewis and Neider, 2017] Lewis, J. E. and Neider, M. B. (2017). Designing wearable technology for an aging population. *Ergonomics in Design*, 25(3):4–10. [Cited on pages 4, 13, 15, 16, 17, 18, 30, and 35]

[Li et al., 2021] Li, C., Neugroschl, J., Zhu, C. W., Aloysi, A., Schimming, C. A., Cai, D., Grossman, H., Martin, J., Sewell, M., Loizos, M., et al. (2021). Design considerations for mobile health applications targeting older adults. *Journal of Alzheimer's Disease*, 79(1):1–8. [Cited on pages 12, 16, 18, 19, and 20]

[Lima et al., 2022] Lima, F. V., Kadiyala, V., Huang, A., Agusala, K., Cho, D., Freeman, A. M., and Druz, R. (2022). At the crossroads! time to start taking smartwatches seriously. *The American Journal of Cardiology*, 179:96–101. [Cited on pages 2 and 14]

[LiveConnect24, 2023] LiveConnect24 (2023). What are the benefits of a smartwatch? visited on 2023-01-23. [Cited on page 2]

[Luo, 2023] Luo, S. (2023). Smartwatch materials decoded! visited on 2024-08-02. [Cited on page 14]

[Manini et al., 2019] Manini, T. M., Mendoza, T., Battula, M., Davoudi, A., Kheirkhahan, M., Young, M. E., Weber, E., Fillingim, R. B., and Rashidi, P. (2019). Perception of older adults toward smartwatch technology for assessing pain and related patient-reported outcomes: pilot study. *JMIR mHealth and uHealth*, 7(3):e10044. [Cited on pages 3 and 21]

[Mauldin et al., 2018] Mauldin, T. R., Canby, M. E., Metsis, V., Ngu, A. H., and Rivera, C. C. (2018). Smartfall: A smartwatch-based fall detection system using deep learning. *Sensors*, 18(10):3363. [Cited on pages 2 and 14]

[Miraz et al., 2021] Miraz, M. H., Ali, M., and Excell, P. S. (2021). Adaptive user interfaces and universal usability through plasticity of user interface design. *Computer Science Review*, 40:100363. [Cited on page 9]

[Morey et al., 2019] Morey, S. A., Stuck, R. E., Chong, A. W., Barg-Walkow, L. H., Mitzner, T. L., and Rogers, W. A. (2019). Mobile health apps: improving usability for older adult users. *Ergonomics in Design*, 27(4):4–13. [Cited on page 12]

[Moxley et al., 2022] Moxley, J., Sharit, J., Czaja, S. J., et al. (2022). The factors influencing older adults' decisions surrounding adoption of technology: Quantitative experimental study. *JMIR aging*, 5(4):e39890. [Cited on page 20]

[Neves and Mead, 2021] Neves, B. B. and Mead, G. (2021). Digital technology and older people: Towards a sociological approach to technology adoption in later life. *Sociology*, 55(5):888–905. [Cited on pages 19 and 20]

[Norman and Nielsen, 1998] Norman and Nielsen (1998). The definition of user experience (ux). visited on 2024-10-30. [Cited on page 10]

[Nurgalieva et al., 2019] Nurgalieva, L., Laconich, J. J. J., Baez, M., Casati, F., and Marchese, M. (2019). A systematic literature review of research-derived touchscreen design guidelines for older adults. *IEEE Access*, 7:22035–22058. [Cited on page 12]

[Organisation, 2023] Organisation, U. N. (2023). World social report 2023: Leaving no one behind in an ageing world. visited on 2023-11-06. [Cited on page 4]

[Organisation, 2024] Organisation, U. N. (2024). Global issues ageing. visited on 2023-11-06. [Cited on page 4]

[Park et al., 2020] Park, L. G., Ng, F., K Shim, J., Elnaggar, A., and Villero, O. (2020). Perceptions and experiences of using mobile technology for medication adherence among older adults with coronary heart disease: A qualitative study. *Digital Health*, 6:2055207620926844. [Cited on pages 19 and 20]

[Patsoule and Koutsabasis, 2014] Patsoule, E. and Koutsabasis, P. (2014). Redesigning websites for older adults: a case study. *Behaviour & Information Technology*, 33(6):561–573. [Cited on pages 1, 11, and 34]

[Peek et al., 2014] Peek, S. T., Wouters, E. J., Van Hoof, J., Luijkx, K. G., Boeije, H. R., and Vrijhoef, H. J. (2014). Factors influencing acceptance of technology for aging in place: a systematic review. *International journal of medical informatics*, 83(4):235–248. [Cited on pages 20 and 21]

[Perez-Cruz, 2019] Perez-Cruz, Y. (2019). *Expressive design systems*. Number 31. A Book Apart. [Cited on page 5]

[Rodríguez et al., 2009] Rodríguez, M. D., Gonzalez, V. M., Favela, J., and Santana, P. C. (2009). Home-based communication system for older adults and their remote family. *Computers in Human Behavior*, 25(3):609–618. [Cited on page 21]

[Rusu et al., 2015] Rusu, C., Rusu, V., Roncagliolo, S., and González, C. (2015). Usability and user experience: What should we care about? *International Journal of Information Technologies and Systems Approach (IJITSA)*, 8(2):1–12. [Cited on page 10]

[Samaddar and Petrie, 2023] Samaddar, S. and Petrie, H. (2023). Care: Designing a smartwatch app for older people. In *36th International BCS Human-Computer Interaction Conference*, pages 66–75. BCS Learning & Development. [Cited on pages 10, 47, 48, and 49]

[SamsungGroup, 2024a] SamsungGroup (2024a). Galaxy watch7 lte (44mm). visited on 2024-09-29. [Cited on page 14]

[SamsungGroup, 2024b] SamsungGroup (2024b). What does a smartwatch do? visited on 2024-08-01. [Cited on page 14]

[Seidler et al., 2010] Seidler, R. D., Bernard, J. A., Burutolu, T. B., Fling, B. W., Gordon, M. T., Gwin, J. T., Kwak, Y., and Lipps, D. B. (2010). Motor control and

aging: links to age-related brain structural, functional, and biochemical effects. *Neuroscience & Biobehavioral Reviews*, 34(5):721–733. [Cited on page 17]

[Sharp et al., 2023] Sharp, H., Rogers, Y., and Preece, J. (2023). *Interaction design: beyond human-computer interaction*. John Wiley & Sons, Inc, Hoboken, sixth edition edition. [Cited on pages 4 and 9]

[Siirtola, 2019] Siirtola, P. (2019). Continuous stress detection using the sensors of commercial smartwatch. In *Adjunct Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers*, UbiComp/ISWC '19 Adjunct, page 1198–1201, New York, NY, USA. Association for Computing Machinery. [Cited on page 14]

[Siren and Knudsen, 2017] Siren, A. and Knudsen, S. G. (2017). Older adults and emerging digital service delivery: A mixed methods study on information and communications technology use, skills, and attitudes. *Journal of aging & social policy*, 29(1):35–50. [Cited on page 19]

[Story, 2001] Story, M. F. (2001). Principles of universal design. *Universal design handbook*, 2. [Cited on pages ix, 48, and 49]

[Thorpe et al., 2016] Thorpe, J. R., RÖ nn Andersen, K. V., Bień, P., Özkil, A. G., Forchhammer, B. H., and Maier, A. M. (2016). Pervasive assistive technology for people with dementia: a ucd case. *Healthcare technology letters*, 3(4):297–302. [Cited on pages 2, 15, and 21]

[Valenzuela et al., 2018] Valenzuela, T., Okubo, Y., Woodbury, A., Lord, S. R., and Delbaere, K. (2018). Adherence to technology-based exercise programs in older adults: a systematic review. *Journal of Geriatric Physical Therapy*, 41(1):49–61. [Cited on page 19]

[Vargemidis et al., 2021] Vargemidis, D., Gerling, K., Abeele, V. V., Geurts, L., and Spiel, K. (2021). Irrelevant gadgets or a source of worry: exploring wearable activity trackers with older adults. *ACM Transactions on Accessible Computing (TACCESS)*, 14(3):1–28. [Cited on pages 3 and 21]

[Vilarinho et al., 2015] Vilarinho, T., Farshchian, B., Bajer, D. G., Dahl, O. H., Egge, I., Hegdal, S. S., Lønes, A., Slettevold, J. N., and Weggersen, S. M. (2015). A combined smartphone and smartwatch fall detection system. In *2015 IEEE international conference on computer and information technology; ubiquitous computing and communications; dependable, autonomic and secure computing; pervasive intelligence and computing*, pages 1443–1448. IEEE. [Cited on pages 2 and 14]

[Wildenbos et al., 2019] Wildenbos, G. A., Jaspers, M. W., Schijven, M. P., and Dusseljee-Peute, L. (2019). Mobile health for older adult patients: Using an aging barriers framework to classify usability problems. *International journal of medical informatics*, 124:68–77. [Cited on pages 4 and 18]

[Wildenbos et al., 2018] Wildenbos, G. A., Peute, L., and Jaspers, M. (2018). Aging barriers influencing mobile health usability for older adults: A literature based framework (mold-us). *International journal of medical informatics*, 114:66–75. [Cited on pages 15, 16, 17, and 18]

Appendix A

Proposed guidelines profile sheets

Provide large buttons and redable text

1

Buttons and text are crucial elements of the interface – make sure they are easy to read and interact with.

Given that visual acuity tends to decline with age, it is essential to use a large text size for improved legibility, reduced eyestrain and faster reading times. The recommended font types are Arial, Helvetica, Century Gothic, Times New Roman, Bookman or Book Antigua. Handwritten and decorative fonts should be avoided as they can be difficult to read. It is also necessary to use large buttons and icons. Large interactive elements, in combination with Guideline 6, ease interaction for users with less precise movement control.

Classification: **Visual**, **Motor**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; Iancu and Iancu, 2020; Li et al., 2021; Hou and Hu, 2023; Hou et al., 2022], **Web** [Patsoule and Koutsabasis, 2014; Hou and Hu, 2023], **General** [Farage et al., 2012; Lidwell et al., 2010], **Wearable** [Lewis and Neider, 2017].

Related guidelines: n.a.

Conflicts with: Reference guideline 180 [Li et al., 2021].

Figure A.1: PG1 profile sheet.

Favour loud but adjustable sound volume

2

The default sound setting should be loud and customisable according to the user's needs.

The device should have a high default volume level, ensuring an audible signal of at least 60 dB. In addition, the level must be easily adjustable so that the output sound of the device can be adapted to the user's needs, according to the circumstances.

Classification: **Hearing**, **Motivational**.

Domain(s): **Mobile** [Iancu and Iancu, 2020; Li et al, 2021], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: 10 and 11.

Conflicts with: n.a.

Figure A.2: PG2 profile sheet.

Ensure high contrast 3

Provide high contrast between foreground and background.

Providing high contrast enhances visibility and readability, making it easier for users to distinguish the different elements. A high contrast between foreground and background can be achieved, for example by using light text on dark background, or vice-versa. Also, avoid background images with several colours or patterns. This is particularly relevant for both visually impaired users and those in situations such as low-light conditions or prolonged screen usage.

Classification: **Visual**.

Domain(s): **Mobile** [Iancu and Iancu, 2020; Gomez-Hernandez et al., 2023], **General** [Farage et al., 2012].

Related guidelines: 16.

Conflicts with: n.a.

Figure A.3: PG3 profile sheet.

Be objective

4

The purpose of each element of the interface must be relevant and easy to understand.

Ensure clarity regarding the purpose of each component of the interface, and consistency throughout the application, to minimise the possibility of misinterpretation. Users experiencing cognitive strain may struggle to distinguish between interactive and non-interactive elements, so try to emphasise the elements with which it is possible to interact and avoid ambiguous elements. The function of each interface element must be immediately apparent, and finding information within the interface should require minimal effort.

Classification: **Cognitive**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; Li et al., 2021], **Web** [Patsoule and Koutsabasis, 2014].

Related guidelines: 12, 15 and 17.

Conflicts with: n.a.

Figure A.4: PG4 profile sheet.

Avoid complex gestures 5

Tasks should require simple gestures rather than complex or rapid sequences of movement.

The use of gestural interaction as an input method does not have to rely on complex gestures or rapid sequences of movement such as double tap and pinch. Interaction based on more complex gestures relies on familiarity with the technology, the ability to memorise these gestures and good control of movements, which could put some users at a disadvantage. Focus on minimal gesture interactions such as single taps and scrolling.

Classification: **Motor**, **Cognitive**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: n.a.

Conflicts with: Reference guideline 19 [Iancu and Iancu, 2020].

Figure A.5: PG5 profile sheet.

Ensure distance between controls

6

Provide adequate spacing between elements on the interface.

It is necessary to provide enough space between interface elements in order to have a clear interface, but above all, to prevent accidental presses because motor limitations can greatly reduce the precision of the interactions. Also, use smaller spacing to group related elements together, in order to help users understand the relationships between different components.

Classification: **Motor**, **Cognitive**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; Iancu and Iancu, 2020; Morey et al., 2019], **Web** [Patsoule and Koutsabasis, 2014].

Related guidelines: n.a.

Conflicts with: n.a.

Figure A.6: PG6 profile sheet.

Use multisensory feedback 7

Provide a combination of sensorial feedback to increase the probability that users get the information.

It is convenient to consider not using just one means of communicating with the user, who may have perceptual limitations. For example, a user with reduced hearing acuity may not hear auditory feedback. Using several types of feedback (visual, auditory, and tactile) will increase the likelihood of information reaching users correctly. As another example, when the user presses a button, a sound (auditory feedback) and a vibration (tactile feedback) could be emitted, and the button could have a visual effect showing that it has been pressed (visual feedback). Feedback should be clear and consistently provided.

Classification: **Visual**, **Hearing**, **Motor**, **Cognitive**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; Iancu and Iancu, 2020; Li et al., 2021], **Wearable** [Lewis and Neider, 2017].

Related guidelines: 10 and 12.

Conflicts with: n.a.

Figure A.7: PG7 profile sheet.

Support corrections 8

Ensure that there is a secure way to exit from any screen and an option to rectify or cancel any action taken.

Design applications in such a way that there is one main screen (for example which can show all the main categories of the application). This screen should serve as a safe point of return for users. Also, the user should be able to step back from any unwanted action (unless it is technically impossible to do so). If the smartwatch doesn't have a physical button for going back, then ensure that every interface includes a clear return option. This encompasses any method to return to a previous safe state, such as a “back” or a “cancel” button. This will reassure users, allowing them to retrace their steps, and reduce the fear of experimenting or getting lost in the application.

Classification: **Cognitive**, **Motivational**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; De Barros et al., 2014 ; Li et al., 2021; Nielsen, 2005], **Web** [Patsoule and Koutsabasis, 2014; Nielsen, 2005], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: n.a.

Conflicts with: n.a.

Figure A.8: PG8 profile sheet.

When designing buttons, include both icons and text labels

9

Combine the use of icons with text, to reinforce the understanding of the button's purpose.

The combined use of an icon and text helps to understand and remember the function of the interface buttons. These two elements ought to work as a cohesive unit. The text should make explicit the consequent action, so that users can quickly understand its purpose without needing to evaluate other elements in the interface. This is particularly important for users who may not be familiar with specific icons. As for the icons, they should provide a visual cue as they can be quickly recognised and reinforce the text.

Classification: **Visual**, **Cognitive**.

Domain(s): **Mobile** [De Barros et al., 2014; Gomez-Hernandez et al., 2023; Huang et al., 2019], **General** [Farage et al., 2012].

Related guidelines: 18.

Conflicts with: Reference guideline 32 [Iancu and Iancu, 2020].

Figure A.9: PG9 profile sheet.

When using sound, prefer low frequencies 10

High-pitched sounds can be hard to hear or even uncomfortable for older adults.

Age-related hearing loss often results in a diminished ability to perceive high-frequency sounds, especially those above 4000 Hz. To overcome this hindrance, consider using sounds with lower frequencies, ranging from 500 to 2000 Hz.

Classification: **Hearing**.

Domain(s): **Mobile** [Iancu and Iancu, 2020], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: 2 and 7.

Conflicts with: n.a.

Figure A.10: PG10 profile sheet.

Allow for customisations 11

Applications must be customisable to suit the user's needs.

In order to maximise the user experience, it is recommendable to allow users to adapt the application to their needs and preferences. Users should have the option to select alternative methods for presenting elements of the interface, such as the size and style of text and icons, brightness and contrast between the background and the text. Also, it is relevant to consider allowing customisation in terms of functionality, by providing, by default, the more basic functions and the possibility of activating advanced features when/if users wish so.

Classification: **Visual**, **Motivational**.

Domain(s): **Mobile** [Iancu and Iancu, 2020; Morey et al., 2019], **Web** [Patsoule and Koutsabasis, 2014], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: n.a.

Conflicts with: n.a.

Figure A.11: PG11 profile sheet.

Declutter the interface 12

Irrelevant information and superfluous details should be avoided to help users to stay focused.

To assist users in maintaining concentration during the use of an application, any distraction should be avoided. Only display elements that are strictly relevant to the current task, avoid unnecessary details or secondary functions that could divert or compete for attention. Also, draw the user's attention to the elements they need to interact with in order to continue the task, such as the next important button. Reduce the number of colours, fonts, and visual effects to reduce cognitive effort.

Classification: **Cognitive**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023], **Web** [Patsoule and Koutsabasis, 2014], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: 4, 15 and 17.

Conflicts with: n.a.

Figure A.12: PG12 profile sheet.

Avoid time-based interactions

13

There should be no time constraint for carrying out an action.

Users may need time to read and process information. It is important that they don't fail to accomplish their goals if they are not fast enough. To overcome the anxiety that might raise from time-based interactions, it should become clear that they don't have to rush. Therefore, increase response time, time for feedback information, and time-outs, or ideally, don't impose any time constraints. This will allow users to interpret the interface properly and make a decision about their next action at their own pace.
Also, try to communicate scheduled actions in time (e.g., take medication when notified by the device) instead of announcing actions that imply to memorise their time (e.g., take medication at 7 p.m.).

Classification: **Cognitive**, **Motor**, **Motivational**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; Iancu and Iancu, 2020], **General** [Farage et al., 2012] , **Wearable** [Lewis and Neider, 2017].

Related guidelines: n.a.

Conflicts with: n.a.

Figure A.13: PG13 profile sheet.

Integrate speech to complement output/input

14

Enable the use of speech recognition, voice command and voice-response technology.

In order to make the application easier to navigate and to enable the device to be used according to user preferences and needs, voice recognition and voice command technologies should be used. In addition, voice response technology can also be very useful for giving feedback to users or reading texts to them. But also, coupled with the customisation capability referred to in guideline 11, this technology could mean increased user motivation when, for example, a message recorded by a familiar voice is used. A slow speech rhythm should be maintained with pauses at punctuation points. Computer-generated voices should be avoided.

Classification: **Visual**, **Hearing**, **Motivational**.

Domain(s): **Mobile** [Iancu and Iancu, 2020; Li et al., 2021], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: 2, 10 and 11.

Conflicts with: n.a.

Figure A.14: PG14 profile sheet.

Simplify task execution 15

Minimise the quantity of steps and options required to complete a task.

To reduce cognitive effort while performing a task, minimise the number of steps and task complexity. Steps include taking decisions, inputs, and button presses. If a task requires a large number of steps (particularly if it actually is perceived as such), users can feel discouraged or lose track of their objective. In some cases, the use of voice for inputting text or commands might contribute to reduce the complexity of a task.

Classification: **Cognitive.**

Domain(s): **Mobile** [Iancu and Iancu, 2020; Morey et al., 2019; Gomez-Hernandez et al., 2023; Li et al., 2021], **General** [Farage et al., 2012], **Wearable** [Lewis and Neider, 2017].

Related guidelines: 4 and 12.

Conflicts with: Reference guideline 29 [Iancu and Iancu, 2020].

Figure A.15: PG15 profile sheet.

Use colour effectively 16

Particular attention must be paid to the colours chosen for the interface.

The more effective colours for older users are those with longer wavelengths, also known as "warm colours", such as red, orange, and yellow. The use of short-wavelength colours ("cool colours"), such as blue, green, and purple, as well as either pale or fluorescent colours, should be avoided. If short-wavelength colours are used, high levels of contrast will be needed to facilitate perceptibility. In addition, minimise the number of colours and apply them consistently throughout the interface, to help users learn and recognise the application patterns.

Classification: **Visual**.

Domain(s): **Mobile** [Morey et al., 2019], **General** [Farage et al., 2012].

Related guidelines: 3.

Conflicts with: n.a.

Figure A.16: PG16 profile sheet.

Emphasise the most important information

17

Important and most commonly used information should be more prominent.

Information should be presented in a hierarchy according to its importance. Most important information should be easily recognisable, for example, by using larger or bolder text, or a distinctive colour. Also, most frequently used actions should be easily accessible, for example, by placing them at the top of a list.

Classification: **Cognitive**.

Domain(s): **Mobile** [Iancu and Iancu, 2020], **Web** [Patsoule and Koutsabasis, 2014].

Related guidelines: 4.

Conflicts with: n.a.

Figure A.17: PG17 profile sheet.

Use intuitive icons 18

Use concrete icons that effectively represents the concepts.

It is important to use easily understandable icons that are closely related to the functions they represent. Avoid abstract icons. If possible, choose icons that illustrate representations of the real world, such as a telephone icon for making a call. Also, avoid using graphically complex icons. Opt for simple designs that retain the semantics without unnecessary embellishments that could be confusing and hardly perceptible considering the typical dimensions of an icon. Finally, be consistent (e.g., use the same icon in all occurrences of a same concept), to optimise understanding, recognition, and memorisation.

Classification: **Visual**, **Cognitive**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023], **General** [Farage et al., 2012; Lidwell et al., 2010].

Related guidelines: 9.

Conflicts with: n.a.

Figure A.18: PG18 profile sheet.

Support the sense of privacy 19

Strengthen users' confidence in their privacy by implementing clear, transparent measures that protect their data and ensure they feel secure while using the application.

Clearly distinguish between private and public information within the application. Ensure that the data sharing settings are properly presented to prevent accidental sharing of private information. Always ask for explicit consent before sharing personal data, subject to confirmation.

Classification: **Cognitive**, **Motivational**.

Domain(s): **Mobile** [Morrey et al., 2019].

Related guidelines: n.a.

Conflicts with: n.a.

Figure A.19: PG19 profile sheet.

Use plain language

20

Use simple and unambiguous language.

To accommodate users who might lack familiarity with technology, avoid using technical terms in the interface. Use vocabulary that is widely recognisable in the context in which the application is used, and avoid neologisms or other vocabulary that older adults may not be acquainted with. Always try to use simple and short messages.

Classification: **Cognitive**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; De Barros et al., 2014], **General** [Farage et al., 2012].

Related guidelines: n.a.

Conflicts with: n.a.

Figure A.20: PG20 profile sheet.

Offer assistance 21

Assistance should be provided to the user while using the application, as well as initial training.

When a user is learning how to use an application, initial training by video tutorials or face-to-face is advised. Video tutorials provided on a smartphone, or other device, connected to the smartwatch, could be very useful, as smartwatch screens may not allow clear viewing of those videos or animations.
Provide users with helpful information while using the application, easily identifiable and accessible (e.g., by using a button with a specific look or colour). Also, provide users with a point of contact (e.g., phone help line) for further information, if required.

Classification: **Cognitive**, **Motivational**.

Domain(s): **Mobile** [Gomez-Hernandez et al., 2023; Morrey et al., 2019; Li et al., 2021], **Web** [Patsoule and Koutsabasis, 2014].

Related guidelines: n.a.

Conflicts with: n.a.

Figure A.21: PG21 profile sheet.