

2020

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**AN AGE-FRIENDLY INTERFACE
DESIGN FOR SMART HOME FOR
OLDER ADULTS AGEING IN PLACE**

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Dissertação apresentada ao IADE - Faculdade de Design, Tecnologia e Comunicação da Universidade Europeia, para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Design de Interação realizada sob a orientação científica do Professor Doutor Bruno Silva, do IADE – Faculdade de Design Tecnologia e Comunicação da Universidade Europeia e do Instituto de Telecomunicações, NetGNA lab, na Universidade da Beira Interior, Covilhã e da Professora Auxiliar Doutora Hande Ayanoglu, do IADE - Faculdade de Design Tecnologia e Comunicação da Universidade Europeia.

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palavras-chave

Smart home; Age-friendly Design; User Interface Design; Older Adults; Independent Living.

resumo

A faixa etária de 65 anos foi identificada como o grupo demográfico que mais cresce no mundo. Com o aumento da expectativa de vida, os idosos preferem permanecer independentes em suas casas. Os sistemas de casas inteligentes e tecnologias assistivas foram desenvolvidos para permitir que os idosos permaneçam em suas próprias casas à medida que envelhecem, aumentando a segurança, a independência e a qualidade de vida. Embora existam muitas aplicações móveis relacionadas a ao bem-estar dos idosos, eles ainda enfrentam desafios consideráveis em usabilidade, viabilidade e acessibilidade em relação ao design de interfaces. Há uma lacuna nas pesquisas recentes sobre avaliação da interface do utilizador (UI) projetada ou adaptada para atender às necessidades e habilidades dos idosos. O principal objetivo deste trabalho é desenvolver e avaliar um design de interface de utilizador amigável para idosos, para uma casa inteligente com um sistema de monitoramento de saúde para aumentar a independência dos idosos, permitindo que envelheçam em suas próprias casas. Além disso, a tese faz parte de um projeto em andamento que visa desenvolver um sistema de casas inteligentes e de monitoramento de saúde para idosos. Para atingir o objetivo principal da tese, foram estabelecidos objetivos secundários para desenvolver e avaliar as UIs, como a investigação da revisão de literatura, avaliação heurística e teste com utilizadores. No primeiro estágio de avaliação, os especialistas identificaram os potenciais problemas de usabilidade por meio da análise de tarefas que poderiam impactar a experiência dos idosos ao interagir com as UIs. Em uma segunda etapa de avaliação, foi realizada uma revisão do protótipo do projeto em relação aos problemas identificados na primeira etapa. A segunda avaliação ocorreu com os utilizadores finais, através de testes de usabilidade remotos e não moderados, devido à pandemia de Covid-19, aplicando técnicas de SUS e NPS. Conclui-se que os testes com utilizadores devem ser suportados com mais potenciais utilizadores do sistema, aplicando testes individuais e moderados para coletar informações mais detalhadas, e fornecer melhores insights para designers e desenvolvedores para criar interfaces mais utilizáveis para atender às necessidades e habilidades dos adultos mais velhos.

Keywords

Smart home; Age-friendly Design: User Interface Design; Older Adults; Independent Living.

abstract

The age group of 65 years has been described as the fastest growing demographic in the world. As life expectancy increases, older adults prefer to remain independent at home. Smart Home systems and Assistive Technologies have been developed to enable older adults to live in their own homes as they age, enhancing safety, independence and quality of life. Although considerable Smart Home mobile applications exist focused on older adult's wellbeing, they still face considerable challenges in usability, feasibility and accessibility regarding design of interfaces. There is a gap in recent research on evaluation of User Interface (UI) designed or adapted to address older adults' needs and abilities. The main objective of this work is to design and evaluate age-friendly user interface design for smart home and health monitoring system that increases independence of older adults by enabling them to age in their own homes. In addition, the thesis takes part of an ongoing project that aims to design and develop a smart home and health monitoring system for older adults. To reach the main goal of the thesis, secondary objectives were established to develop and evaluate the UIs, such as the literature review investigation, heuristic evaluation and user testing. On the first evaluation stage, experts identified the potential usability problems through task analysis that could impact the experience of older adults as they interact with the UIs. On a second evaluation stage, a design review was applied on the prototype regarding the problems identified on the first stage. Second evaluation took place with the end users and an unmoderated remote usability testing was conducted due to Covid-19 pandemic by applying SUS and NPS techniques. It is concluded that user testing should be supported with more target users, applying individual and moderated tests to gather more detailed feedback and provide better insights to designers and developers to create more usable interfaces to address the needs and abilities of older adults.

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1. Introduction

1.1 Problem statement

In 2019, as reported by the United Nations (United Nations, 2019), the range of 65 years of age was identified as the world fastest-growing population. As life expectancy increase, most of older adults prefer to remain independent in their own places (Xu, Fritz, & Shi, 2016). This emphasizes the importance of ageing research, especially innovative solutions (i.e., smart home systems and assistive technologies) that have significant potential to empower older adults to remain independent, safe and comfortable at home. The smart home concept can be defined as a lifestyle support that represents a house installed with sensors and control devices connected through a communication network (Marikyan, Papagiannidis, & Alamanos, 2019). It empowers users to remotely control household appliances and it can provide comfort, security, convenience and energy efficiency. A smart home environment aims to assist and support residents to feel more comfortable, safe and independent at their home, using monitoring, warning and remote controlling integrated systems (Liu, Stroulia, Nikolaidis, Miguel-Cruz, & Rios Rincon, 2016). Smart and assistive technologies can provide older adults self-care, relieve caregivers support and also supply new opportunities for personalized healthcare monitoring (*World report on Ageing And Health Summary*, 2015). Moreover, it can offer constant health and safety management enhancing their convenience and comfort in their daily activities (Marikyan et al., 2019). This innovative technology can have a great impact to improve quality of life and encourage independent living at home, so older adults can achieve long and healthy life (Alaa, Zaidan, Zaidan, Talal, & Kiah, 2017).

This thesis project is focused on a smart home and health monitoring mobile application to support older adults ageing at home. The system is based on pressure, motion, temperature and air quality sensors that monitors the daily activities of the user and it sends the information to the system hub. The collected data will set alarms and reminders to assist older adults and their caregivers in predicting, preventing or providing emergency support. The project aims to take into consideration age-friendly design guidelines of a mobile application to address older adults' needs (Johnson & Finn, 2017). The proposed system is composed of three interactive interfaces: Smart TV app, home hub tablet and smartphone app, to work as a personal assistant at home. In

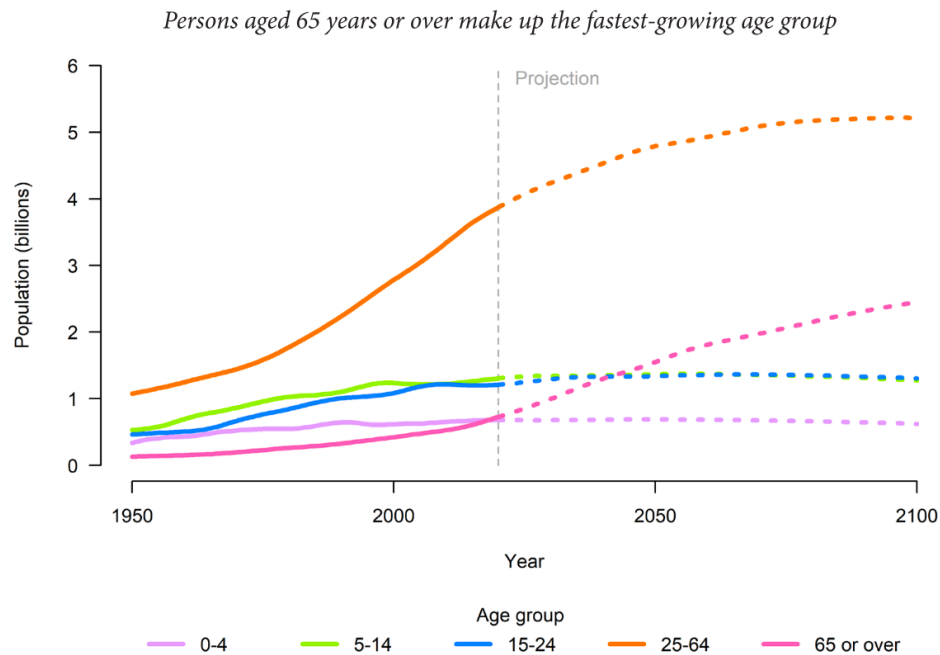
this related work, the smartphone application interfaces were evaluated to apply the findings on the other system interfaces according to an age-friendly style guide.

Currently, a large number of existing mobile applications are focused on health monitoring and assistive living; though, most of the existing systems have not been developed or adapted enough to support older adults needs and abilities (Kalimullah & Sushmitha, 2017). In this sense, the older adults still face considerable challenges among User Interfaces (UIs) (Kalimullah & Sushmitha, 2017). It is essential to take into consideration the natural ageing declines that can potentially impact their experience with the technology and provide them accessible age-friendly products and services (Kalimullah & Sushmitha, 2017), (Petrovčič, Rogelj, & Dolničar, 2018). Technologies, tools and devices, when properly designed to address older adults' abilities, needs and preferences, can empower their sense of wellness and independence.

The primary objective of this study is to design a smart home and health monitoring user interface and evaluate the potential usability problems faced by older adults, concerning age-friendly design guidelines. In addition, an age-friendly style guide is proposed for the system that can enable designers and developers the scalability of the product concerning consistency and accessibility.

1.2 Motivation

According to the World Health Organization (WHO), for the first time in history, the majority of the world population can expect to live over 60 years of age (Beeby, Ensell, Lambert, & White, 2015). In 2019, as reported by the United Nations, the range of 65 years of age was identified as the world fastest-growing population (see Figure 1). Therefore, by 2050, is projected that the share of older adults population will reach 28.7% of the total population in the European Union (Eurostat, 2019). In Portugal, adults with 55 years or more will be 47.1% of the total population (Eurostat, 2019). Also, the percentage of the older Portuguese population (65 years of age and older) increased from 19.4% to 21.5% and the life expectancy has been rising with current estimates of 83.4 years for women and 77.7 for men (Portal do Instituto Nacional de Estatística, 2017).



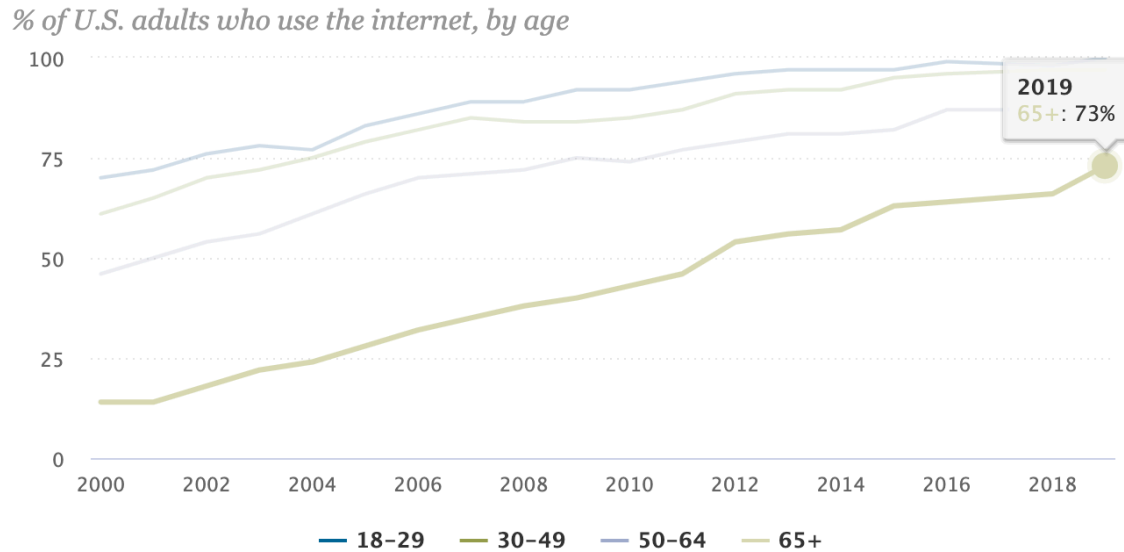
Data source: United Nations, Department of Economic and Social Affairs, Population Division (2019). *World Population Prospects 2019*.
 * excluding Australia and New Zealand

Figure 1 - "Estimated and projected global population by broad age group, 1950-2100, according to the medium-variant projection" (United Nations, 2019)

Due to increased life expectancy and low birth rates, the European social structure will face significant challenges in economy, social security, health care systems and quality of life in older population. In 2013, 13.4 % of households in Europe were composed of a single person aged 65 or over (Eurostat, 2015). In 2017, the share of older men aged 65 years or more living alone was 22.4%, while the share of older women was 40.4% across Europe (Eurostat, 2019). As life expectancy increase, most of older adults prefer to remain independent in their own places (Xu et al., 2016). The concept of ageing at home enable older adults to live in their own homes as they age despite health and mobility changes (Carnemolla, 2018). As life expectancy grows, in many countries the older adults' population is retiring later in life (Nielsen, 2013). Therefore, it is important not to stereotype the ageing population based on common perceptions and assumptions when developing comprehensive and accessible solutions. This outdated stereotypes for older adults' lifestyle and behavior limits the comprehension of their problems and the development of innovative opportunities for the ageing population needs (*World report on Ageing And Health Summary*, 2015). Therefore, a new perspective should be taken into consideration for the future ageing population.

Considering the advances in technology, in the field of healthcare and wellness, it has taken a step forward for making health monitoring easy on the daily basis (Alsinglawi, Nguyen, Gunawardana, Maeder, & Simoff, 2017). Many existing assistive technologies have the potential to improve health, wellbeing and quality of life, especially for the older population. The concept of integrating technology into older adults' homes is one of many assistive technologies that aims to provide comfort, safety and also improve quality of life by monitoring and predicting daily living activities. Those called smart home environments have been highly increased to facilitate the assisted living and health monitoring so older adults can live independently in their home, and also improve the relationship and proximity with their families and caregivers (Alsinglawi et al., 2017).

The literature indicates the potential of smartphones and mobile applications as inherent technologies to integrate assistive technologies (Petrovčič et al., 2018), and also to enable older adults to be more efficient in performing successfully in smart devices. In 2019, according to study conducted by the Pew Research Institute, 73% of the people aged over 65 were connected to the internet ("Demographics of Internet and Home Broadband Usage in the United States | Pew Research Center," 2017) (see Figure 2). Despite the increasing digital literacy among users aged over 65, they might have different perceptions, behaviors and needs than younger adults when interacting with technology (Lexie, 2019). Currently, a large number of smart devices, smartphones and mobile applications exist to attend older adults' needs; however, they still face considerable challenges in usability, feasibility and accessibility among User Interfaces (UIs), such as small fonts, low color contrasts and complex interactions (Kalimullah & Sushmitha, 2017). Therefore, it is necessary first to take natural ageing cognitive and motoric declines into consideration that may impact their experience with the technology and provide them accessible age-friendly products and services (Kalimullah & Sushmitha, 2017). Once older adults are introduced to the basic functions of new tools and systems, they feel included to the technology, interested in and curious about smart devices that can enhance their daily activities (Kalimullah & Sushmitha, 2017). Although, when they can't adapt or understand those tools and devices it can cause the sense of frustration and isolation (Barney & Parkinson, 2016, Chapter 21).



Source: Surveys conducted 2000-2019. Data for each year based on a pooled analysis of all surveys conducted during that year.

Figure 2 - Who uses the internet (*"Demographics of Internet and Home Broadband Usage in the United States | Pew Research Center," n.d.*)

There are significant studies (Czaja, Boot, Charness, Rogers, & Fisk, Arthur, 2009; Johnson & Finn, 2017; Pericu, 2017) about the natural ageing, cognitive, sensitive and motoric declines and how it affects the older adults learning process and experience when navigating on the web or using mobile applications. Some cognitive abilities, such as vocabulary, can be resilient to an aging brain and sometimes even improve with age. However, other abilities, such as conceptual reasoning, memory, and processing speed, decline gradually over the years. On the other hand, some activities can be associated with high cognitive function in older adults, such as intellectual engaging activities (e.g., doing puzzles, reading, using a computer, playing musical instruments), physical activities and social engagement (Harada, Natelson Love, & Triebel, 2013). Ageing behavior process can be hard to generalize. It always depends on the context living of the older adult. Therefore, to assist the development of age-friendly products and services, there is a slightly gap on recent research on heuristics and usability for UIs to address older adults needs, abilities and limitations (Salman, Wan Ahmad, & Sulaiman, 2018). Age-friendly design aims to help older adults read, notice, scan and understand the information displayed on the interface. Age-friendly guidelines would not only help older adults, but would also be more user friendly

for all users (Johnson & Finn, 2017). Developing an age-friendly system design, to a complex smart home and health monitoring system, enables the opportunity to increase the adoption of assistive technologies by older adults. As the older adult's population increases, they turn to be potential beneficiaries of digital products. The age-friendly design should go further off accessibility, it should also make the technology attractive, powerful, easy and enjoyable to use (Johnson & Finn, 2017).

Usability is a key aspect of the multidisciplinary field of Human Computer Interaction (HCI) to ensure the ease of use of a system, tool or device. When designing and building interactive systems the user should be first priority. It is about to understand human capabilities and limitations (Dix, Finlay, D. Abowd, & Beale, 2004). In many user interfaces designs, with low contrast colors, small fonts, small targets, it can make it difficult for older adults easily use and accept mobile technologies and other smart devices (Johnson & Finn, 2017). Among current studies of heuristic evaluation of mobile applications to support older adults' users, Silva, Holden, & Jordan, 2015 identified a research gap on heuristic evaluation of the user interfaces (UI) designed or adapted for older adults (Salman et al., 2018) and also a lack of usability studies of smart home applications.

In this sense, this research analyses the difficulties faced by older adults when interacting with mobile technologies and assistive systems. Regarding User-Centered evaluation methods to focus on the human experience and interactions, such as heuristics evaluation and user testing, it is possible to take advantage of experts' and real users' feedbacks to inspect usability problems and provide findings to improve the usability of a smart home system.

1.3 Objectives

The main goal of this research project is to design and evaluate age-friendly user interface design for smart home and health monitoring system that increases independence of older adults by enabling them to age in their own places. To achieve the main goal, the following secondary objectives of this thesis are:

- Investigate the literature review on current smart home and health monitoring technologies, and user interface design guidelines suitable for older adults.
- Experts evaluation through heuristics evaluation to identify and map usability problems that occur in the smart home and health monitoring prototype.

- User testing with target users to identify potential usability problems, difficulties and acceptance of the smart home and health monitoring prototype.

1.4 Critical factors for success

The critical factors for success of this thesis is to reach the population of older adults to evaluate the usability of a proposed smart home and health monitoring system.

1.5 Study diagram

The study diagram of the thesis is represented on Figure 3.

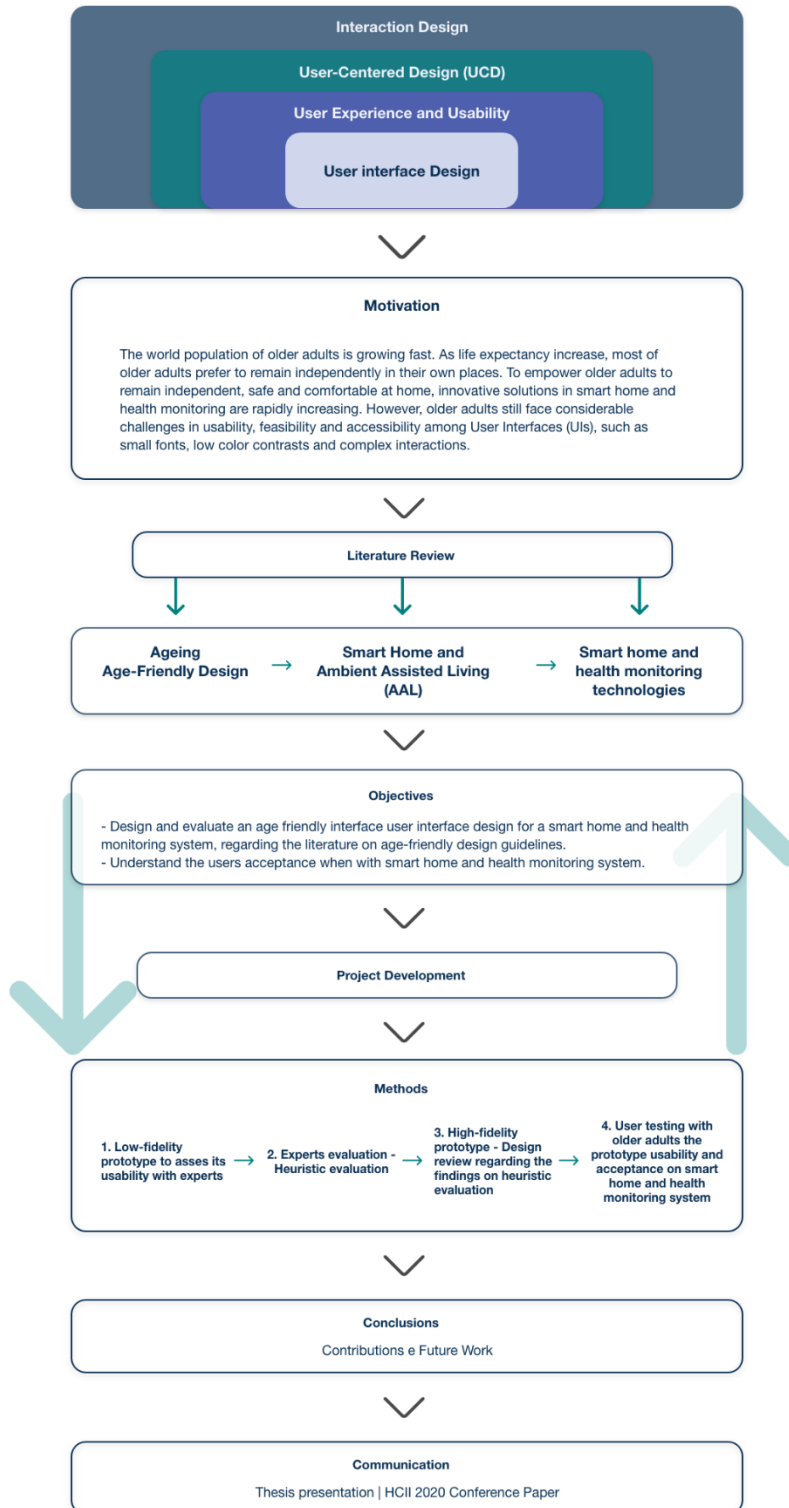


Figure 3 - Study Diagram

1.6 Contributions

The major findings of this work were presented at the International Conference Human Computer Interaction 2020, with the scientific paper: Adriana Silva, Hande Ayanoglu, Bruno M.C. Silva, "An Age-friendly System Design for Smart Home: Findings from Heuristic Evaluation", in International Conference Human Computer Interaction 2020 (HCII 2020), held virtually, 19-24 July.

Also at the International Conference Human Computer Interaction 2021, after the acceptance of the scientific paper: Adriana Silva, Hande Ayanoglu, Bruno M.C. Silva, "Remote User Testing for an Age-friendly Interface Design for Smart Homes", in International Conference Human Computer Interaction 2021 (HCII 2021), to be held virtually, 24-29 July 2021 (proceedings in press).

1.7 Document organization

This study is divided into five chapters which are included as follows:

Chapter 1 describes about the general background, the problem statement, the motivation, the main research objectives and the organization of the study.

Chapter 2 deals with the literature review to relate the main research topics to the final objective of the study. It discusses about ageing, smart home and assistive technologies concepts and the current existing assistive technologies to address the fast-growing population of older adults. Also, how older adults relate to technology and assistive systems and how can age-friendly design provide more usable age-friendly system's user interfaces.

Chapter 3 provides the research methodology to be adopted for the research process.

Chapter 4 describes the project development process of the smart home and health monitoring prototypes and its usability evaluation, from experts and users' perspectives.

Chapter 5 summarize the research work performed. It describes a clear view about the study results, the limitations and contributions intended on this study.

2. Literature Review

This chapter states out a literature review that describes the theoretical perspectives and already existing projects that contribute to a foundation of research assumptions made in section 1. Sections 2.1 to 2.3 presents the predominant research areas that contribute to this research work are explored: Interaction Design; Ageing; Smart Home and Ambient Assisted Living. Then, section 2.4 presents a literature review on smart home and health monitoring technologies.

2.1 Interaction Design

Defined by Don Norman, 2013, “interaction design draws upon principles of psychology, design, art, and emotion to ensure a positive, enjoyable experience.” Interaction design is about how people interact with technology. It is about creating user experiences enhancing the way people behave, work, communicate and interact with technology (Rogers, Preece, & Sharp, 2002). The focus of interaction design is to understand how users act, react and interact to events. That is the reason that people from different background and disciplines, such as psychologists and sociologist, become involved with designers, developers, artists, photographers, film experts, and so on. (Rogers et al., 2002). It’s all about understanding and studying the user’s behavior.

2.1.1 User-Centered Design (UCD), User Experience (UX) and User Interfaces (UI)

User-Centered Design or Human-Centered Design, as it is called by Don (Norman, 2013), is an iterative design approach that puts user’s needs, abilities and behavior at first place, to ensure that designs match those needs, abilities and behavior of intended users. Good design starts with psychology, technology and people research, to understand the real problem that design should solve (Norman, 2013). To understand the target user and what are their needs and requirements, UCD approach offers numerous methods to involve the user on project development, such as user observation, user interview, testing solutions with task performance, applying questionnaires, and so on (Rogers et al., 2002). A better understanding of users is important to perceive that users have different needs, therefore different interactive products need to be designed accordingly (Rogers et al., 2002). The UCD iterative design process concerns continual refinement, continual changes to make systems usable and useful by focusing on user needs (Technical Committee ISO/TC 159 Ergonomics Subcommittee SC 4 Ergonomics of human-system interaction., 2018).

User Experience are users perceptions and responses resulting from the use of a product, system or service (Technical Committee ISO/TC 159 Ergonomics Subcommittee SC 4 Ergonomics of human-system interaction., 2018). These results can include emotional perceptions, beliefs, preferences, comfort, behaviors and achieved accomplishments before, during or after using a product or service. User experience goals includes usability components, usefulness and emotional impact (Hartson & Pyla, 2012). The user experience is the result of a user's interaction with an artifact in a usage context. Therefore, the same product can have different perceptions of user experience regarding the user's context of use (Hartson & Pyla, 2012). Providing positive user experiences matters to the users and a bad experience could impact the user's decision to not user the product. A positive user experience should provide a cohesive, intuitive, and even pleasurable impact to the user (Deaton, 2003).

The interaction of the user with a system or interactive products occurs through a user interface (UI). The user interface includes all components of an interactive system to provide information and controls for the user to accomplish specific tasks within the interactive system (Technical Committee ISO/TC 159 Ergonomics Subcommittee SC 4 Ergonomics of human-system interaction., 2018). In the late 70's and 80's the personal workstations emerged, and the user interfaces came up. The challenges at that time was to provide interfaces that could make complex computers systems into accessible and usable by other people, besides engineers (Rogers et al., 2002). Hence, user interfaces are the way users experience and interact with the system. The scientific, logical and artistic senses are required to develop effective user interfaces to intuit and design for different perspectives and different users that will experience any given aspect of the system (Anderson, McRee, & Wilson, 2010). The way the information is presented on the UI is crucial for users' better comprehension and usability of the system (Anderson et al., 2010). Thereby it is important to reinforce that the structure of user interfaces must be meaningful and useful for the end users, not only for the engineers and software developers. Consequently, through the UCD process design with an iterative design process, involving the users on the development process, leads to the possibility to provide useful interfaces and meaningful experience for the users (Hartson & Pyla, 2012).

2.2 Ageing

According to the *World report on Ageing And Health*, 2015 ageing is a natural process that leads to a gradual decrease in psychological reserves and decline in a wide variety of abilities (vision, hearing, mobility and cognition) that impact the elderly experience in their everyday activities. As society ages and increase lifespans, numerous opportunities could be developed on assistive and mobile technologies to attend the needs of this growing demographic population. The evolution of mobile technologies has the potential to help the older adults to keep mentally, socially and physically active as they age (Xu et al., 2016). However, not all of this innovation has been developed to attend their requirements and needs. People with disabilities and older adults' population can experience several issues when interacting with technology, even harder with smartphones, tablets and mobile applications, not properly developed and designed to address accessibility issues. Fortunately, that trend is changing and more and more devices and mobile applications are increasing the focus on the elderly as primary users (Díaz-Bossini & Moreno, 2014).

The human-aging process starts over 20 years old, and over 40 years old people already have enough reduced eyesight and requires larger fonts to read. Middle-aged people, between 25 and 60 years old, have the ability to used web sites decreased by 0.8% per year (Nielsen, 2013). Older adults often feel neglected when using websites and mobile applications as design does not take into consideration their needs and interests. Abilities such as hearing, vision, and manual dexterity decrease as we age. Interfaces with small text size, low color contrast and undersized targets are often the major problems that makes digital products inaccessible for older adults (Lexie, 2019).

The evolution of mobile technologies has changed the way how society interacts with the world. It facilitates the performance of daily activities and support better and faster communication. Unfortunately, this change has not reached all population groups. People with disabilities and the older adult's population experience several challenges and difficulties. Fortunately, accessibility has been an actual concern in our society (Díaz-Bossini & Moreno, 2014). Accessibility is a global concern that requires access to information by all individuals, concerning people with different disabilities, with distinct requirements, needs and preferences (Romero Marino, Rodriguez-Fortiz, Hurtado Torres, & Haddad, 2018).

Despite the increasing concern in accessibility, according to Don Norman, an 84 years designer and author of “Design of Everyday Things”, he claims that the world is still designed against the older adults.

“Despite our increasing numbers the world seems to be designed against the elderly. And when companies do design things specifically for the elderly, they tend to be ugly devices that shout out to the world “I’m old and can’t function!” We can do better.” (Norman, 2019)

According World Health Organization (WHO), the changes associated with ageing process are really complex. At biological level, can cause physical disabilities, cognitive dysfunctions and general decline on individual capacities. But these changes aren’t linear or even associated with specific age of years. Besides biological changes, elderly can also face psychological and social changes; one example is to be able to deal with the loss of close relatives. As they gradual decline cognitive and motion skills, more meaningful and relevant goals and activities are prioritized. However, elderly emphasize practices that optimize existing abilities and also try to find other ways to compensate for other abilities losses (*World report on Ageing And Health Summary*, 2015).

The process of aging is natural decline in a wide variety of abilities that impact on various aspects of everyday lives (Díaz-Bossini & Moreno, 2014). Some cognitive abilities, such as vocabulary, can be resilient to an aging brain and sometimes even improve with age. However, other abilities, such as conceptual reasoning, memory, and processing speed, decline gradually over the years. Ageing behavior process can be hard to generalize. It always depends on the context living of the older adult. On the other hand, some activities can be associated with high cognitive function in older adults, such as intellectual engaging activities (puzzles, reading, using the computer, playing musical instruments e.g.), physical activities and social engagement (Harada et al., 2013).

It is important to observe that demographic changes are also increasing the digital literacy among the group of older adults, they are increasing their skills at using the internet and mobile applications. The Baby Boomer generation, born between 1946 and 1964, is now retiring, and different from the older generations, they have experienced more interaction with information technology communication (Lexie, 2019). They are also called the Silver Surfers, they lead the generation of older adults who experienced the world of usability (Pericu, 2017). According to the Office for National Statistics in the UK, in 2018 the recent internet usage statistics in the age

group from 65 to 74 increased from 52% in 2011 to 80% in 2018. And older adults aged 75 years recent usage of internet increased from 20% in 2011 to 44% in 2018 (“Internet users, UK - Office for National Statistics,” n.d.).

The simple definition of a “Senior Citizen” is people aged 65 years or older. However, in some countries and contexts, 65 years is too young to be considered a Senior Citizen. As life expectancy grows, in many countries the older adults’ population is retiring later in life (Nielsen, 2013). It is essential not to stereotype the ageing population based on common perceptions and assumptions when developing comprehensive and accessible solutions. This outdated stereotypes for older adults’ lifestyle and behavior limits the comprehension of their problems and the development of innovative opportunities for the ageing population needs. (*World report on Ageing And Health Summary*, 2015) A new perspective should be taken into consideration for the future ageing population. The remaining life expectancy must be prioritized, in order to chronological age. Therefore, it is fundamental to understand what older adults expect for their later life, whether they are fulfilled with themselves, and what opportunities they can engage with to improve quality of life (Pericu, 2017).

As life expectancy increase, most of older adults prefer to remain their independence in their place (Xu et al., 2016). The concept of Ageing in Place enable older adults to live in their own homes as they age despite health and mobility changes (Carnemolla, 2018), and the smart technologies has a significant potential to provide comfort, safety, wellness and enable older adults to remain independent at home.

2.3 Smart Home and Ambient Assisted Living (AAL)

The word “smart” has become an essential term for innovation in technology (Marikyan et al., 2019). Everything defined as “smart” in technology is developed with some kind of artificial intelligence. The key attribute of a smart technology is the capacity of obtain information and work it through artificial intelligence to respond according to an action (Marikyan et al., 2019). However, the smart home concept is not a recent creation. The first smart home concept started in 1898 with Nikola Tesla, with the invention of remote controls. In the early 1900s, with the industrial revolution, some home appliances were introduced, as vacuum cleaners, washing machines, refrigerators e.g. Although, these were not “smart” appliances, it was the first meaningful introduction for the technology at home (“The Evolution of Smart Home

Technology,” 2018). The smart home is represented by smart devices and sensors that are integrated with intelligent systems, providing monitoring, support and customized services. The Smart Home concept can be defined as a lifestyle support that represents a house installed with sensors and control devices connected through a communication network. It empowers the users to remotely control household appliances and it can provide comfort, security, convenience and energy efficiency (Marikyan et al., 2019). A smart home environment aims to assist and support residents to feel more comfortable, safe and independent at their home, using monitoring, warning and remote controlling integrated systems (Skistims, 2016). It has the potential to improve quality of life and encourage independent living, particularly for and ageing population. It can offer constant health and safety management enhancing their convenience and comfort in their daily activities (Marikyan et al., 2019).

As an essential component of smart homes, the Internet of Things (IoT) serve users effectively by connecting home appliances with various digital devices. These integrated systems, which includes device controls and sensors communication, control the system with user interfaces that interacts with smartphones, tablets, smart TVs, smart watches (Alaa et al., 2017). Smart Home systems should not only provide automation to users, but also provide interaction and customized control over the environment.

In recent years, the Smart Home and Ambient Assisted Living concepts are increasing the attention on the field of real-time feedbacks, to inform the residents about environment conditions and to improve comfort and wellbeing (Fabi, Spigliantini, & Corgnati, 2017). This innovation technology can have a great impact to assist the older adults and people with disabilities at home so they can achieve long and healthy life (Alaa et al., 2017). It has the potential to provide older adults self-care, relieve caregivers support and also supply new opportunities for personalized healthcare monitoring (*World report on Ageing And Health Summary*, 2015).

AAL is a monitoring environment system that can measure the wellness of the elderly living independently at home, although they need medical supervision or a professional caregiver. AAL system can monitor daily activities to predict and remind early warnings of any complicated health problem in elderly home. The AAL4ALL is a Portuguese project aiming an AAL ecosystem to serve as a standard model for the future AAL projects, to monitor and support the elderly daily activity and enable the connection with other people, like friends, relatives and

caregivers. The AAL4ALL goal is to allow distinct services to connect with and integrate other devices to the system. The intention is to build a strong collaborative network, to provide better system performance (Costa, Novais, & Simoes, 2014). It is expected that these systems can reduce the healthcare costs and provide better customized services so more elderly people can choose to live independently and healthy in their homes (Skistims, 2016).

According to Lloret, Canovas, Sendra, & Parra, 2015 when implementing an AAL system, several details should be considered. First of all, the system should not require the elderly's attention. The sensors and the system should be non-invasive to monitor, prevent and to set alarms in dangerous situations. The sensors should be strategically located in the house, and also used in wearable devices, smart phones, watches or glasses. This could make the system more acceptable by the elderly, so they don't feel uncomfortable or discriminated. However, despite AAL systems advantages being very helpful to provide independence and wellness, the human assistance is still irreplaceable.

2.4 Smart home and health monitoring technologies

The increasing of IoT (Internet of Things), smart devices, wearable, cloud computing, sensor networks, have converted several kinds of products available for assisted living. Smart Home environments, Ambient Assisted Living and monitoring systems and devices for older adults are becoming a substantial technology and social trend (Marikyan et al., 2019). On a general overview of past research on smart home projects, the mainly desired objectives are: provide comfort, health monitoring, security and independent living, within sensors, data information, multimedia devices and communication protocols (Ni, García Hernando, de la Cruz, et al., 2015).

According to the survey from Ni et al., 2015, Smart Home applications enhancing older adults quality of life and health status can be classified in three main categories: "Specific health monitoring", "Daily activities monitoring, prediction and reminding" and "Detection of anomalous situations". However, these categories are not mutually exclusive, the same application can contain features and services that fit into one or more of them.

Specific health monitoring category can be related to specific diseases such as diabetes, stroke, dementia, Alzheimer to monitor vital signs and daily activities in order to control medical conditions and provide emergency support. Daily activities monitoring, prediction and reminding

can be helpful for age-related cognitive declines, to detect patterns in activities to predict actions and provide reminders (Marikyan et al., 2019). The Smart Kitchen is a daily activity monitoring project that provides older adults and disable people smart environments so they can feel more independent to accomplish their daily activities in the kitchen. Based on a modular architecture system, it integrates household appliances, sensors and communication standards within user interfaces to increase user's autonomy on daily kitchen-activities (Blasco, Marco, Casas, Cirujano, & Picking, 2014). The detection of changes in older adults' daily activities routines can lead to signs of possible health risks and diseases based on activity patterns. And detection of anomalous situations aims to identify uncommon pattern behavior which do not conform with the user's normal behavior and to provide emergency support. This category is mainly used in fall prevention and detection applications (Ni, García Hernando, & de la Cruz, 2015).

On a systematic review of the smart home literature (Marikyan et al., 2019), it is shown that research studies and smart home practical projects can provide guidelines on the development of smart home technologies to improve quality of life at home. Through the analyses of relevant literature on smart home services and functions it was identified common recurring patterns. The common services identified were classified into five categories: comfort, monitoring, health therapy, support and consultancy. On Table 1 shows which are the common functions examples related to the services provided and what smart home categories can fit in each service.

Table 1 - Common smart home features encountered on the literature

Services	Functions	Devices	Smart Home Categories
Comfort	Automation of daily routines of home appliances	Dishwasher Washing machine Refrigerator Cooker	Daily activities monitoring, prediction and reminding
	Remote home management	Closet/drawer/mirror Window/door/gate Mailbox/garden devices	

	Intelligent environmental and sustainable services	Heat/gas/electricity/light sustainable	
	Smart leisure	TV/Radio/home cinema	
Monitoring	Health and lifestyle monitoring	Infrared sensors Wearable sensors Wearable accelerometer Internal sensors (to monitor physiological signs) EGG (epileptic seizure, sleep disorder) Heart rate Blood oxygen level Blood pressure Blood glucose level Temperature	Specific health monitoring Daily activities monitoring, prediction and reminding Detection of anomalous situations
Health therapy	Remote interaction Remote therapy Remote medical prescription	Tele healthcare Tremor delivery Drug delivery Hormone delivery	Specific health monitoring Daily activities monitoring, prediction and reminding
Support	Support patients with hearing issues	Alarm system based on visual signs Teletype machine Special electronic display screen for	Specific health monitoring

		hearing-impaired people Special display screen	Daily activities monitoring, prediction and reminding
	Support during home rehabilitation	Robotic devices for rehabilitation	Detection of anomalous situations
	Assist patients with mobility issues	Tailored interface Companion robot Mobility devices (e.g. electronic wheelchair) Computerized voice generation (in order to communicate)	
	Support with socialization	Robots	
	Patients with Visual disabilities	Audible beacon Tailored screen Specially designed remote control (e.g. voice recognition)	
Consultancy	Suggestions	Sensors	Daily activities monitoring, prediction and reminding

The literature discusses the potential and perceived benefits of smart home technology (Alaa et al., 2017; Marikyan et al., 2019). Marikyan et al., 2019 outcomes the users perspective in smart home technologies that can enable the comprehension of crucial factors on positive perceptions that might increase the technology acceptance. While Alaa et al., 2017 discusses the technological insights, gaps and recommendations. Therefore, they converge to similar potential

benefits in smart home systems. The mainly groups of benefits are: health-related; environmental and financial on energy optimization; and psychological wellbeing and social isolation.

a) Health-related benefits

Smart home technologies can provide a significant support to enable older adults to age at home enhancing safety, independence, wellbeing and also provide alternatives for institutional and family care (Carnemolla, 2018). From users perspective, health-related services in comfort, monitoring and consultancy, such as medical services, health monitoring, medical alerts, and easy communication with health institutions are not always associated as benefits of a smart home system. Though older adults might be more sceptical regarding smart home benefits (Marikyan et al., 2019). However, if they realize that the home health-monitoring technology can allow them to remain in their own homes and age in place they perceive it to be useful and can improve quality of life (Liu et al., 2016).

b) Environmental and financial benefits in energy optimization

Cost efficiency and energy saving are the most preferred perceived benefits on home automation. These automated systems can manage and conserve energy efficiently (Alaa et al., 2017). It also has the potential to be associated with health-related benefits regarding home-care and medical remote monitoring (Marikyan et al., 2019).

c) Psychological wellbeing and social isolation

Home health-monitoring Technologies for older adults with cognitive decline and mental health has the potential to reduce the symptoms of depression and the visits to the emergency department (Liu et al., 2016). However, there is no evidence that smart home technologies can effectively improve quality of life and fall prevention (Liu et al., 2016). On users perspective, they might not wish monitoring and assistive systems due to concerns that they will be labeled as vulnerable people (Marikyan et al., 2019).

On the overall, older adults still have low perception of usefulness of complex smart home systems. The feeling of technological isolation or losing control over technology overcome the acceptance of the technology (Marikyan et al., 2019). Despite the potential benefits of this technology, is still a technological-drive research. A theoretical framework in user-centered

methodology and usability studies would enable researchers, developers and designers to better understand older adults needs and requirements to embrace to advantages of smart home technology (Liu et al., 2016).

3. Methodology

The present work aims to discuss an age-friendly user interface design in a smart home environment, considering a User-Centered Design (UCD) approach, to focus on the human experience and interactions to identity the everyday problems on older adults' life. The UCD requires that you understand who is your target user and what are their needs, perceptions, behaviors and limitations (Wilson, 2005). The opportunity to have your users feedback in your development process is a powerful advantage to your product usability (Wilson, 2005)

The objective of these methods is to identify the potentially usability problems faced by older adults that could impact the experience as they interact with the user interfaces. By incorporating User-Centered evaluation methods, such as heuristics evaluation and user testing, it is possible to take advantage of experts' and real users' feedbacks to discover usability problems and findings to improve the usability of a smart home system.

The UCD approach, as an iterative design process, is suitable for this project so the evaluation is not a single phase of the design research (Dix et al., 2004). Regarding evaluation techniques, this thesis considers two perspectives: expert analysis and user participation. The evaluation has three main goals: to assess the usability and accessibility of the system's functionality according to older adults needs, to assess users' experience of the interaction, and to identify specific problems with the system (Dix et al., 2004).

3.1 Methods

The main objective of this thesis is to propose design guidelines for an age-friendly interface design for a smart home and health monitoring system aiming comfort, independence and safety at home. For achieving this, the following methods were applied:

- Literature review to investigate current existing technologies on smart home and health monitoring systems and age-friendly interface design guidelines.

- Heuristics to obtain the experts perspective to inspect usability on the proposed interface design.
- Unmoderated user testing to determine how usable is the proposed system from users perspective.

3.1.1 Literature review

The initial research step was to conduct a literature review in order to get an overview of smart home, assisted living and health monitoring concepts and technologies for older adults ageing at home. Also, an overview of age-friendly design guidelines and natural ageing process to understand how these can impact the design and development of assistive technologies for older adults.

The literature review provides a theoretical framework to establish the importance of the study and related existing solutions to compare the results with other findings (Creswell, 2014). To begin the literature research, some key words were identified: Smart Home, Interaction Design, Age-friendly Design, User Interface Design, Heuristic Evaluation, User Testing. With the key words, the research was conducted in in order to obtain recent journals, articles, books, systematic reviews, surveys, sorted by date, from 2014, when related to smart home technologies.

3.1.2 Heuristics

Heuristic evaluation is a usability inspection method to find usability issues in a user interface design. Within a small set of usability experts, the heuristic evaluation goal is to judge the compliance of the interface according to usability principles, called heuristics (Nielsen, 1992). In this thesis, the 10 Nielsen's heuristic was applied so usability experts could evaluate the first prototype concept to anticipate potential usability problems that could be faced by older adults. Then, after the finding of the expert-based evaluation, the usability issues could be fixed so it could be tested with the real end users of the smart home and health monitoring system.

3.1.3 Unmoderated User testing

Through the heuristic evaluation method, experts identified potential usability problems that would probably impact older adults' experience. As an iterative design process, these usability issues are fixed so the smart home and health monitoring system could be more usable for older adults. According to the process, the design review was applied on the prototype with the intention to fix the majority usability problems identified.

User testing is the key component of usability testing. It can include observation, user satisfaction and interviews (Rogers et al., 2002). It is the most suitable evaluation for testing prototypes and working systems. The goal is to determine how usable a product is. Planning a user testing is crucial to understand which tasks are important for the product and for the user to test it. To perform a user testing session, tasks should be planned in advance, such as the performance measures. The session includes recording data using a combination of video and interaction, and it is recommended to perform the test in controlled ambient to avoid user distractions (Rogers et al., 2002).

The initial intention on user testing was to conduct individual moderated sessions, with screen video recording to use this resource to measure tasks performing and allow detailed analyses of users' difficulties and feedback. However, due to COVID-19 pandemic, the individual moderated sessions could not be applied.

In order to perform the usability tests, the procedure had to be modified to remote and non-moderated tests to attend the social isolation protocol due to COVID-19. Yet, due to the limitations of remote accessible usability tools, the test could not be recorded.

The non-moderated tests were applied using the System Usability Scale and Net Promoter Score techniques to measure user's satisfaction when interacting with the smart home and health monitoring system prototype. According to Tullis & Stetson, 2004, applying the SUS questionnaire with a small sample of users (8-12 users) is it possible to measure the perceived usability of the system and to get 75% accuracy on usability assessment of how users get to see the product prototype.

4. Project Development

4.1 Definition of the project

This thesis presents the user evaluation stage (Heuristics and user testing) and a proposed design guide from an on-going project aiming to develop an age-friendly system design for smart homes to increase independence of older adults ageing at home. The ongoing project will propose a system design that explores daily activities by monitoring, predicting and reminding functionalities, aiming for comfort and independent living for older adults at home. The findings on usability and the age-friendly style guide supported by this thesis project can provide insights for designers and developers for more usable interfaces to address the needs and abilities of the older adult's population.

According to the literature review on smart home systems on Chapter 2, this project will propose a smart home and health monitoring system based on common functionalities identified addressing assistive technologies for older adults. The objective is to adapt those common functionalities into user interfaces properly designed for older adults according to the literature on age-friendly design guidelines. According to the compilation of guidelines provided by Johnson & Finn, 2017, not all of them were exclusively accessibility for older adults, however it shows that older adults tend to have more frequent and serious usability difficulties with user interfaces that don't follow age-friendly design guidelines. The age-friendly design should go further off accessibility, it should also make the technology attractive, powerful, easy and enjoyable to use (Johnson & Finn, 2017). Therefore, the project takes into consideration age-friendly design guidelines addressing older adults' abilities and requirements.

The project will propose a system design that explores daily activities by monitoring, predicting and reminding functionalities, aiming for comfort and independent living for older adults ageing at home. The system is based on pressure, motion, temperature and air quality sensors that monitor the daily activities of the user and send the information to the system hub. The collected data will set alarms and reminders to assist older adults and their caregivers in predicting, preventing or providing emergency support. The proposed system is composed of three interactive interfaces: Smart TV app, home hub tablet and smartphone app, to work as a personal assistant at home. A simplified type of data model was defined to help identifying the relationship between the system sensors, devices, data objects and users, as illustrated on Figure 4. In this work, the smartphone application interfaces were evaluated to apply the findings on the other system interfaces and to propose a system style guide.

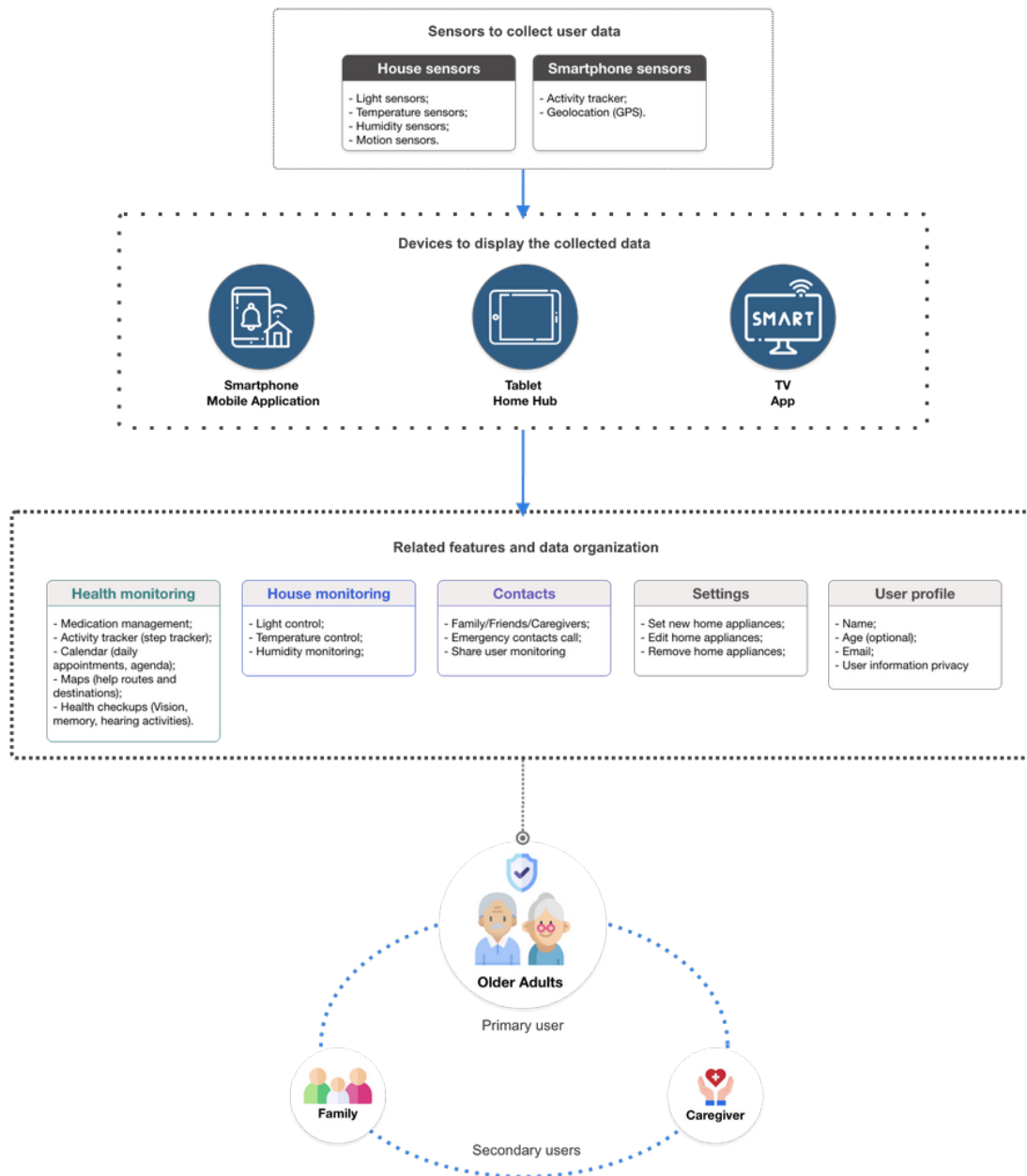


Figure 4 - Data model to illustrate the relationship between the system sensors, devices, data objects and users

The Smart Tv app interface's main goal is to display reminders and alarms, such as medical management alarms, activity tracking to avoid sedentarism, doorbell ring alarm and risk and danger alarms from the kitchen appliances. Then, while watching TV, users don't miss important notifications.

The tablet interface's purpose is to work as a home hub of the system that will gather all the collected data to be displayed in health and house monitoring dashboards. It can also allow users to set preferences on house routine automation for lights, windows, air quality, cooling and heating, and any other equipment that can be connected in the smart home system. The users can customize the dashboard with favorite and more important features according to their preferences. The tablet home hub can be placed at a home wall or as a table portrait so users can easily perceive and access the system.

The smartphone interface's objective is to work as a personal assistant for the user, focused on health and home monitoring. As a personal assistant, the mobile app can follow the user inside and outside home to keep in track user's wellbeing, safety and independence.

The aim of developing age-friendly user interfaces to a complex smart home and health monitoring system is to enable the opportunity to increase the adoption of assistive technologies by older adults. The universe of ICTs can offer a wealth of information, empowerment, and potential, and we should not exclude part of the population from being independent ICTs users. As the population of older adults increase, they turn to be potential beneficiaries of digital technology. (Johnson & Finn, 2017)

4.2 Ideation

The navigation plan helps to organize and combine the information environment to provide a logical structure that helps users complete tasks (Murphy, 2005). Structuring information of the system involves defining the level of relevance of the information and relate them to one another. It is important to organize the information to minimize efforts on working memory demand. For older adults, information organization can influence the ability to use system interfaces (Czaja et al., 2009). Grouping and labelling the information into meaningful and distinctive categories help users to find what they need in the system (Murphy, 2005). Based on the smart home and health common features presented in the literature review and identified needs and abilities of older adults, the main information of the system were organized in five categories: (1) Health monitoring; (2) House monitoring; (3) Contacts; (4) Settings; (5) User profile, as represented on the Figure 5 of navigation plan.

Important information must be placed front and center of the screen to be immediately visible, without scrolling (Johnson & Finn, 2017). Due to small screen sizes on smartphone, scrolling is often necessary and must be clearly indicated that the content continues below. However long pages must be avoided, if the content is too long slip up into multiple pages. Horizontally scroll is not recommended, most of the users would miss that content (Johnson & Finn, 2017).

Especially for older adults that the natural aging process tends to decline the motor skills, making complex gestures challenging (Czaja et al., 2009). Hit targets must be big enough for the user and must have spaces between the targets to be clear and easy to find (Johnson & Finn, 2017). Beyond minimal and clear visual design, the interaction with the mobile application must be simple and easy use.

To maximize the legibility of essential text on smartphone screens is recommended font size larger than 14 points (Johnson & Finn, 2017). It is important to use plain and mixed case fonts, boldface and avoid fancy font styles. The contrast of colors is also crucial for a good legibility (see Figure 6). It is recommended the usage on plain background and to try to achieve at least 50:1 of contrast ratio (e.g., black text to white background) (Czaja et al., 2009). However, off-white backgrounds are better than pure white in contrast with dark text because pure white can cause eyestrain in older adults (Johnson & Finn, 2017).

Good	12 pt serif fonts such as Times Roman is good choice for older adults.
Bad	8 pt Times Roman is bad size for seniors.
Good	12 pt sans serifs font such as Arial is an excellent choice.
Bad	<i>A script font is a poor choice for older adults.</i>
Good	Black text on white background or white on black is legible.
Bad	Black text on dark gray background is a poor choice.

Figure 6 - Examples of good and bad formats for text (Czaja et al., 2009)

Mobile devices are more likely to be used in varied environments, including outdoor, where the sunlight or strong light can cause a visual impact for the users on the interface (“Mobile Accessibility: How WCAG 2.0 and Other W3C/WAI Guidelines Apply to Mobile,” 2015). Therefore, the color pallet of the interface can minimize visual contrast impact. The wise choose of colors for functional proposes, such as to highlight information or to distinguish areas of the screen, can be more readable not only for older adults but for all users. And avoid using too many different and sparkly colors (see Figure 7 bad and good examples of interface colors) (Johnson & Finn, 2017).



Figure 7 - Bad and good examples of interface colors (Johnson & Finn, 2017)

b) Motor Control Guidelines

After 50 years of age, most people start reducing manual dexterity and, eventually, the precision of arms, hands and finger movements starts decreasing (Johnson & Finn, 2017). With declining coordination, older adults can experience difficulty of hitting small targets. Hand tremors are also a common cause of distress in gestures. According to Johnson & Finn, 2017, in these cases, the risk of missing targets or make unintended gesture increases when targets are too small or too close to each other. Therefore, targets on upper sides of a touch screen are harder for older adults to reach. (see Figure 8).



Figure 8 - Tapping the upper side icons requires users to stretch their arm farther than does tapping the bottom icons (Johnson & Finn, 2017)

For older adults, it is important to keep simple input gestures. If possible, use simple one-finger gesture on mobile interfaces, eg., tap and swipe gestures. Wherever is possible enable users to input data via gestures rather than using a keyboard (Johnson & Finn, 2017).

c) Cognition Guidelines

Spatial memory or spatial cognition is the ability to navigate in real or virtual spaces by consulting a mental map that represents the path and relationships between places and information (Czaja et al., 2009). As people age, spatial memory declines and also the ability to easily navigate in menu hierarchies. This reduces the ability of older adults to find a path to accomplish a task with numerous choices along the way. Many websites and mobile applications

display many possible user actions on a single page and, often with poor labeling, leading older adults to have trouble in interface navigation (Johnson & Finn, 2017). Older adults users are more likely than younger users to miss information or changes of status that are not on the focus of their attention. Providing consistent elements and few possible choices, calls to action and interaction elements can relieve this problem (Czaja et al., 2009). Allow users to focus their attention on one task at a time (Johnson & Finn, 2017). (see the comparison on Figure 9).

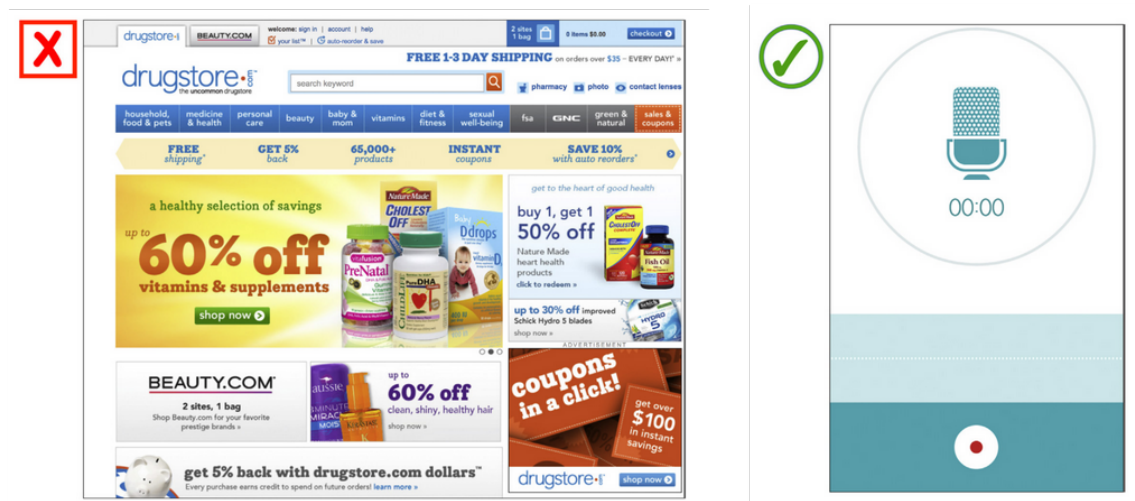


Figure 9 - Interfaces examples with many calls to action and of a single call to action

The navigation must be consistent making categories unique. Long and complex tasks should be divided into sub steps, providing steps feedbacks and clearly indicate how to go forward, back or undo (or cancel) (Johnson & Finn, 2017). Allow users to easily recover from errors and, wherever is possible, try to prevent them. This can minimize the feeling of frustration of the users. Providing consistent reminders and alerts as strong cues can help older adults users recognize their status and options. Consistency in terminology is also crucial on navigation structure. Keep the same labels, links, buttons when they have the same effects and actions, makes interaction elements functionally and visually consistent (Johnson & Finn, 2017). Within the principles of age-friendly design in mind, first options were sketched out to define the task flow and to help identifying the hierarchy of the features on the interface (see Figure 10).

Also, the wireframes in Figure 11 helped to define the navigation options, big tap targets, applying simple interactions, gestures to minimize the use of the keyboard and scrolling.

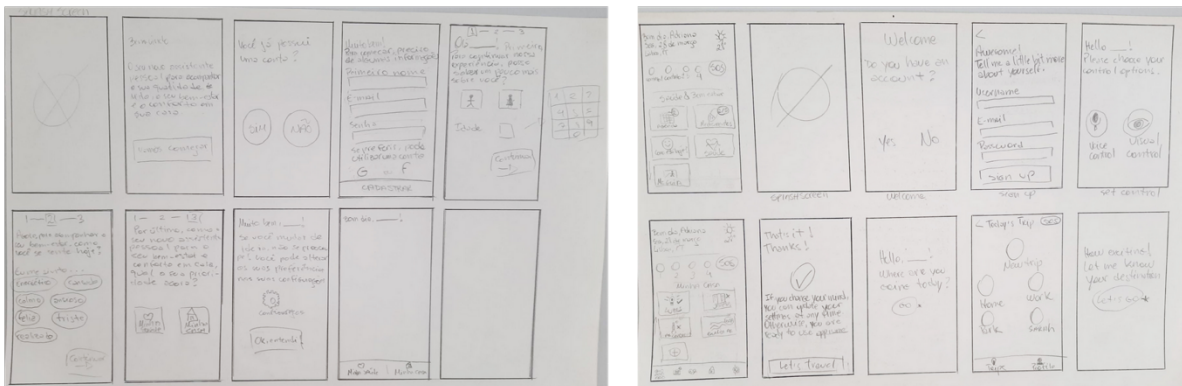


Figure 10 - First sketches of the interface

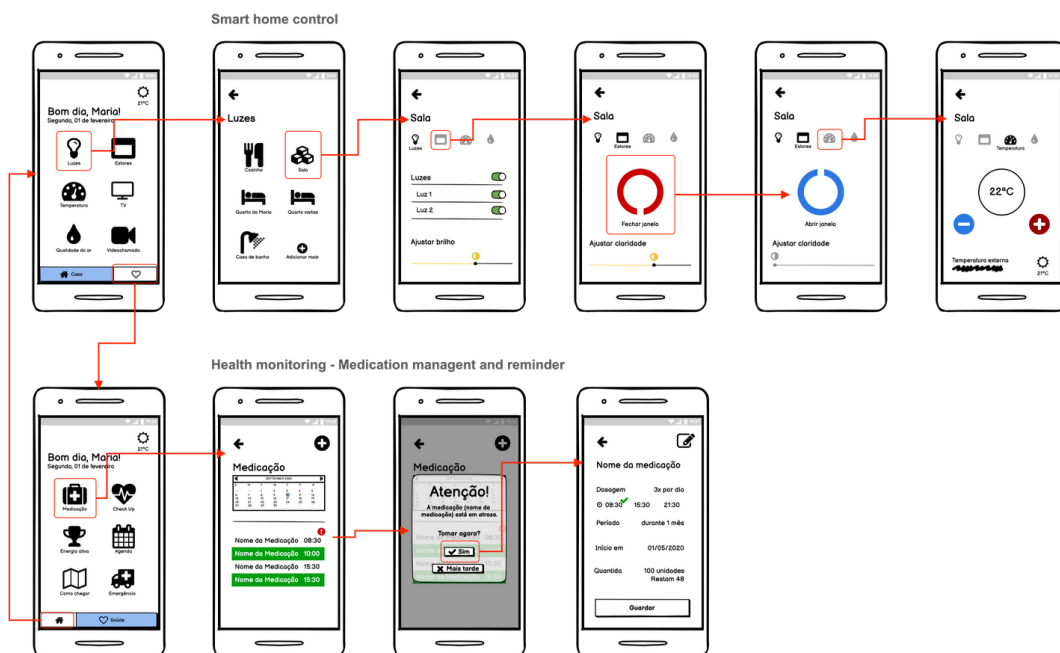


Figure 11 - Wireframes

Following next section of the document, is presented the low-fidelity and high-fidelity prototypes developed, applying age-friendly guidelines and evaluation process.

4.3 Prototyping and evaluation

According to user-centered design process, iterative design and evaluating requires the development of prototypes of products or systems interfaces to support development cycle (Czaja et al., 2009). On this thesis, 2 iterations were done to assess the usability of the smart home and health monitoring mobile prototype. On the first iteration, within a low-fidelity prototype presented in section 4.3.1, it was applied the expert-based evaluation, the heuristic evaluation by Nielsen's guidelines, presented on section 4.3.2. With the identified findings from heuristics results, on section 4.3.3 the prototype was modified to move forward to the second iteration. The second iteration, within a high-fidelity prototype, user testing was applied with the target users to assess its usability and acceptance of the smart home and health monitoring system., which is presented on section 4.3.4.

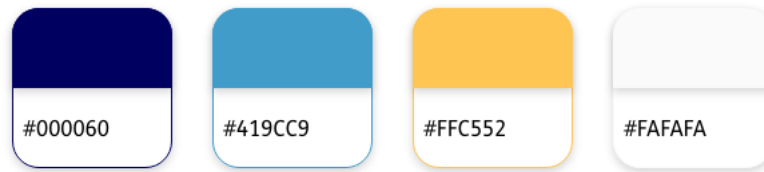
4.3.1 Low fidelity prototype

Referring to older adults needs and to age-friendly guidelines, the first screen layouts were designed in order to create a low-fidelity prototype enhancing a logical and intuitive user flow for the smart home and health monitoring features. Low-fidelity prototypes evolves from wireframes, that transforms the skeletal representation of screens layout and interaction objects into tangible ideas (Hartson & Pyla, 2012). The low-fidelity prototype plays an important role to check and test its functionality rather than the visual appearance. It can represents a basic visual hierarchy and only some visual components of the final product, such as tabs, menus, dialogue boxes, buttons and navigation elements (Hartson & Pyla, 2012).

To define a color palette, a combination of colors, for the low-fidelity prototype it was considered first the context of the product. As part of a smart home product, the intention is to provide the sensation of trust, security, technological and confidence and for that reason the Blue color was defined as a primary color. The yellow, considering the health monitoring, it comes to bring optimism, warmth and enlightenment (Cantwell, 2015). And the off-white comes to bring contrast with primary and secondary colors (see Figure 12).

Colors

Primary colors



Secondary colors



Figure 12 - Color palette defined for the low-fidelity prototype

To maximize the legibility on user interfaces, the typeface used on the prototype, named by FS Me, is an accessible type designed by Jason Smith (Fontsmith, 2018). The typeface was a result of research and design project in partnership with Mencap, the UK leading charity for people with disabilities, to meet the requirements of the UK government of accessibility guidelines (Fontsmith, 2018). The aim of the FS Me typeface is to provide more legibility and readability, not specifically for a special audience but is an inclusive typeface for everyone. (“FS Me: ‘The accessible type,’” 2015) It takes into consideration important details that makes difference in reading and comprehension (Fontsmith, 2018). As illustrated on Figure 13, extended letter tails can provide clearer letter shapes, differentiation of forms, such as not only simply mirror the letter “b” to create letter “p” and “d”, and more open counters to improve legibility (Fontsmith,

2018). For the prototype, the minimum font size was defined for 16pt for small body text and 38pt for headlines (see Figure 14).

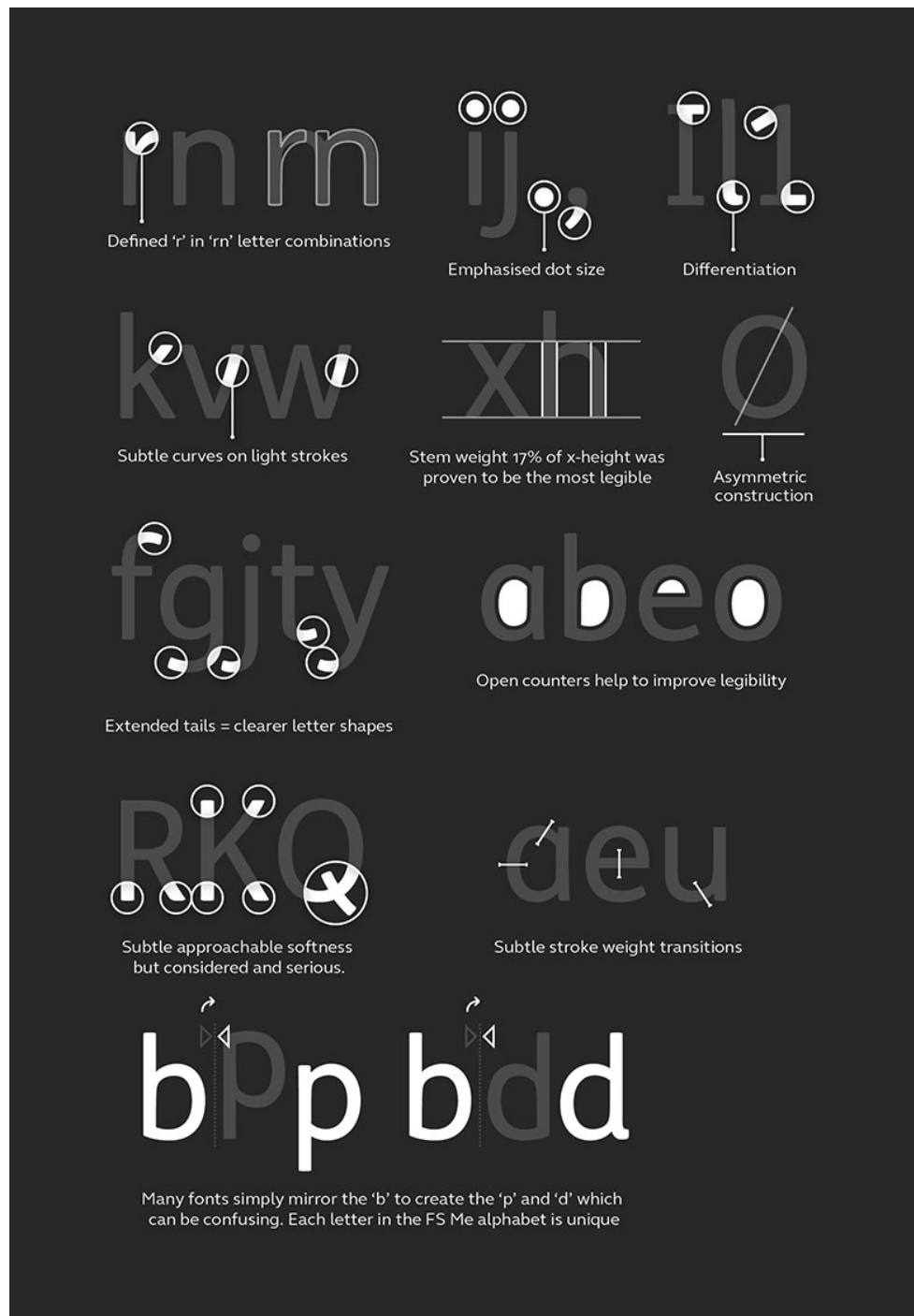


Figure 13 - FS ME typeface ("FS Me: 'The accessible type,'" n.d.)

Typeface: FS Me Trial

Character Styles

Headline

Bold 38.25pt

Title

Regular 30pt

Header

Bold 25.32pt

Large Body

Regular 22.35pt

BUTTON

Regular 20.35pt

Body

Bold 18pt

Body

Regular 18pt

Small Body

Regular 16pt

BUTTON

Regular 16pt

Paragraph Styles

Large Body

Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est eopksio laborum. Sed ut

Body

Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est eopksio laborum. Sed ut perspiciatis unde omnis istpoe natus error

Small Body

Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est eopksio laborum. Sed ut

Figure 14 - Typeface style guide

Older adults often have more trouble in remembering or understanding the meaning of “new” symbolic icons of the digital age. Even currently common icons, such as icons for settings, hamburger menu and share, are not completely understood by every older adult (Johnson & Finn, 2017). Regarding this, the icons were defined trying to get closer as possible from the real word references (see Figure 15).



Figure 15 - Icons selection for the low-fidelity prototype

According to age-friendly vision guidelines mentioned on section 4.2, the position of content drives the user attention and important information should be placed in front and center of the screen. Therefore, the Figure 16 shows the information organized on the user interface in three big groups, (1) header, (2) clear space for important information and (3) navigation bar, with the intention to highlight important and consistent information for the user. Big hit targets were also considered with the intention to be clear, easy to find and provide simple gestures interactions. With the intention to create an effective graphical language the icons were labeled to make it easily interpreted. Also, the usage of plain and mixed case font, with high contrast color with the off-white background could help maximize legibility.

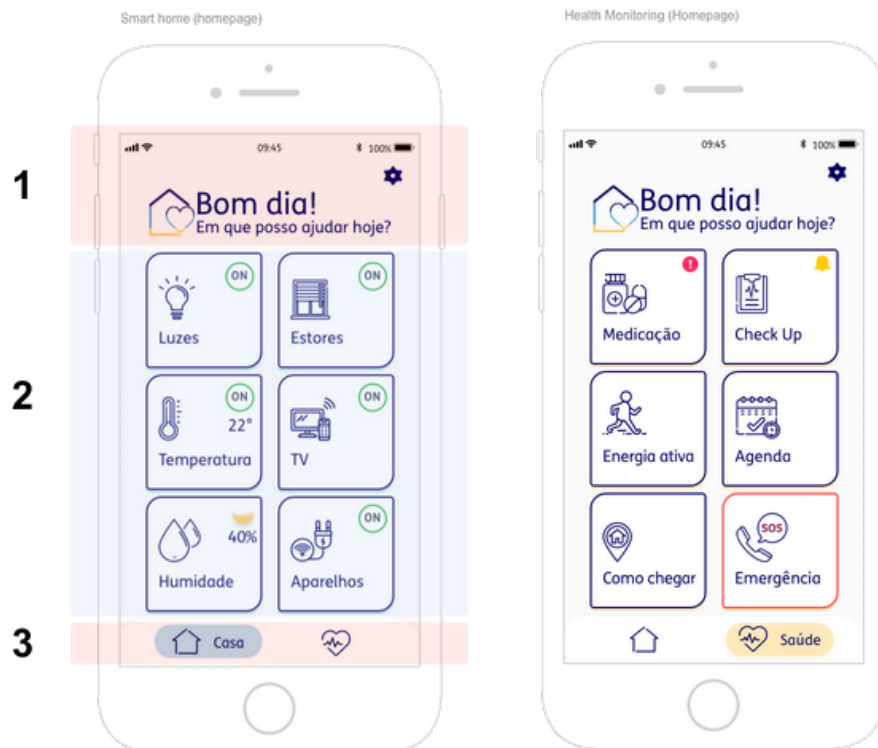


Figure 16 - Interface structure

On the navigation bar on Figure 17, according to vision and cognitive guidelines, the intention was to provide the user cues from status and location on the user interface. In this case, to show the user the label, form and color on the navigation bar to indicate when current the page is selected.

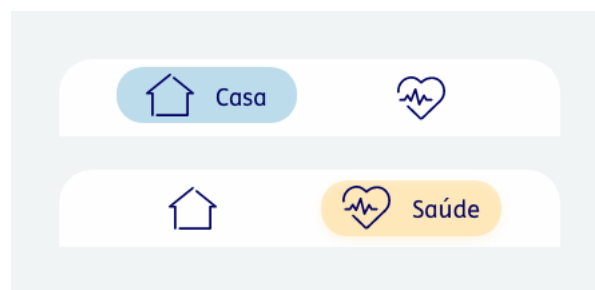


Figure 17 - Navigation bar

On the controllers, with the intention to accomplish simple gesture interactions according to motor guidelines, the interactions defined in the user interface don't require complex gestures, as multi-fingers gestures and gestures incorporated with quick movements. The one-tap gestures on slider controllers, with buttons to add and subtract values, could minimize unprecise dragging gestures (see Figure 18). Controllers could also help minimize the use of keyboard with input information in complex forms, as it shown on Figure 18.

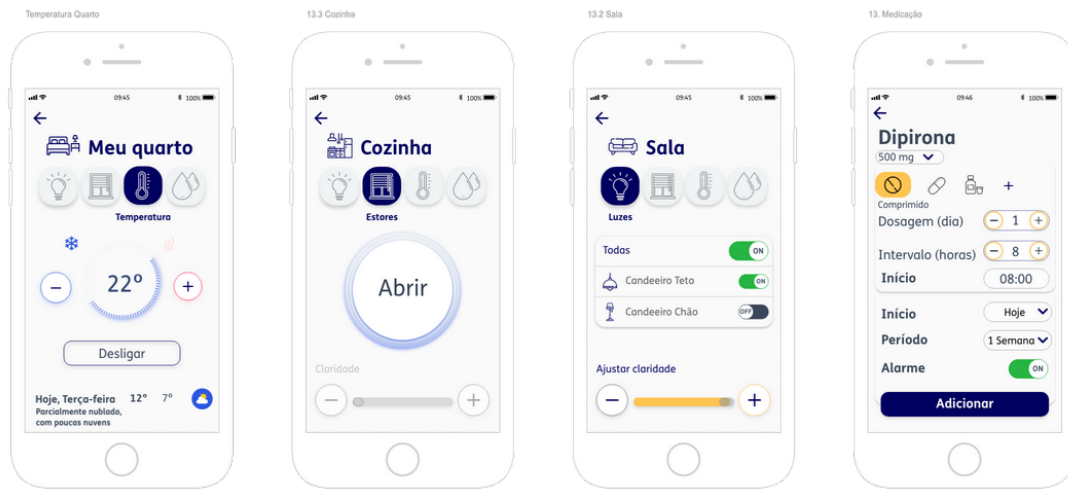


Figure 18 - Interface controllers

As this project takes place in Portugal, the prototype was developed in Portuguese, with intention to be able to contribute with international communities. To design the user interfaces, the following features for smart home and health monitoring were considered.

a) Smart Home features

- **Lights control (Luzes):** it allows the user to control the light from the whole house or by each room. The user can turn the lights on and off and also control the brightness of the light. The lights can also be controlled by presence/motion sensors to minimize the risk of older adults to walk in dark places.
- **Windows (Estores):** it allows the user to control the windows, open and close the windows from the whole house or by each room. The windows can also be automated

to close whenever the user leaves the house to minimize the risk of leaving the windows open, providing security for the user.

- **Temperature (Temperatura):** it can be automatically set according to the external temperature to maintain the ideal temperature inside the house. So older adults do not suffer in extreme hot or cold seasons. The user can also control cooling and heating, turn on and off.
- **TV:** in allows the user to control the TV channels and save favorite ones, control volume, turn on and off.
- **Home Appliances (Aparelhos):** it allows the user easily add or remove home appliances that would be compatible with the system.
- **Humidity (Humidade):** is a monitoring feature that indicates the user the level of humidity of the house. The humidity can cause some respiratory problems, then the system provides advices and alarms if the level of humidity is dangerous for older adult's health.

b) Health monitoring

- **Medication management and reminder (Medicação):**
 - Medication management: it allows users to have a list view of current intake medications, with instructions for the user properly administrate the medication.
 - Medication reminder: the user can create alarms to administrate medication, including frequency, dosage and duration.
 - Add new medication: to add a new medication, the user has 2 possible options. They can add a new medication using a barcode package or through the medical prescription number provide on every medical prescription in Portugal. With the medical prescription, the system can automatically have the medication name, dosage, frequency and duration. With the barcode, the system provides the medication name and the pill dosage, and the user can input the dosage and frequency of the treatment.

- **Health checkups (Checkup):** health checkups are brain games for older adults users to stimulate vision, memory and hearing senses and abilities. They can keep up their historical performance and share their results with friends, family and caregivers.
- **Calendar (Agenda):** it allows users to set reminders for events, medical appointments, relatives and friends birthdays, and set to do's list to keep their routine organized and updated.
- **Guide me (Como chegar):** it is a navigation tool to provide users the best routes and times to arrive in certain destination. It is also connected with the calendar, then users can find the best way to arrive to their destination. The user can allow to share their location with family and caregivers to provide any needed or emergency help.
- **Active energy:** activity motoring and step tracker of daily exercises routine. It allows the user to set daily, week, month goal to keep healthy and active. The user can receive monitoring alerts about daily goals and share the activity monitoring with family and caregivers. It also allows the family and care givers to receive notification messages if any abnormal lack of activity is detected.
- **Emergency call (Emergência):** it displays an automatic call to the emergency services and also provide family and caregivers an automatic notification message. The user can give permissions for family and caregivers to be on the emergency contacts list. As the emergency call is activated, the authorized contacts receive notification messages in every 5 minutes until they confirm to the system that the notification was read.

The smart home and health monitoring interfaces are presented on Figures 19 and 20.

Link to access to low-fidelity prototype: <https://xd.adobe.com/view/7436b63d-e39f-45a8-71b9-09ef74a0d2f1-0207/>

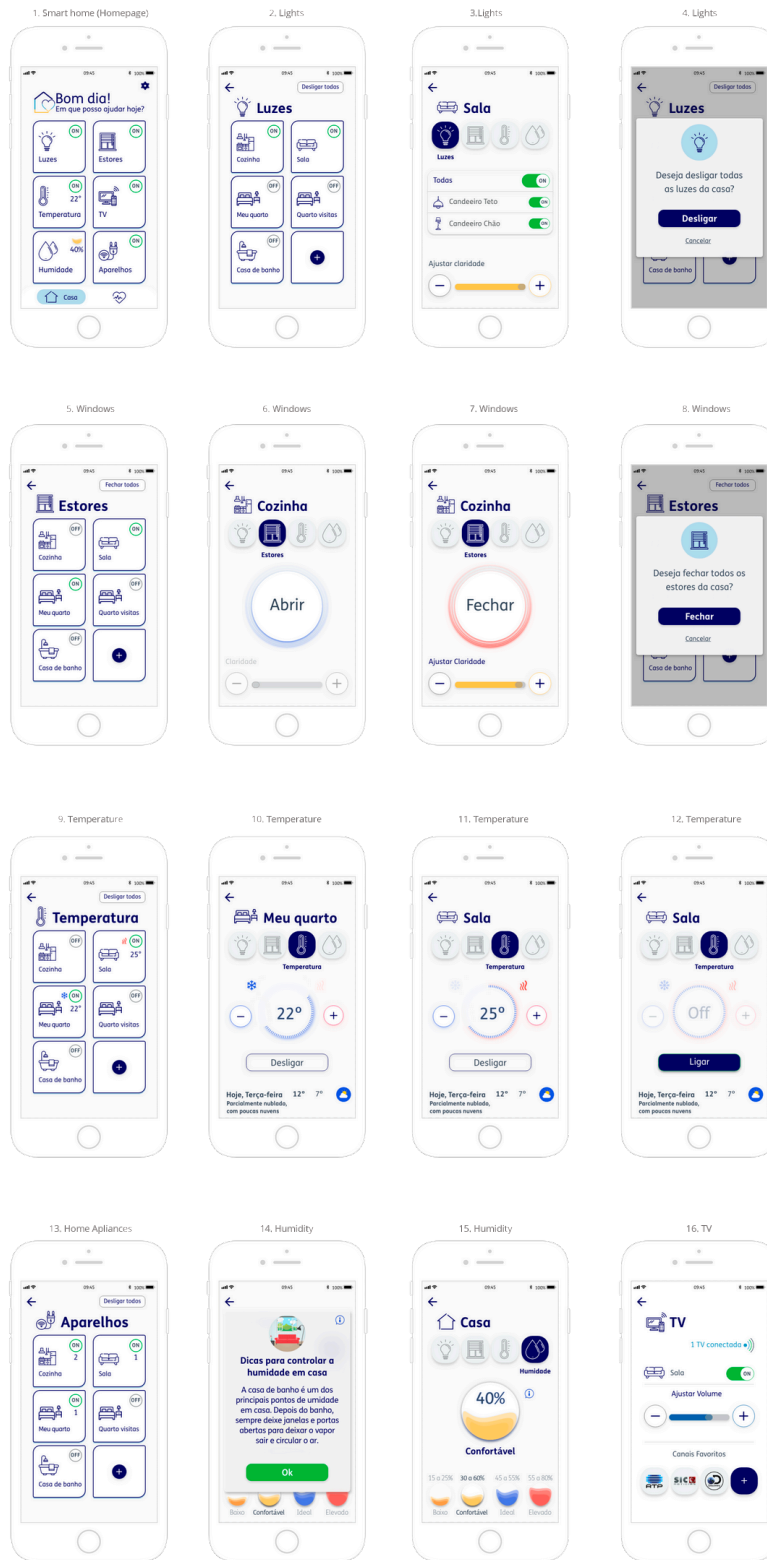


Figure 19 - Smart home interfaces of the low-fidelity prototype

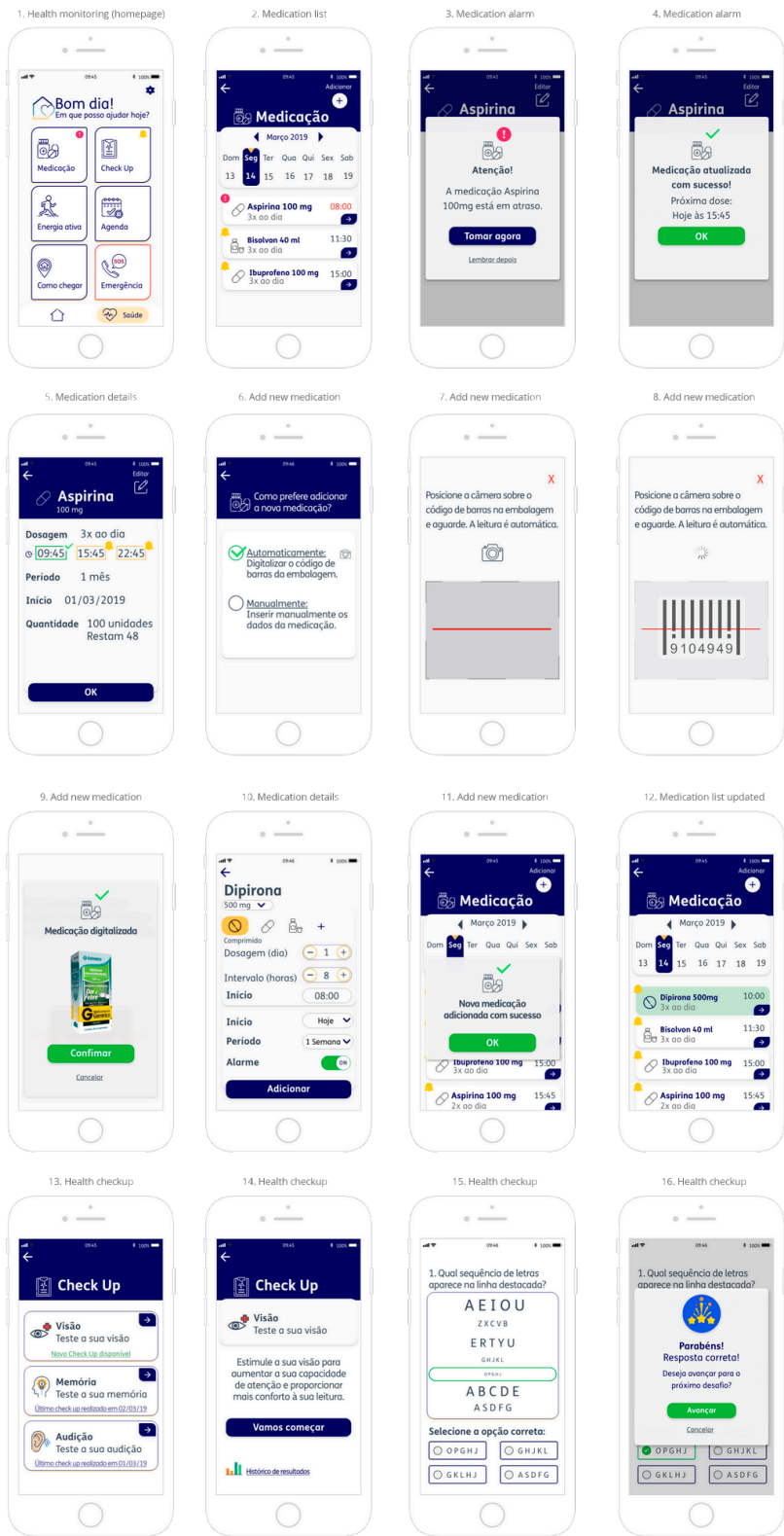


Figure 20 - Health monitoring interfaces of the low-fidelity prototype

4.3.2 Heuristics¹

The expert-based method developed by Nielsen (Nielsen, 1992) is applied to evaluate the usability problems of the smart home and health monitoring prototype supporting older adults. The objective of the heuristic evaluation is to evaluate the UI usability characteristics according to the principles and guidelines. The 10 Heuristics are as follows: “Consistency and Standards” (H1), “Visibility of the system” (H2), “Match between the system and the real world” (H3), “User control and freedom” (H4), “Error prevention” (H5), “Recognition rather than recall” (H6), “Flexibility and efficiency to use” (H7), “Aesthetic and minimalist design” (H8), “Help users recognize, diagnose, and recover from errors” (H9) and “Help and documentation” (H10). According to Rogers et al. (Rogers et al., 2002), if heuristic evaluation is conducted on a functioning product or a conceptual prototype, the experts need to have some specific user tasks in mind to focus the inspection. Therefore, representative user tasks were defined for the experts.

a) Participants

Three experts with high expertise in user experience were selected to participate in the study. The user experience experts have also relevant expertise in performing heuristic evaluation in digital products.

b) Procedure

The procedure was published online (see Appendix A). Each evaluator received by email the heuristic evaluation sheet with the instructions and list of tasks with a link for the interactive prototype. These tasks were selected due to their representation of the main functions of the system related to health and home features. The procedure was done in three stages:

- (i) **Briefing Stage.** This stage entailed giving the evaluators the description and objective of the project with the information in detail about the goals and procedure of the heuristic evaluation.

¹ Title 4.3.2 was extended and presented in HCI International 2020. The paper is in publication. Title: “An Age-friendly System Design for Smart Home- Findings from Heuristic Evaluation”

- (ii) **Task Analysis.** In this stage, the evaluators performed tasks analysis to find usability problems they face within each interface of each given task. The flow of each task was shown in Figures 21, 22, 23, 24, 25, 26, 27, 28 and 29.

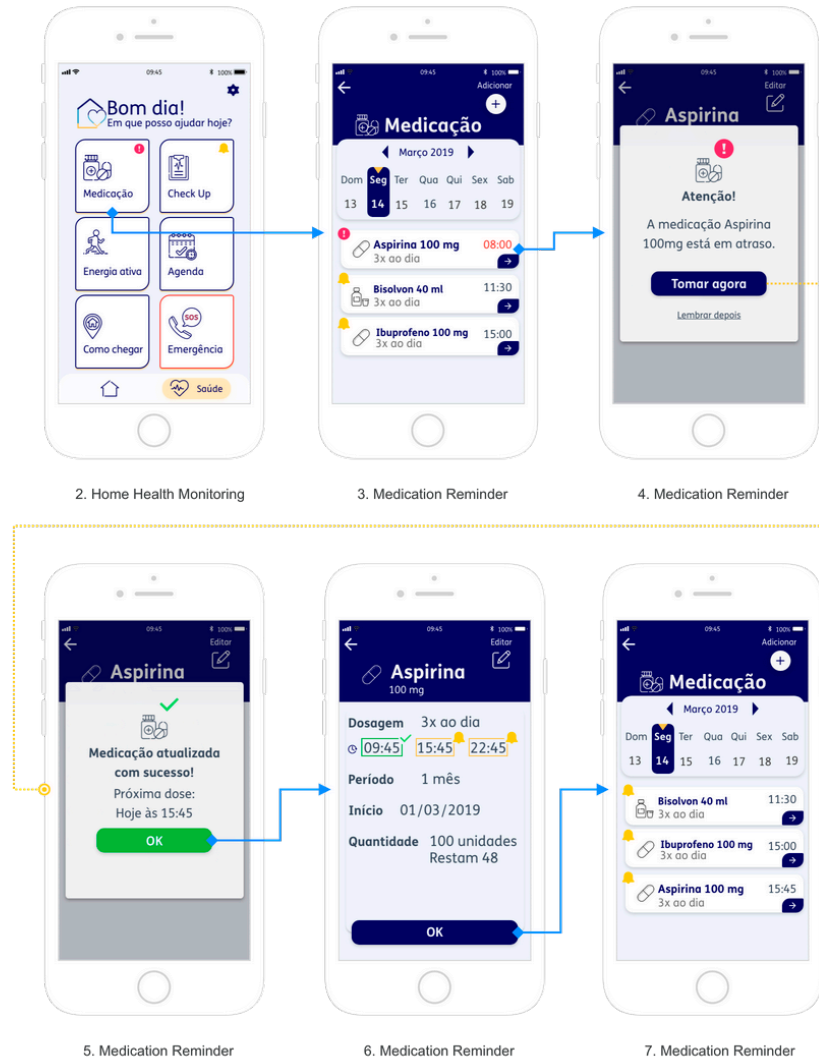


Figure 21 - User flow of Task 1 “You should take “Aspirina” 3 times a day. Check if you are taking it correctly”.

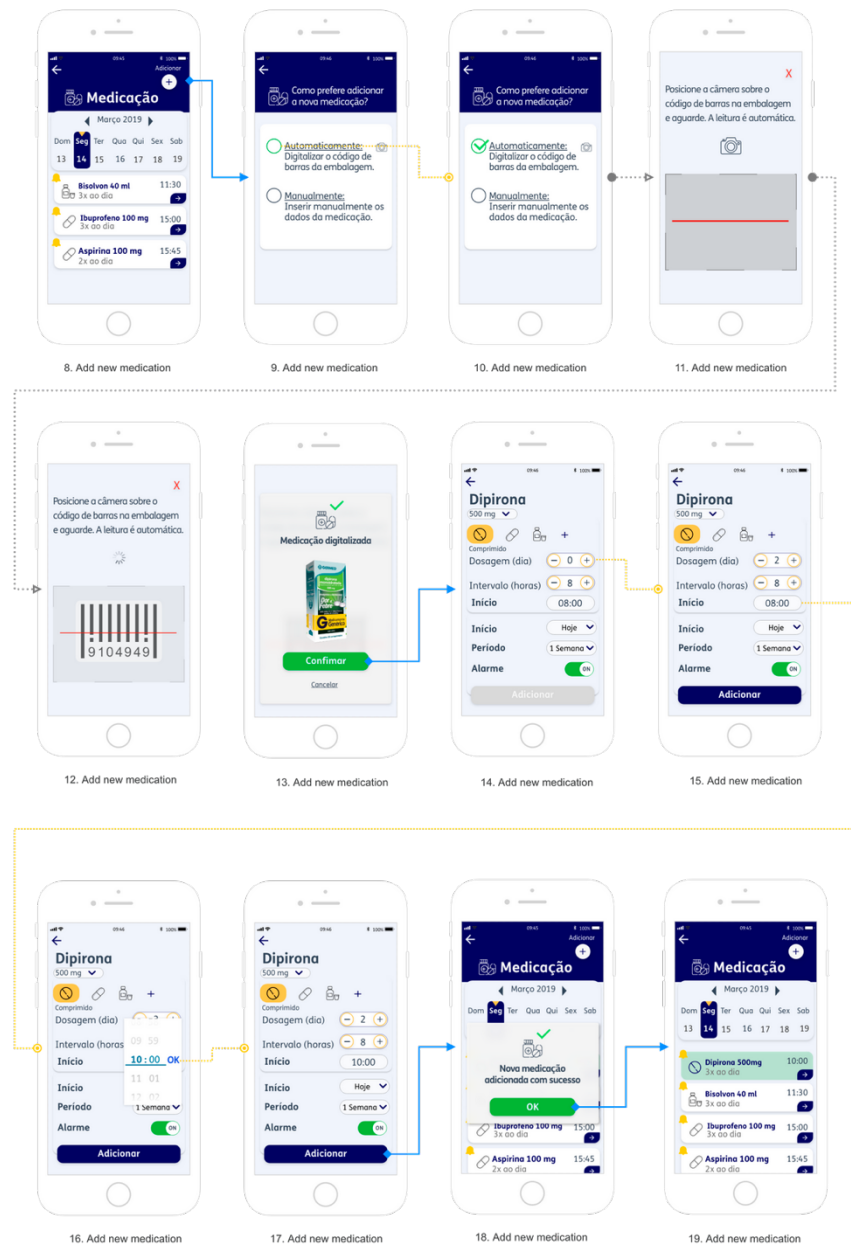


Figure 22 - User flow of Task 2: You should take 2 pills of “Dipirona” per day, starting at 10 a.m. for one week. Add “Dipirona” to your medicine reminder list.

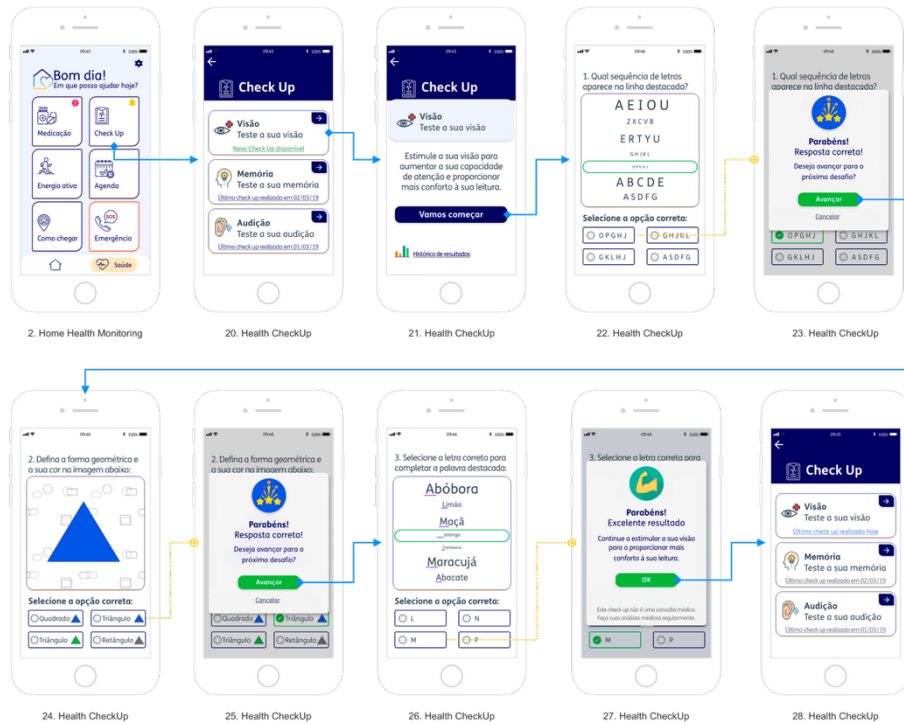


Figure 23 - User flow of Task 3: New check-ups become available from time to time. Check if you are missing any available health checkup.

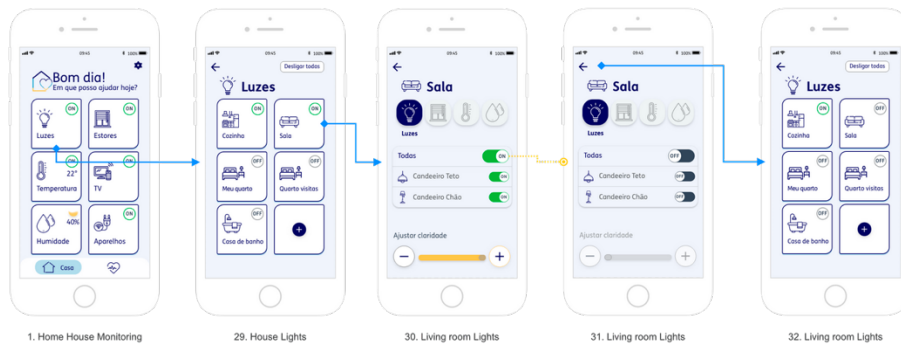


Figure 24 - User flow of Task 4: You remembered that you left the living room lights on and you are in your bedroom, reading a book. Turn off the lights in the living room.

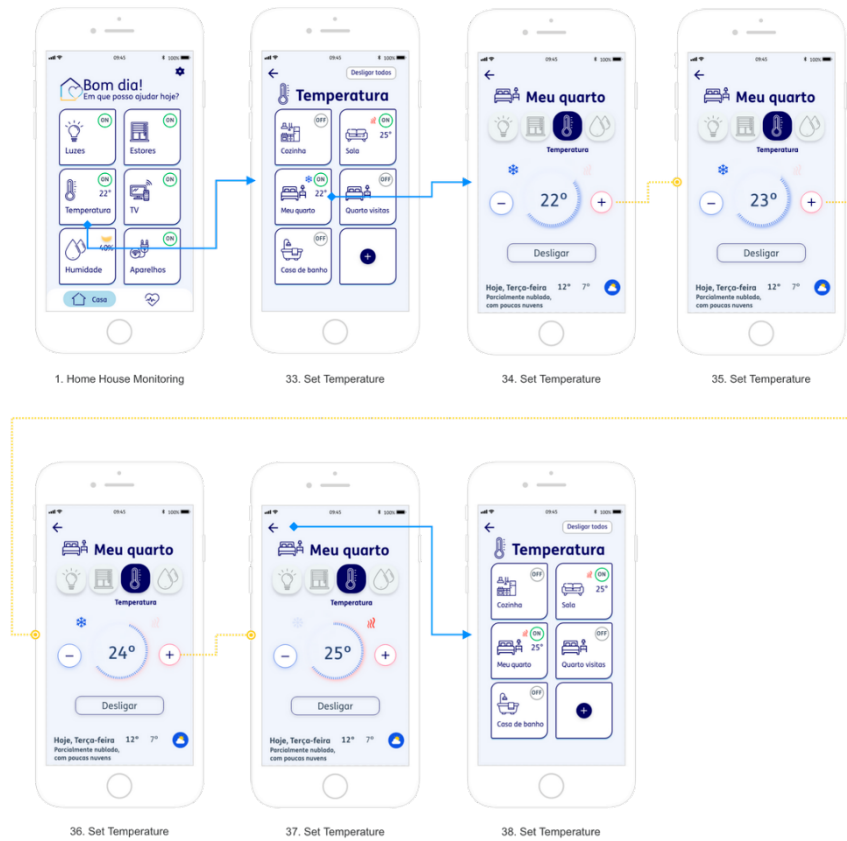


Figure 25 - User flow of Task 5: You are feeling cold in your bedroom. Increase the temperature to 25°C.

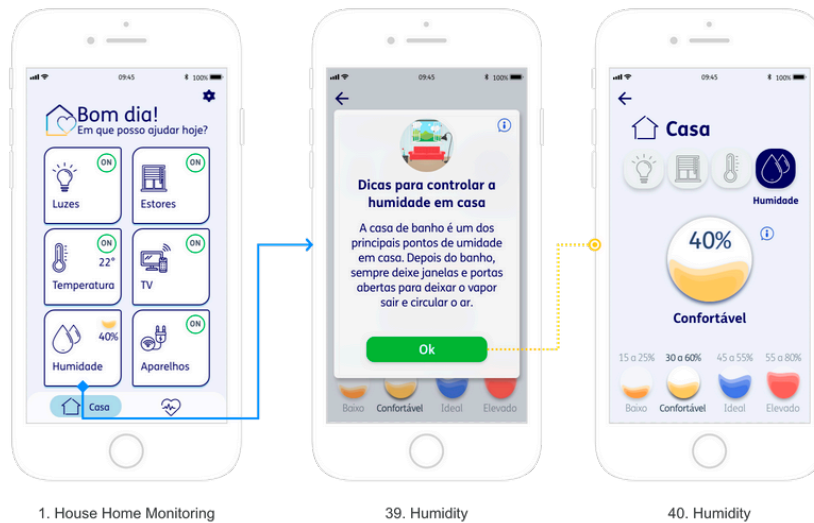


Figure 26 - User flow of Task 6: It's raining a lot lately and it causes humidity problems at home. Check the humidity of the house.

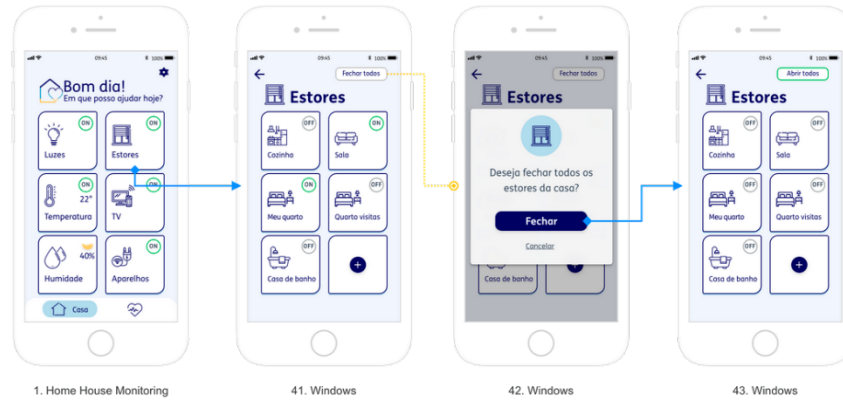


Figure 27 - User flow of Task 7: You are arriving at the supermarket and it just started to rain. Check if you left your windows open.



Figure 28 - User flow of Task 8: A cake is in the oven while you are watching TV in the living room. You decided to open the kitchen window to release the heat. Check if the kitchen window is open.

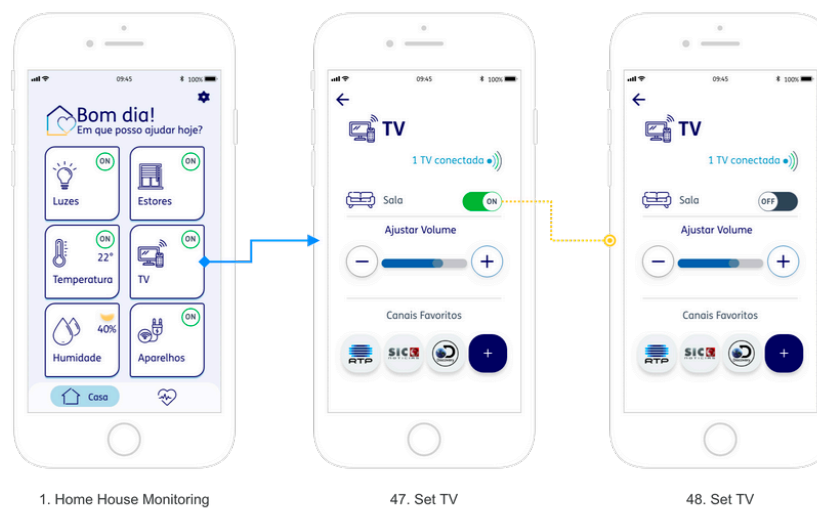


Figure 29 - User flow of Task 9: You are not at home and you wonder if you left your TV on. Check if the TV in the living room.

(iii) Evaluation Stage. In this stage, the evaluators conducted the evaluation (Nielsen's 10 Heuristics) on the usability problems that they found in the interactive prototype and prioritize them according to Nielsen's five-point Severity Ranking scaled from 0-4, where 0- indicates no problem, 1- cosmetic problem, 2- Minor problem, 3- Major problem, and 4- catastrophic (Nielsen, 1994). During the evaluation, evaluators also compiled a document where they reported the usability problems, the descriptions of the problems, place of occurrence on the UIs, and related to the violated heuristics and the severity ratings applied.

c) Results

The data were reported both quantitatively and qualitatively. Quantitatively, after receiving the heuristics severity ratings by each evaluator, the results were combined. Qualitatively, the evaluators performed task analysis to identify the problems and, also, sent a report by compiling their feedback regarding the problems.

i) Task analysis and heuristic evaluation

The UI compliance to Nielsen's heuristics was inspected while the experts performed the representative tasks. Evaluators were asked to highlight and describe each usability problem while they were performing each task. The problems were sorted in 6 categories: labelling, visual hierarchy, visual consistency, terminology, feedback and interaction. The most common usability problems found in the task analysis is reported in Table 2.

Table 2 - Common usability problems identified

Task description	Place of occurrence	Problem Category

Task 1: You should take “Aspirina” 3 times a day. Check if you are taking it correctly.	4, 5. Medication reminder; 6. Medication reminder	Interaction
	2. Home Health Monitoring; 4, 5. Medication reminder; 6. Medication reminder	Feedback
	1. Home House Monitoring; 4, 5. Medication reminder; 6. Medication reminder	Labelling
	6. Medication reminder	Visual consistency
	2. Home Health Monitoring; 6. Medication reminder	Visual hierarchy
Task 2: You should take 2 pills of “Dipirona” per day, starting at 10 a.m for one week. Add “Dipirona” to your medicine reminder list.	13, 14, 15, 16, 17, 18. Add new medication	Interaction
	13. Add new medication	Feedback
	14, 15, 16, 17. Add new medication	Labelling Terminology Visual hierarchy
	9, 10, 14, 15, 16, 17. Add new medication	Visual consistency
Task 3: New check-ups become available from time to time. Check if you are missing any available health checkup.	20, 28. Health Checkup	Labelling
	22, 23, 24, 25, 26, 27. Health Checkup	Interaction
	2. Home Health Monitoring; 20, 21, 28. Health Checkup	Terminology
	20, 22, 23, 24, 25, 26, 27, 28. Health Checkup	Visual consistency
Task 4: You remembered that you left the living room lights on and you are	1. Home House Monitoring; 29. House Lights; 30, 31, 32. Living room Lights	Terminology

in your bedroom, reading a book. Turn off the lights in the living room.	1. Home House Monitoring; 29, 32. House Lights;	Visual consistency
Task 5: You are feeling cold in your bedroom. Increase the temperature to 25°C.	34, 35, 36, 37. Set Temperature 1. Home House Monitoring; 33, 34, 35, 36, 37, 38. Set Temperature	Terminology Interaction Visual consistency
Task 6: It's raining a lot lately and it causes humidity problems at home. Check the humidity of the house.	39. Humidity 39, 40. Humidity	Terminology Visual consistency
Task 7: You are arriving at the supermarket and it just started to rain. Check if you left your windows open.	41, 42, 43. Windows 1. Home House Monitoring; 41, 42, 43. Windows	Interaction Terminology Visual consistency
Task 8: A cake is in the oven while you are watching TV in the living room. You decided to open the kitchen window to release the heat. Check if the kitchen window is open.	44, 45, 46. Windows 41, 44, 45, 46. Windows	Visual consistency Interaction Terminology
Task 9: You are not at home and you wonder if you left your TV on. Check if the TV in the living room is on.	47, 48 Set TV	Labelling Terminology Visual consistency

In total, there were 80 usability problems found, 8 out of 10 heuristics were violated, and 78 violations were encountered. For each usability problem one or more heuristics violations could be assigned. “Consistency and Standards” (H1), “Match between the system and the real world” (H3) and “Aesthetic and minimalist design” (H8) were the most violated heuristic, encountered in 66 usability problems, equivalent to 68% of the overall problems. “Visibility of the system” (H2), “Error prevention” (H5), “Flexibility and efficiency to use” (H7), “User control and freedom” (H4) and “Recognition rather than recall” (H6) were others violated heuristics encountered in 31 usability problems. In heuristics violations, “Consistency and standards” (H1) represents 30% of the violations, followed by “Match between the system and the real world” (H3) with 23% and “Aesthetic and minimalist design” (H8) with 15% of the heuristics violations. While “Help users recognize, diagnose, and recover from errors” (H9) and “Help and documentation” (10) had no violations identified. Heuristics violations percentages are shown in Figure 30.

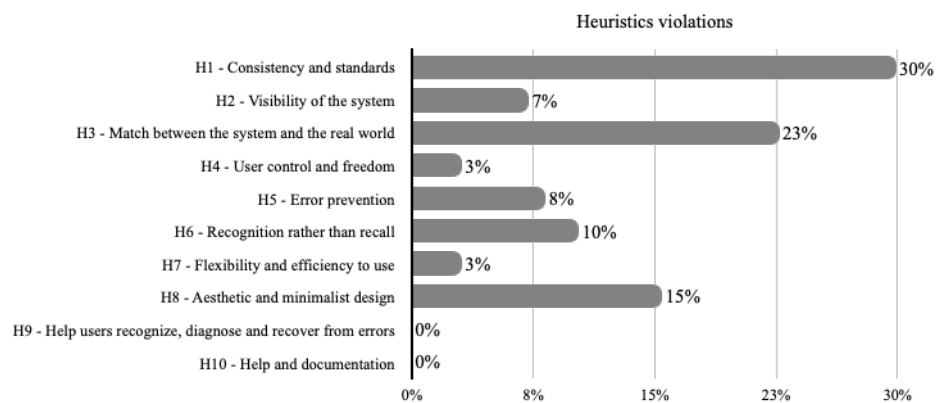


Figure 30 - Percentages per each Heuristics

Experts estimated the severity rating for each Heuristics. The severity mean analysis showed that 3% of the problems were considered catastrophic (mean $>3,5$) and it must be a high priority to fix them (Nielsen, 1994). 13% were considered major usability problems ($3,5 >$ severity rating $\leq 2,5$), according to Nielsen [21] that have the potential for confusing users and making them use the system erroneously. While 81% were minor usability problems ($2,5 >$ severity rating $\geq 1,5$), that might slow down the interactions or cause some unnecessary inconveniences for the

users (Nielsen, 1992). Finally, 6% were considered cosmetic problems. Figure 31 illustrates the average severity rating given among Heuristics.

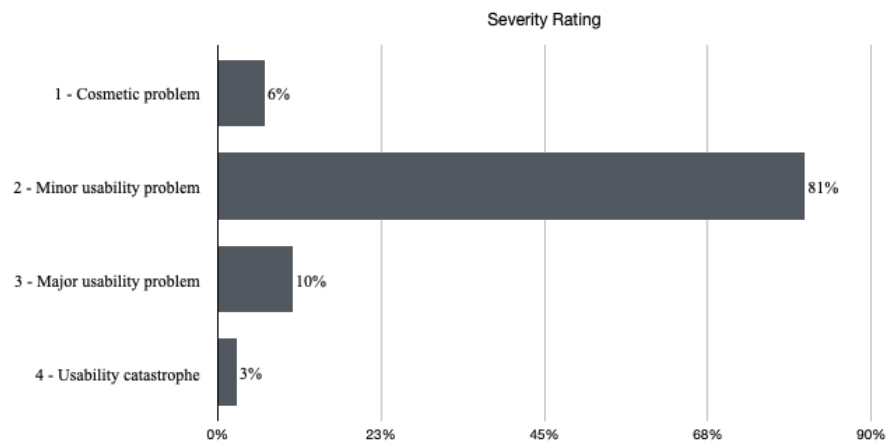


Figure 31 - Severity Rating

On the overall, the experts found eight major and two catastrophic usability problems (see Table 3). At the main screens related to health (Saúde) and home (Casa) features, the experts found the majority of major usability problems and two catastrophic. On the tab navigation bar, the experts considered as catastrophic the unlabeled icons even when the screen is not displayed. This problem can confuse the user and impact the main features of the system. Confusing and technical language was also reported as catastrophic when using terms that might not be familiar for the older users and in generic feedback messages. As the project developed in Portuguese language, the experts recommended to avoid using English terms, highlighting that it is a more familiar language for young users than and for the older ones. As the main page of the system, these catastrophic problems can compromise the system comprehension, consequently they are urgent to be fixed. Major usability problems were encountered on medication features. The experts reported that there is too much complex information on medication details that can make it difficult for users to read and it can highly compromise the user comprehension of this important feature for the user's health. Notifications and status of the system were also reported as major problems as experts reported that is insufficient visual identification and it can be almost unnoticed for the user.

Table 3 - Catastrophic and major usability problems

Place of occurrence	Problem category	Problem description	Heuristic Violated
6. Medication reminder	Visual consistency	- Too much and complex information related with medications routines. - Unaligned text.	H8
2. Home Health monitoring; 1. Home House Monitoring	Labelling	- Missing labels on the homepage icon.	H6
2. Home Health monitoring; 6. Medication reminder; 13. Add new medication	Feedback	- No medication labels on feedback messages.	H6
2. Home Health monitoring	Feedback	- No visual notification to show that a medicine was not taken.	H2
14, 15, 16, 17. Add new medication	Visual hierarchy	- Too much complex information to add new medication details. - Many small inputs to fill and understand.	H8
14, 15, 16, 17. Add new medication	Labelling	- Difficult to understand the “Dosage” (Dosagem) label associated with the context of taking pills.	H5
14, 15, 16, 17. Add new medication	Interaction	- Too much complex information to interact. - No automatic filling in all the fields in the form	H7

		with the medical prescription. - Small input controllers.	
2. Home Health monitoring; 20, 28. Health Checkup; 29. House Lights; 30, 31, 32. Living room Lights; 33, 38. Set Temperature; 41, 43. Windows 47, 48. Set TV	Terminology	- Wrong use of term “Check-up” as well as not appropriate to use the term for Portuguese users. - Subtle way of using the English labels "ON" and "OFF".	H3
34, 35, 36, 36. Set Temperature	Terminology	- Creation of confusion with the term “Desligar” (Turn off).	H1
1. Home House Monitoring; 41, 42, 43, 44, 45, 46. Windows	Terminology	- Incorrect use of Curtains (Estores) instead of Windows (Janelas).	H3

Note. “Consistency and Standards” (H1), “Visibility of the system” (H2), “Match between the system and the real world” (H3), “User control and freedom” (H4), “Error prevention” (H5), “Recognition rather than recall” (H6), “Flexibility and efficiency to use” (H7), “Aesthetic and minimalist design” (H8), “Help users recognize, diagnose, and recover from errors” (H9) and “Help and documentation” (10).

The severity given by heuristics showed that the catastrophic problems were identified in “Match between the real world and the system” (H3) and “Aesthetic and minimalist design” (H8). Most major usability problems were considered into “Recognition rather than recall” (H6). While minor usability problems were considered mostly into “Consistency and standards” (H1) followed by “Match between the system and the real world” (H3) and “Aesthetic and minimalist design” (H8). The distribution of severity rating is shown in Figure 32.

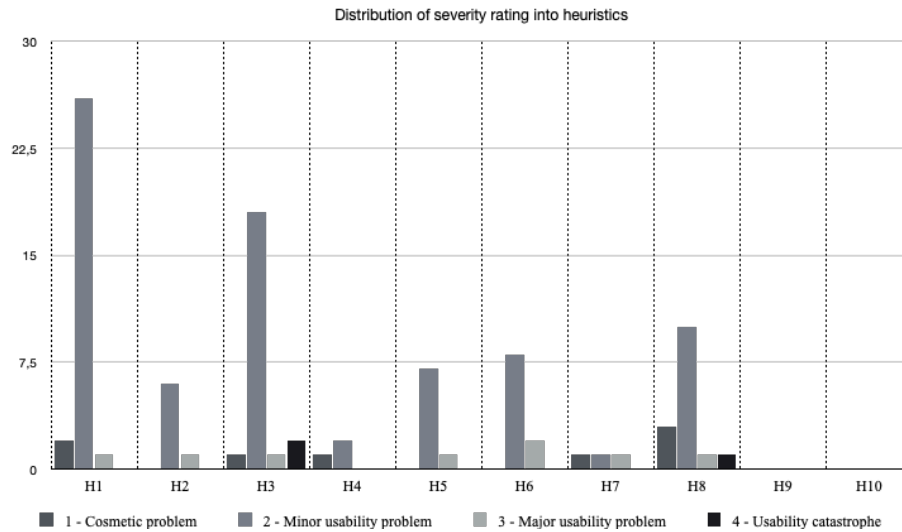


Figure 32 - Distribution of severity rating into heuristics

d) Experts recommendations

Overall, the health monitoring features were considered to be more important for the users than the smart home features. Therefore, experts recommended that the health monitoring screen should be displayed as a homepage by default, instead of house monitoring features.

The usage of plain, obvious and natural language is recommended to improve error prevention and ease of use of a complex system, avoiding technical and English terms, even that it seems to be a common use in other systems.

Minimalist design is also recommended to clarify and visually reinforce important information for the user. They suggested removing unnecessary visual elements (e.g., underlined text, icons with no context of actions, unnecessary pop ups) to keep relevant graphics (e.g., graphics should provide relevant and simple information for the user) and visual consistency so don't distract the user from important information. And create an effective visual language to maintain the visual consistency of the system.

They were concerned that using only Nielsen heuristics on a design process would not improve the interface considerably and provide a granularity of findings on the performed user tasks, according to the identification discovery protocol, identifying as violated heuristics and severity level. Combining these findings with real user testing will provide a return of more discoveries which could be more valuable to improve the interface and the overall experience.

Through the heuristic evaluation method, experts identified potential usability problems that would probably impact older adults' experience. This study showed that applying Nielsen's broad usability rules with evaluators with high expertise in user experience can provide relevance and knowledge to improve usability and experience in age-friendly design. However, more specific existing heuristics for mobile applications (SMASH) (Salman et al., 2018) and for elderly users (Al-razgan, Al-khalifa, & Al-shahrani, 2014) could be explored to inspect age-friendly design guidelines.

e) Conclusions

Through the heuristic evaluation method, experts identified potential usability problems that would probably impact older adults' experience. This study showed that applying Nielsen's broad usability rules with evaluators with high expertise in user experience can provide relevance and knowledge to improve usability and experience in age-friendly design. It can be noticed that Nielsen's heuristics are broadly generic to evaluate age-friendly design guidelines. However, it is still relevant to provide substantial and important findings in the evaluation process.

4.3.3 High Fidelity Prototype

After the heuristic evaluation, it was applied a design review on the low-fidelity prototype, according to the experts findings and recommendations. With the design review, the prototype evolved to a high-fidelity interactive prototype. A high-fidelity prototype for the interaction perspective is to evaluate how users operate the system (Hartson & Pyla, 2012). The intention is to understand how users react to the interface, where users look at when information is displayed and how they manipulate controls. The high-fidelity prototype takes into consideration more detailed interfaces, well-designed icons, more complete task sequences and carefully worded messages (Hartson & Pyla, 2012).

The first modification to consider on the design review was to display the health monitoring features by default homepage, instead smart home features. The second, was to review the layout to provide minimalist design, remove all the unnecessary information, to keep only relevant and consistent graphics to clarify and reinforce visual important information. Third, create an effective visual language to maintain the visual consistency of the system, regarding age-friendly

guidelines. Finally, the design of the others two interactive interfaces of the system, the tablet home hub and TV, applying the components of the design style guide to keep consistency through the system's interfaces.

The style of an interface, in terms of shapes, fonts, colors, and graphical elements can influence how pleasant is to interact with. The usability is the primarily focus when designing interfaces, although aesthetic and pleasing design can have a positive effect on people's perception of the system's usability (Rogers et al., 2002).

For that reason, a few modifications were applied on the color palette of the prototype (see Figure 33). The blue color still represents the smart home section of the system, on the other hand, the yellow on health monitoring was replaced by the green color. The green color represents healing, calming, trust and could bring higher color contrast on the interface elements (Cantwell, 2015). When defining the color palette is important to have in consideration that older adults have more trouble with contrast sensitivity and see subtle differences in shades of gray or any other color (Johnson & Finn, 2017). For that reason, any bright or light color should not be used in important information on the interface.

Colors

Primary colors



Secondary colors



Success

Warning

Error

Figure 33 - Color palette for the high-fidelity prototype

The typeface continues the same, the accessible typeface FS Me, reducing the number of representative font sizes, defining text styles and margins, to help on legibility and keep visual consistency through the interface (see Figure 34).

Typography - FS Me Trial

Title 1/Bold 25px

Heading 1/Regular 20px

Heading 1/Bold 20px

Body Large/Regular 18px

Body Large/Bold 18px

Body Medium/Regular 16px

Body Medium/Bold 16px

Body Small/Regular 14px

Body Small/Bold 14px

Styles

Page Title - Title 1/Regular 25px - #000000

Lorem ipsum dolor sit amet, consetetur sadipscing elitr

Heading - Heading 1/Bold 20px - #000000

Lorem ipsum dolor sit amet

Primary Text - Body Large/Regular 18px - #000000

Lorem ipsum dolor sit amet, consetetur
sadipscing elitr, sed diam nonumy

Secondary Text - Body Medium/Regular 16px -
#707070

Lorem ipsum dolor sit amet, consetetur
sadipscing elitr, sed diam nonumy eirmod
tempor invidunt ut labore et dolore magna
aliquyam erat, sed diam voluptua. At vero

Small Text no action required - Body Small/Regular
14px - #707070

Lorem ipsum dolor sit amet, consetetur sadipscing
elitr, sed diam nonumy eirmod tempor invidunt ut
labore et dolore magna aliquyam erat, sed diam
voluptua. At vero eos et accusam et justo duo

Margins

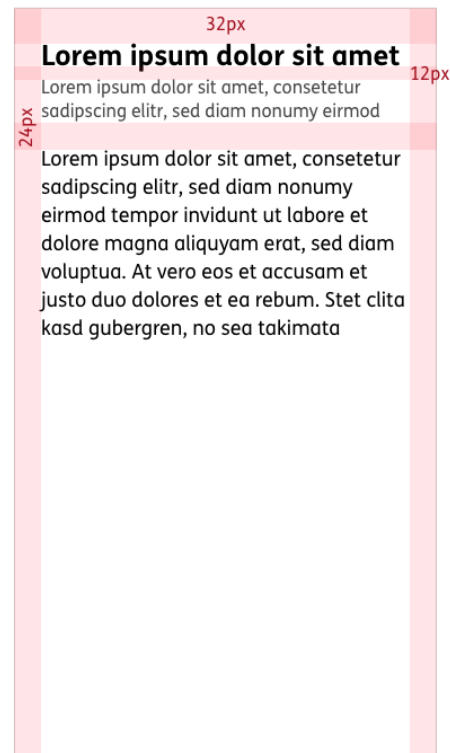


Figure 34 – Typeface text style

To clarify and visually reinforce status notifications on the interface, it was defined patterns on cards components to place notification and system status consistently, with the intention to minimize the risk of older adults miss important notifications on the interface. Consistency is one of the most important elements in intuitive design, especially for older adults (Johnson & Finn,

2017). Cards components are used to show content and actions on a single topic (“Components - Material Design,” 2019), as it shown on Figure 35.

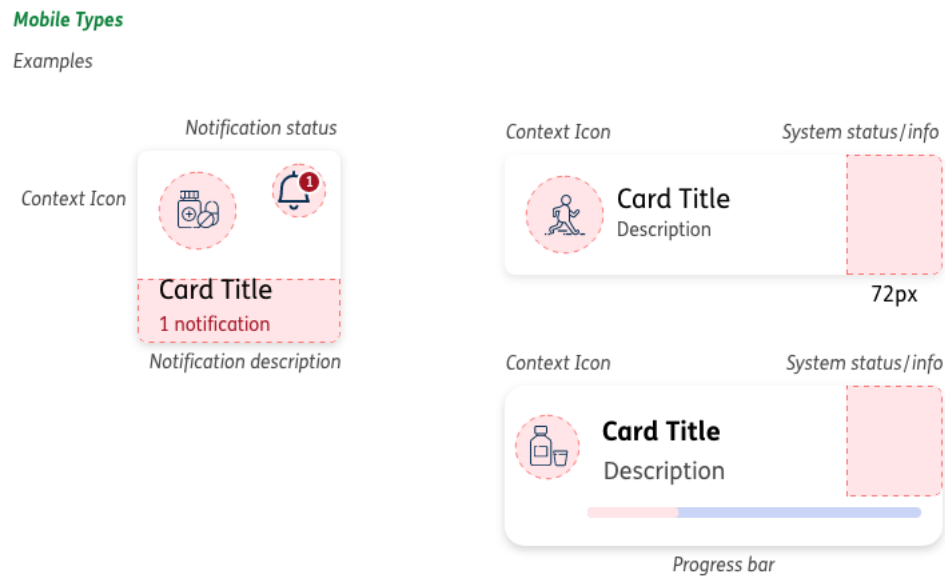
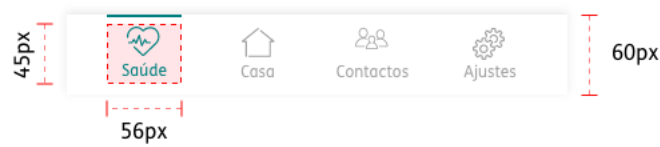


Figure 35 - Cards components

On the bottom navigation bar, major modifications were applied. The navigation structure was reviewed to place the health monitoring section as homepage by default. Also, as a high-fidelity prototype the others important categories of features were considered (see the navigation plan on section 4.2). Bottom navigation bar is used to display the most important features in the app (see Figure 36). Is an ergonomic and easy way to reach on mobile devices. The icons on the navigation bar should be consistent with the displayed features, with short text labels and should use a highlight color to emphasis the active destination (“Components - Material Design,” 2019).



1. First active feature



2. Second active feature



3. Third active feature



4. Fourth active feature

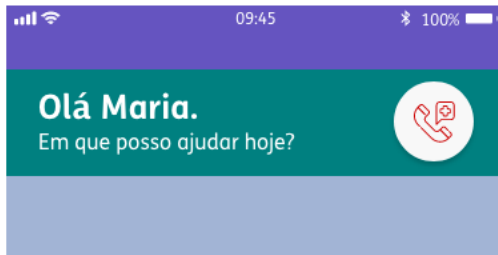


Figure 36 - Updated tab bar navigation

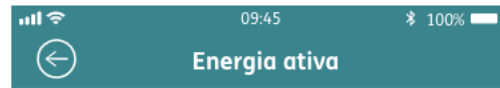
To maintain the visual consistency through the interface, headers are also important components to provide users the current location on the app and also to provide undo, back navigation options and shortcuts to the homepage (“Components - Material Design,” 2019). And applying high contrast colors it could enable better legibility for older adults (see Figure 37).

Homepage Headers

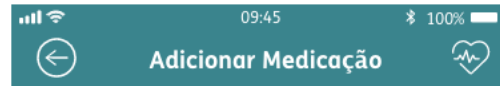
Health Monitoring Header



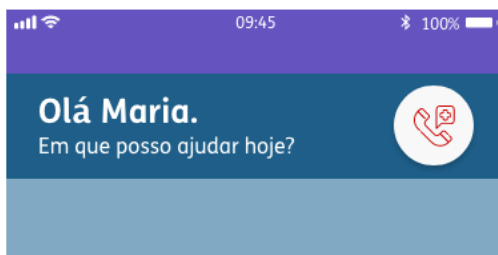
Health Monitoring Header Back



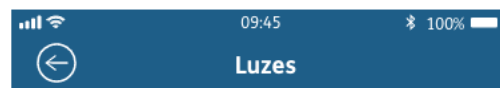
Health Monitoring Header Home



House Monitoring Header



House Monitoring Header Back



House Monitoring Header Home



Figure 37 - Headers components

The design review of the health monitoring and smart home interfaces are presented on Figures 38 and 39. And Figure 40 is presented push notification example, contacts and emergency call. Link to access to high-fidelity prototype: <https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/713b351b-06f7-4d9b-9086-f61a0f006bf5?fullscreen&hints=off>

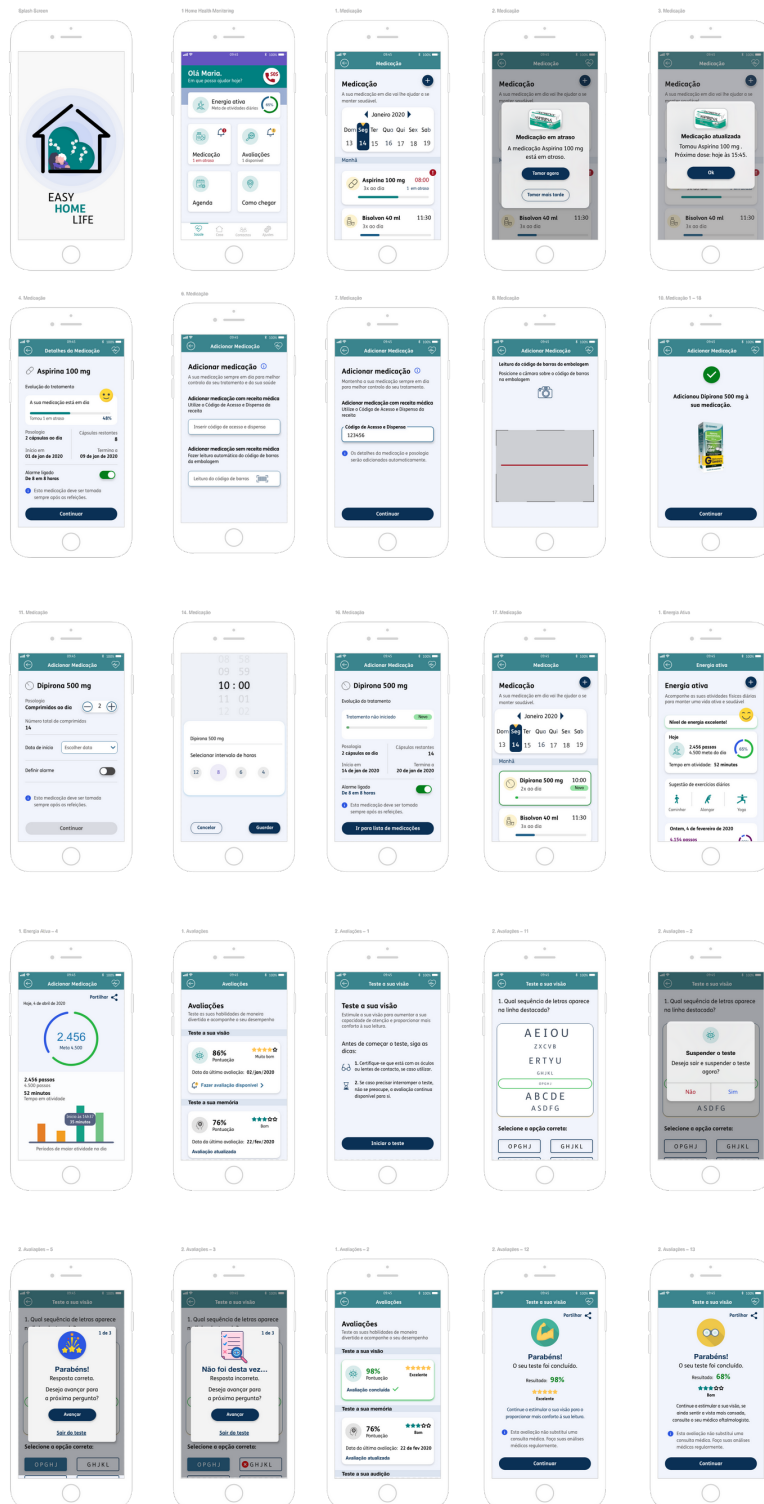


Figure 38 - Health monitoring interfaces of high-fidelity prototype

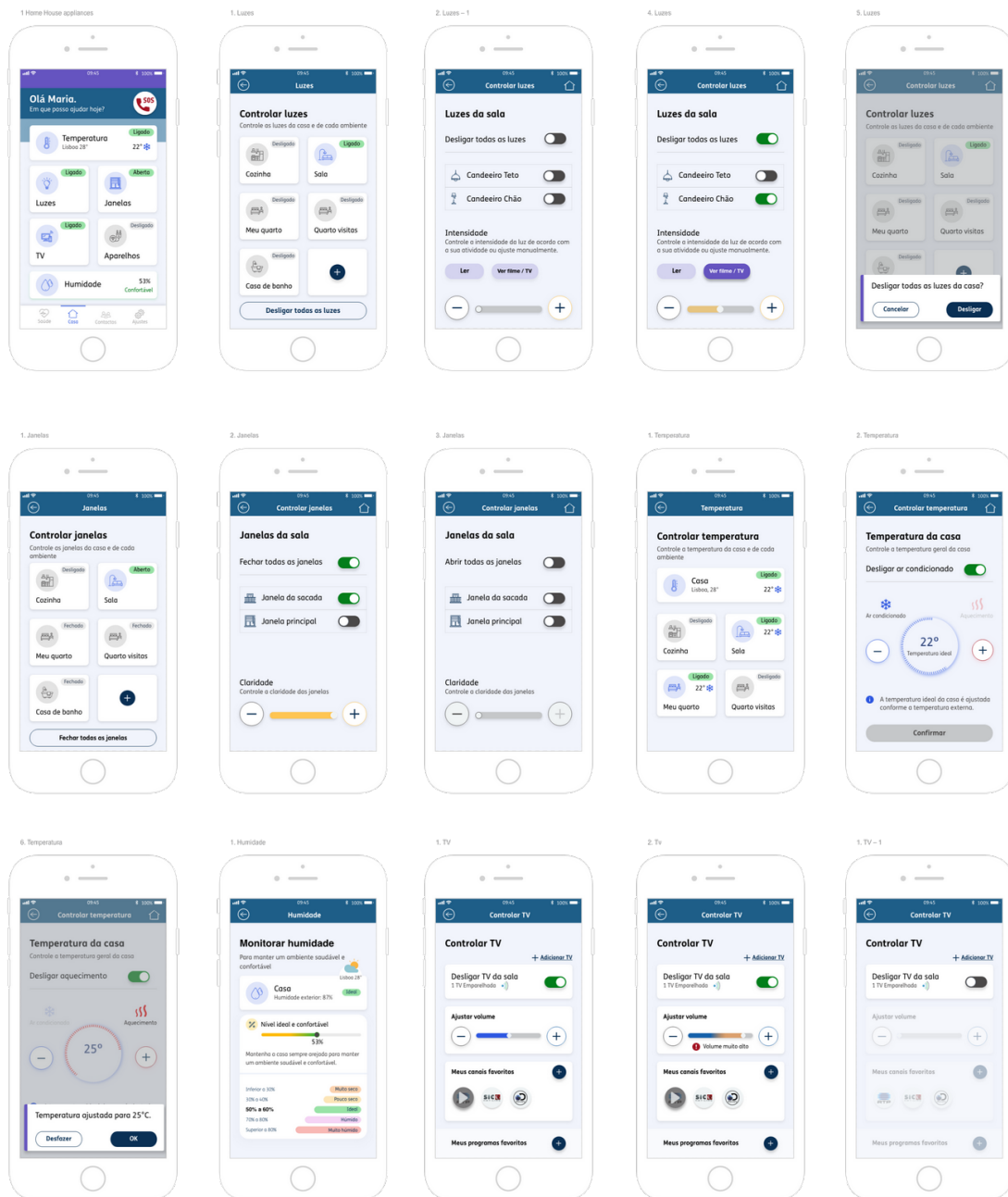


Figure 39 - Smart home interfaces for high-fidelity prototype

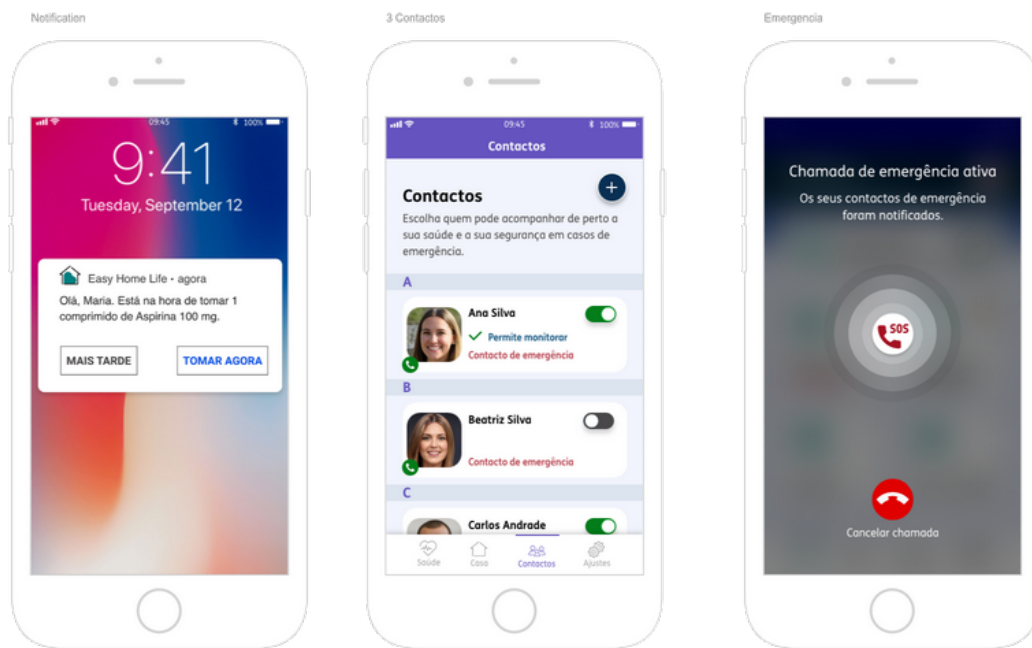


Figure 40 - Push notifications, contacts and emergency call for high-fidelity prototype

With the heuristic evaluation it was possible to define patterns on visual consistency, navigation, structure that could minimize major problems faced by older adults. These patterns were catalogued on a style guide to work as a standard way of creating new interfaces on the system. The style guide includes all kinds of user interface objects, such as fonts, color schemes, graphics, text styles, interaction styles, labeling standards, and so on (Hartson & Pyla, 2012). Style guide reduces the variation of details of components to give consistency of details throughout the system. The complete style guide is presented on Appendix B. With the style guide it was possible to adapt the components on the tablet home hub interfaces and also on the TV application.

For the tablet home hub interfaces, it was developed a control panel screen that will be displayed before the smart home and health monitoring homepage. This control panel will enable older adults to customize favorite and more important information to be displayed as first (see Figures 41 and 42). As the tablet home hub can be fixed on the house wall or be placed in a visible way, older adults could have better readability of the information that they don't want to miss.

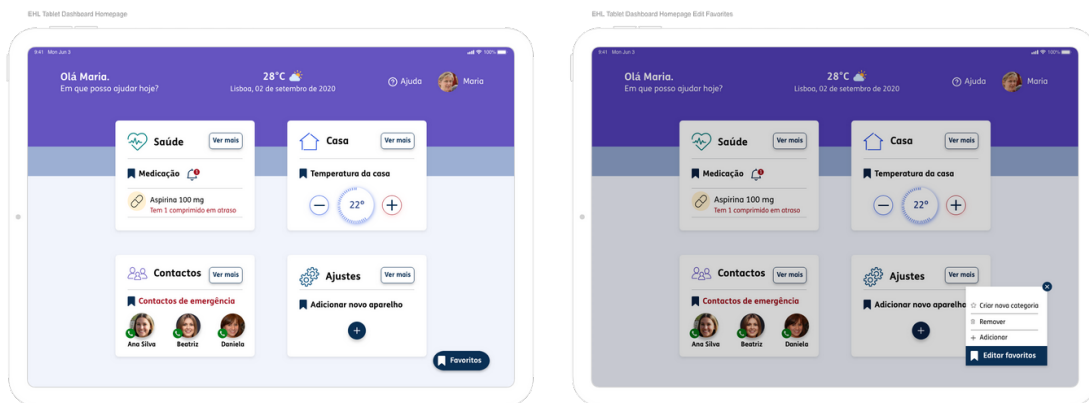


Figure 41 - Tablet home hub control panel

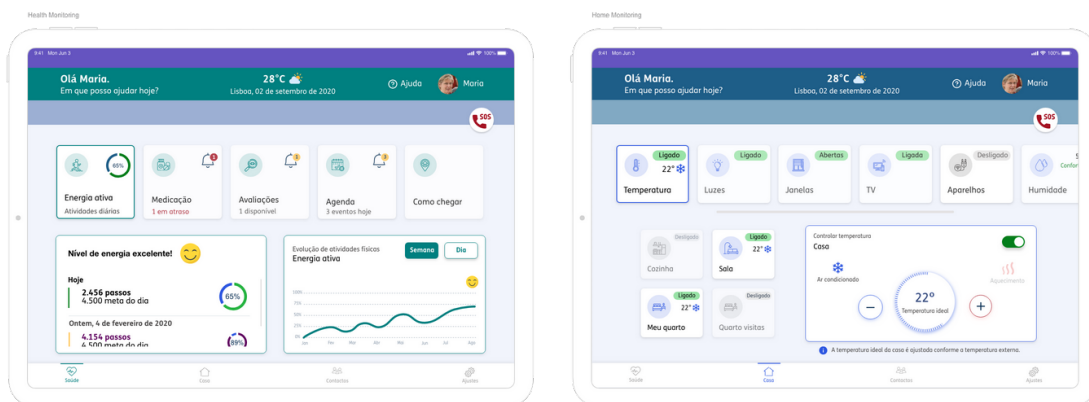


Figure 42 - Tablet home hub - health monitoring and smart home interfaces

On the TV application the user would receive important notifications if while watching television, one example of notifications is presented in Figure 43. The user would also receive notifications on the smartphone and tablet hub so user could dismiss important reminders, such as medication management.



Figure 43 - TV reminder notification

After the design review, the conceptual design of tablet home hub, TV notifications, and the documented style guide, the high-fidelity prototype should be tested with target users to assess its usability, acceptance and usefulness of assistive systems among older adults.

4.3.4 Unmoderated User Testing

As part of the User Centered methodology, after the design review on the interactive prototype, individual usability tests were applied to assess its usability with older adults and to obtain more detailed users' feedback. Through usability testing it could be possible to analyze the interactions and reactions of the older adults with the prototype. While performing the respective tasks it could be possible to perceive its usability and the relevance of the features presented in the system (Rogers et al., 2002).

a) Participants

9 older adults age between 55 and 69 years of age (mean=A, SD= B) participated voluntarily to the study. Five participants were between 65 to 69 years of age, two participants were between

55 to 59 and two from 60 to 64 years of age. As home aggregates, 4 participants live alone, two of them live in two people, and others three live in 4 people or over at home. All the participants agreed to participate voluntarily and anonymously.

b) Procedure

The procedure was published online. Each user received the usability test evaluation sheet (shown in Appendix C) with the instructions and list of tasks with the links for each task to perform on the interactive prototype. Same tasks on the heuristic evaluation, except one, were performed on the user testing. The exception task is the one that is related to humidity on smart home features was replaced by the health-related feature “Energia ativa”. The change was done as health was identified more important than smart home features in the Heuristic Evaluation.

The procedure was done in three stages:

(i) Briefing Stage. In this stage the description and objective of the project was sent to the users with the detailed information about the goals and procedure of the user testing.

(ii) Task Performing. In this second stage the users performed tasks according to the scenarios provided on the document to find if they could complete and understand each given task. For each task, it was given a link to assess the prototype. This could help the users to not get lost during the non-moderated test. The flow of each task is shown in Figure 44, 45, 46, 47, 48, 49, 50 and 51.

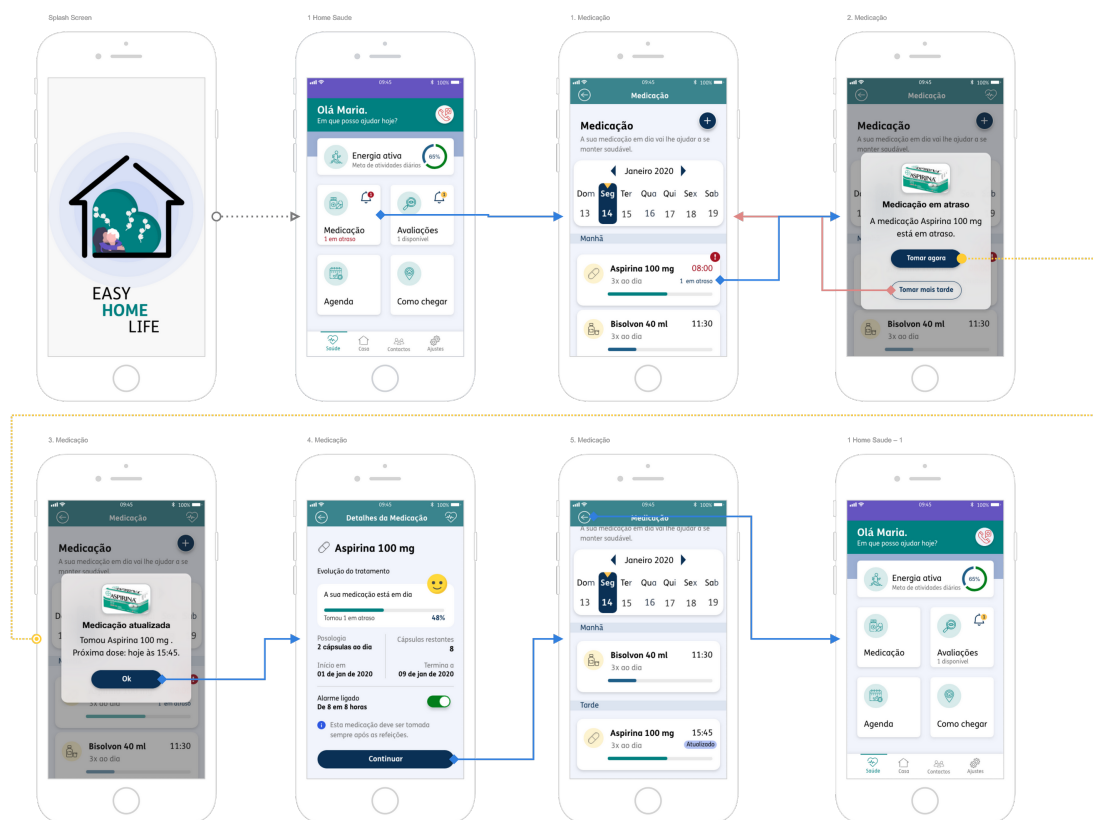


Figure 44 - Task 1. Consultar medicação. Imagine que você quer consultar as suas medicações e verificar se estão em dia.

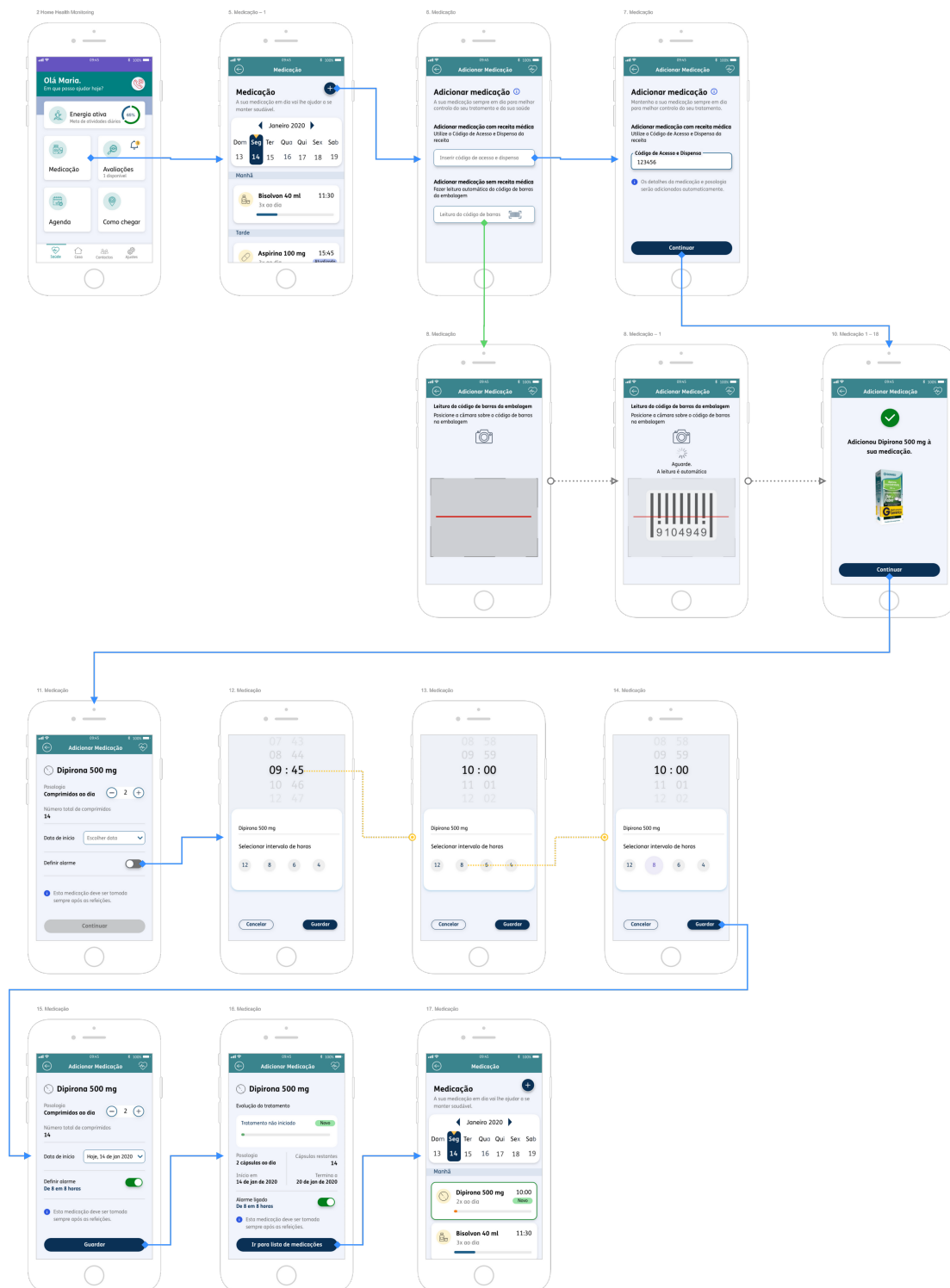


Figure 45 - Task 2. Adicionar medicação. Você vai começar um novo tratamento com Dipirona 500g e quer adicionar à sua lista para não esquecer de tomar a medicação, com início às 10h00, de 8 em 8 horas.



Figure 46 - Task 3. Consultar atividades físicas. Você quer saber como anda a sua rotina de exercícios físicos diários. Identifique o período do dia que mais se exercitou hoje.

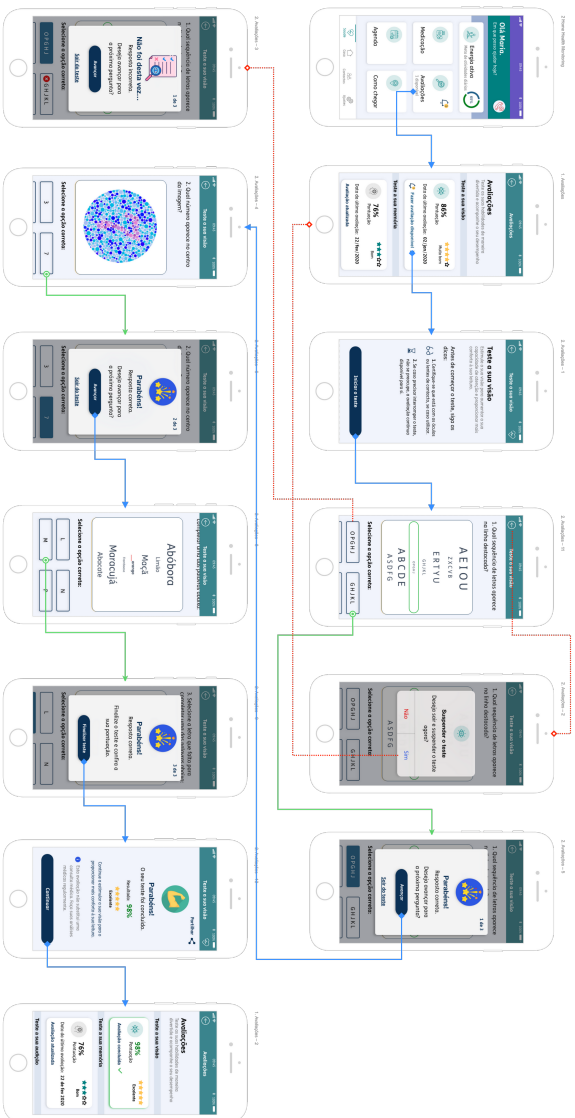


Figure 47 - Task 4. Consultar avaliações de saúde. Consulte se todas as suas avaliações de saúde estão em dia. E deixe suas avaliações atualizadas.

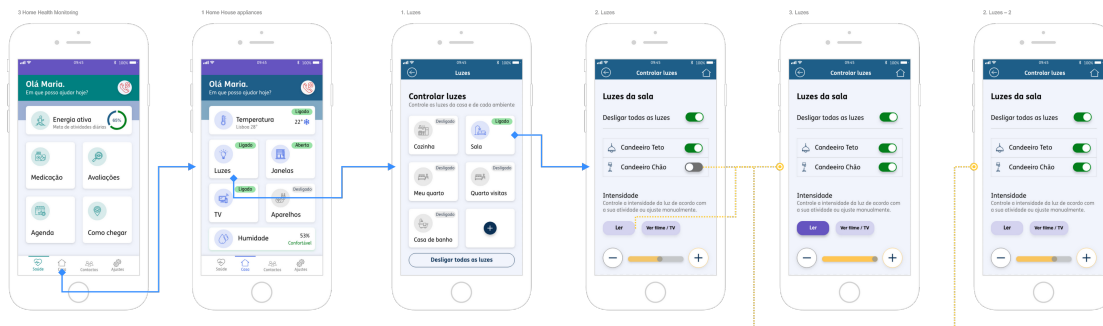


Figure 48 - Task 5. Ajustar luzes. Agora, imagina que você está sentado(a) na sala da sua casa e quer deixar as luzes mais confortável para assistir um filme ou à TV.



Figure 49 - Task 6. Controlar janelas. Ainda na sala, como está um dia frio lá fora, você quer fechar as janelas da sala sem precisar se levantar e ir até lá.

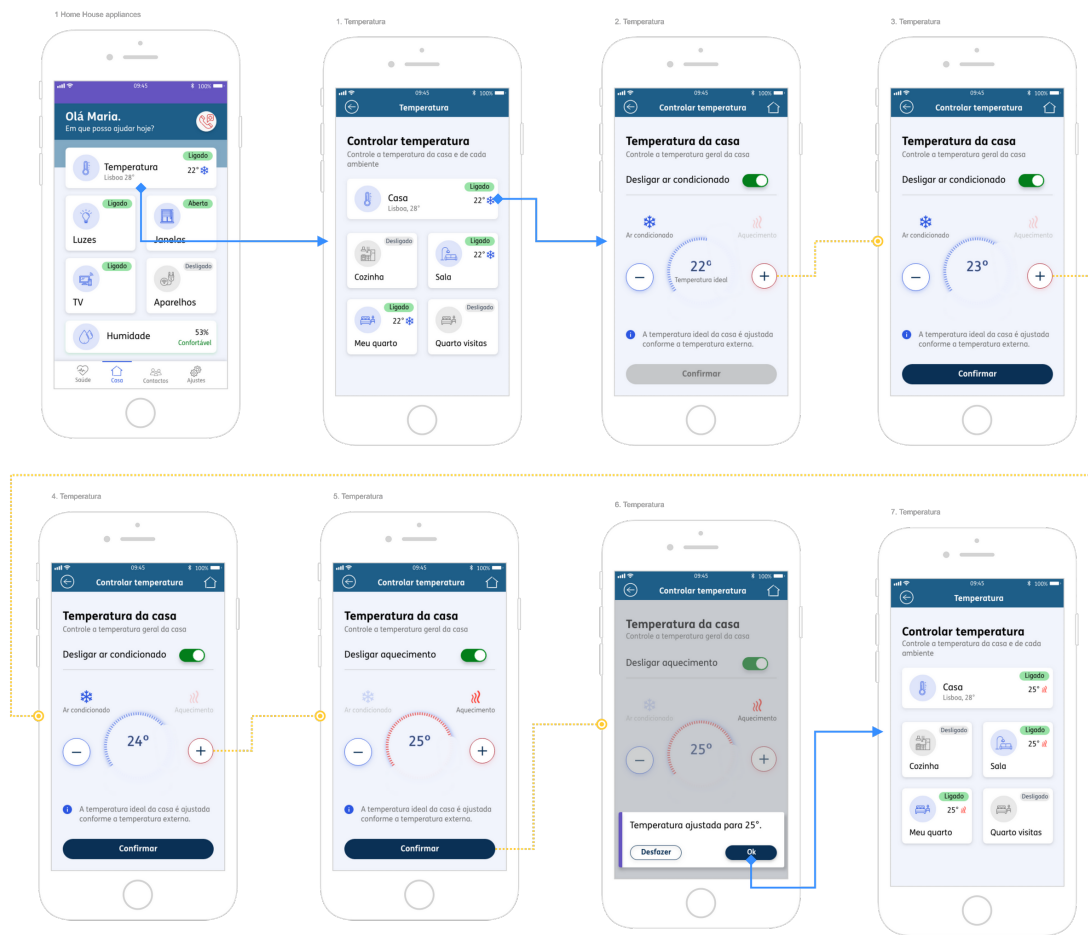


Figure 50 - Task 7. Controlar temperatura. Ainda com um dia frio, você então quer ajustar a temperatura da sua casa toda para 25° graus, para ficar mais quentinha.

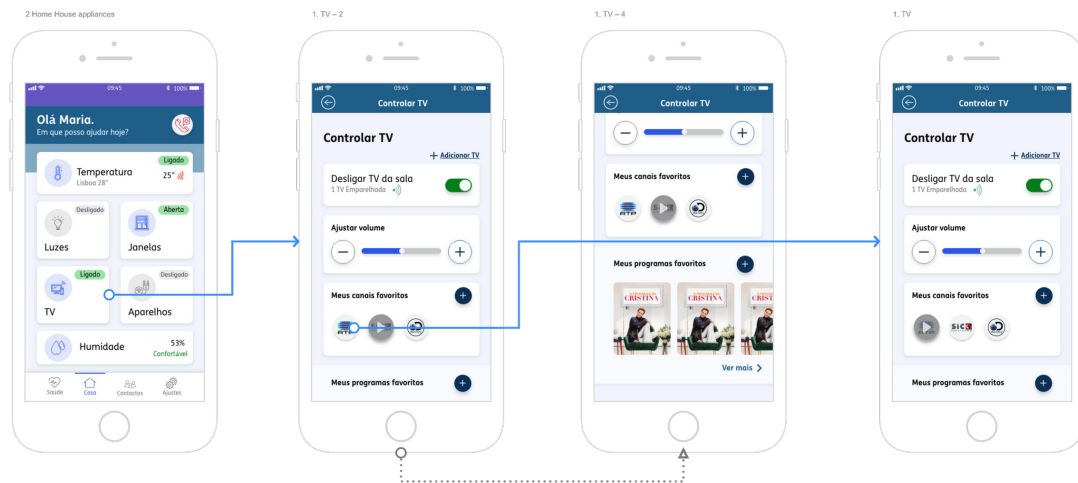


Figure 51 - Task 8. Controlar TV. E agora, para assistir o seu filme, você quer ajustar o canal da sua TV para a RTP.

(iii) Evaluation stage.

In this stage, the users evaluated the prototype evaluation according to the System Usability Scale (SUS) and Net Promoter Score (NPS) questionnaire to quantify the users experience on product satisfaction. The SUS, developed by John Brooke in 1996 (Brooke, 1986), is a 10 items questionnaire using a 5-point Likert scale numbered from 5 (as “Strongly agree”) to 1 (as “Strongly disagree”) and, if any item gets no answer, it should be assigned as a 3 (the center of the rating scale). The original SUS 10 items list were developed in English, however, as the prototype was developed in Portuguese and tested with native Portuguese language users, it was translated to fit user’s context (see Appendix D).

The NPS technique is a method to measure users’ satisfaction level related to a product, service or company (F. F. Reichheld, 2003). NPS is a single question method to categorize the users or customers according to their answer to the question: “On a zero-to-ten scale, how likely is it that you would recommend us (or this product/service/brand) to a friend or colleague?” (F. Reichheld & Markey, 2011). If they respond from 9-10 rating (extremely likely to recommend) they are categorized as “Promoters”, on a 7-8 rating, they are “Passives”, and from 0-6 (extremely unlikely to recommend) they are considered “Detractors”. After NPS, an open-ended follow-up question enabled users to give their feedback to the given rating.

c) Results and discussions

The data were reported quantitatively on SUS measure and NPS score and qualitatively evaluated the correlation of the open-end question to the rating applied. After receiving the SUS results, to calculate each item's score contribution the range would scale from 0 to 4 (Brooke, 2013). For positively worded items (1, 3, 5, 7 and 9), the score contribution is the scale position minus 1. For negatively worded items (2, 4, 6, 8 and 10), it is 5 minus the scale position. To reach the overall SUS score, multiply the sum of the item score contributions by 2.5. Then, SUS scores scales from 0 to 100 (Brooke, 2013). To obtain the final NPS score, then subtract the percentage of detractors from the percentage of promoters (F. F. Reichheld, 2003).

Nine participants performed the given tasks on the interactive prototype and answered the SUS questionnaire. 3 participants scored over 80 points, 2 participants scored over 70 points while 4 participants had lower scores between 37,5 and 57,5 (see Figure 52). Although, on the final SUS score the total average score was 65,6. According to Bangor, Staff, Kortum, Miller, & Staff, 2009 the score 65,6 can be considered as a marginal high acceptable rate on acceptability ranges, as it is shown on Figure 53. The main goal of alternating positive and negative items on SUS method is to control willing response bias and not to have the impression that the user is forced to respond only for positive feedbacks (Sauro & Lewis, 2011). However, Sauro & Lewis identified that despite the advantages in alternation items that can be safer against serial extreme responders - participants who respond all high or all low ratings - it can lead users to misinterpretation and mistakes, especially for remote usability testing. Users can misinterpret when responding to negatively items reversing responses from negative to positive and they could accidentally agree with a negative statement when they mean to disagree.

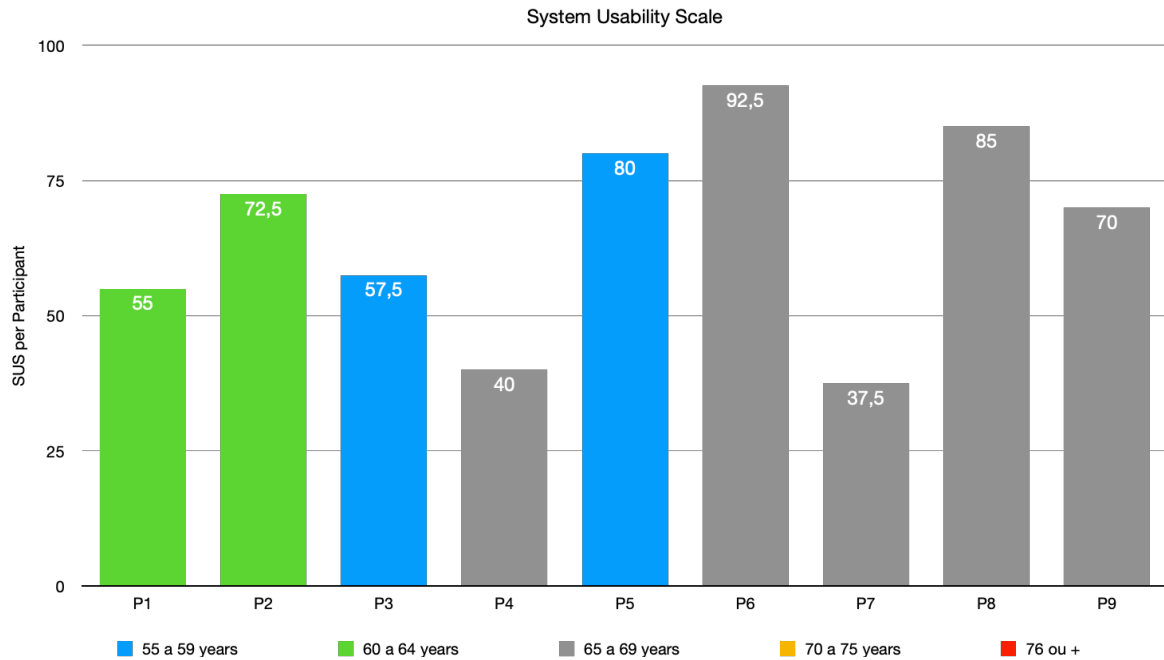


Figure 52 - SUS individual results

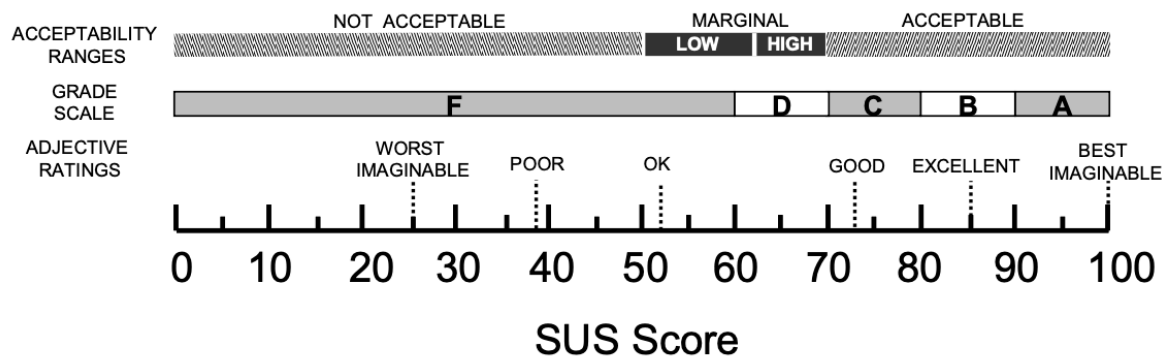


Figure 53 - SUS acceptability range

The NPS score can categorize the respondents into three groups that have typically different attitudes and behaviors: Promoters, Passives and Detractors (F. Reichheld & Markey, 2011). Promoters are the users who respond the NPS questionnaire with a nine or a ten score. They have the potential to be loyal users and can offer constructive feedbacks and suggestions. Passives are the ones who give a seven or an eight. They tend to be passively satisfied with the

product/service/company but are not properly the loyal ones. And finally, the Detractors are the ones who give a rating of six or bellow. Their score can represents disaffection and disappointment, and they tend to share the bad experience with friends, family and colleagues (F. Reichheld & Markey, 2011).

According to Brooke (2013), there could be a relationship between SUS and NPS scores. When users rate a system with a SUS score around 82 (± 5), they also tend to be a “Promoter” (Brooke, 2013). Although, between four “Promoters” identified, only one scored a SUS rating over 80, others two scored over 70 and actually one “Promoter” scored 55. One of the participants was categorized as “Passive”, however scored a SUS rating of 92,2. Finally, four “Detractors” identified scored between 37,5 to 57,5, as presented in Table 4. Although, the participants with low SUS scores also gave low NPS ratings due to their poor usability experience and was consequently identified as “Detractors”.

Table 4 - User testing results per participant

Participant	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	SUS Score	Age	Home Aggregates	NPS	NPS classification
P1	5	4	4	5	5	4	5	4	5	5	55,0	60 a 64	4 +	10,0	Promoter
P2	5	4	4	2	3	3	5	3	5	1	72,5	60 a 64	2	9,0	Promoter
P3	4	2	4	5	5	2	3	4	4	4	57,5	55 a 59	4 +	5,0	Detractors
P4	3	4	4	4	2	4	5	4	2	4	40,0	65 a 69	Live alone	2,0	Detractors
P5	4	4	5	1	4	3	5	1	4	1	80,0	55 a 59	2	6,0	Detractors
P6	4	1	5	1	5	3	5	1	5	1	92,5	65 a 69	4 +	8,0	Passives
P7	2	4	1	4	2	2	4	4	4	4	37,5	65 a 69	Live alone	3,0	Detractors

P8	5	3	4	2	5	1	5	1	5	3	85,0	65 a	69	Live alone	10,0	Promoter
P9	5	4	4	4	5	2	5	4	4	1	70,0	65 a	69	Live alone	10,0	Promoter
Average											65,6					

In this sense, according to the NPS rating given by the respondents, it was identified the same percentage of Promoters and Detractors, both with 44%. And 11% was identified as Passives. To calculate the final NPS score it should subtract the percentage of Promoters from the percentage of Detractors (illustrated in Figure 54) (F. F. Reichheld, 2003). Regarding the same percentage of Promoters and Detractors, the final result lead to 0.

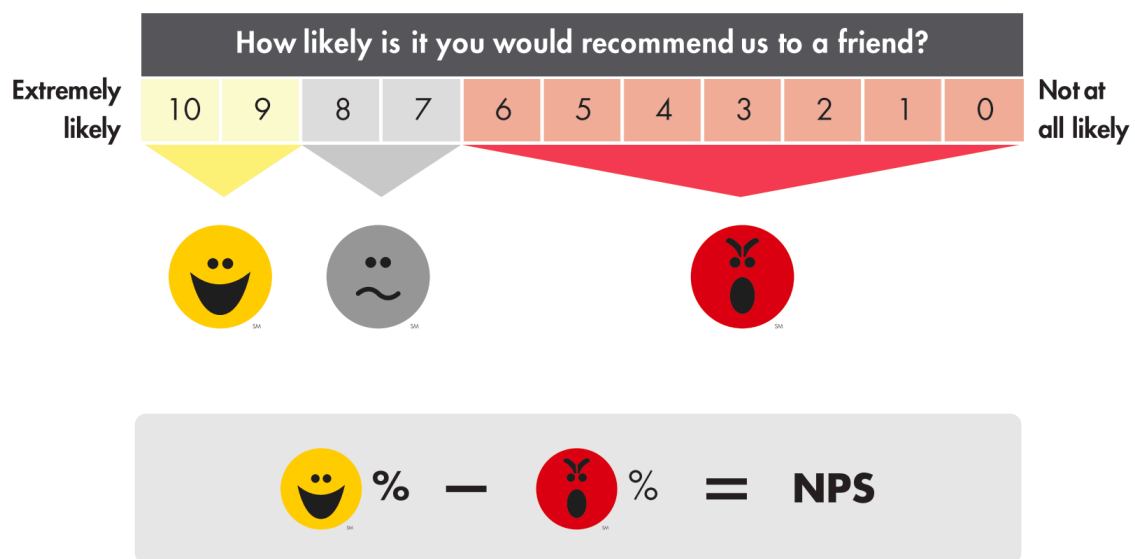


Figure 54 - How to accurate the NPS according to F. Reichheld & Markey, 2011

On the open-ended follow-up optional question, 3 participants gave their feedback about their rating:

P1: *“A praticidade de administrar a casa, o meu dia a dia, minhas obrigações e compromissos. Me agrada a possibilidade de estar em contato com outras pessoas que num clique possam me ajudar numa emergência.”*

P3: *“Uma casa ‘hitech’. Ainda é muito cara.”*

P6: *“Interatividade, facilidade, utilidade.”*

According to users’ feedback, the system was identified as an interactive, useful and practical tool to manage daily activities at home. Also, one of them gave a positive feedback about the emergency support feature. This feature was not mentioned on the list of tasks, however, as it was given the link of the high-fidelity prototype the participants explored other active features. It might show some curiosity and interest about the related feature. Another participant mentioned that smart home is still perceived as an expensive system.

Through the usability testing with the SUS, it was identified that the system’s usability was considered acceptable on the score range. On the other hand, the NPS results shows that it might not be the appropriate metric to measure user satisfaction with the same small sample of users as SUS technique. Hence that, this study showed that non-moderated remote tests with older adults can be a complex method to apply. Based on the fact that the SUS questionnaire could lead to mistakes and misinterpretation, some contradictory results could be related to this complexity among older adults with no preview experience in usability studies (Sauro & Lewis, 2011). Also, Sauro & Lewis highlights the disadvantages when applying negative and positive items in usability questionnaires, such as SUS, using non-moderated remote tests because it is more difficult to correct possible mistakes participants make, and this could lead to a major impact on overall SUS scores.

d) Conclusions

From the user’s perspective evaluation, nine participants between 55 and 69 years of age participated voluntarily on the user testing study. According to the System Usability Scale (SUS) and Net Promoter Score (NPS) techniques it could be able to quantify the users experience and measure the level of satisfaction related to the smart home and health monitoring system. The

SUS results identified that the system's usability was considered acceptable with a final score of 65,6. However, it was concluded that the unmoderated test with a SUS post-questionnaire can be a complex method to apply with older adults. The SUS questionnaire could lead to mistakes and misinterpretation, some contradictory results could be related to this complexity among older adults, and this could lead to a major impact on overall SUS scores (Sauro & Lewis, 2011). In addition, the NPS metric was identified as not the appropriate to measure user satisfaction with a small sample of users as SUS technique. In this small sample on nine participants the NPS scored zero points, as it was identified the same percentage of Detractors and Promoters ($d\%-p\%=NPS$) (F. F. Reichheld, 2003). On the open-end questions, participants mentioned ease of use, usefulness and practical usage of a system that could help on daily routine activities. On the other hand, it was also perceived as an expensive system.

On the overall, it is concluded that unmoderated remote user testing might be too complex to apply with older adults' users. Considering the SUS technique, on moderated sessions it could be possible to support the participants in any difficulties and doubts to answer the questionnaire. It is concluded that the NPS technique might not provide relevant information with the same small sample as considered on the user testing. It could be applied other technique to measure the level of users' satisfaction within the related prototype.

5. Conclusions and Future Work

As world life expectancy increases, innovative solutions (i.e., smart home systems and assistive technologies) can have significant potential to empower older adults to remain independent, safe and comfortable while ageing at home (Marikyan et al., 2019). It was identified that smart and assistive technologies can provide older adults self-care, new opportunities of caregivers support, and personalized healthcare monitoring (*World report on Ageing And Health Summary*, 2015). Therefore, these innovative technologies can have a great impact to improve older adults quality of life and encourage independent living at home for a long and healthy life (Alaa et al., 2017). It was identified that smart home technologies have been highly increased to facilitate the assisted living and health monitoring for older adults to stay independently at home, and also to improve the proximity with their family and caregivers (Alsinglawi et al., 2017). Currently, a large number of smart devices, smartphones and mobile applications exists to attend older adults

needs; however, they still face considerable challenges among User Interfaces regarding small fonts, low color contrasts, complex interactions and so on (Kalimullah & Sushmitha, 2017). In addition, it was identified a sort of gap on recent research on usability heuristics for UIs to address older adults needs, abilities and limitations, that could support the development of age-friendly products and services (Salman et al., 2018). For that reason, it is necessary to first take older adults abilities and requirements into consideration to provide them accessible age-friendly products and services (Kalimullah & Sushmitha, 2017).

In this sense, the main objective of the thesis is to design and evaluate age-friendly user interface design for smart home and health monitoring system that increases independence of older adults by enabling them to age in their own homes. In addition, the thesis takes part of an ongoing project that aims to design and develop a smart home and health monitoring system for older adults. The intention is to provide insights for designers and developers to create design guidelines for more usable interfaces to address the needs and abilities of the fast-growing older adult's population. However, the thesis is a step to achieve the design guidelines. To reach the main goal of the thesis, the following secondary objectives were established:

- To investigate the literature review on current smart home and health monitoring technologies, and user interface design guidelines suitable for older adults.
- To conduct experts' evaluation through heuristics evaluation to identify and map usability problems that occur in the smart home and health monitoring prototype.
- To conduct user testing with target users to identify potential usability problems, difficulties and acceptance of the smart home and health monitoring prototype.

Regarding the iterative UCD process, with the intention to focus on the human experience, interactions, and user needs, the heuristics evaluation and user testing methods were applied. These methods were suitable for the project to take into consideration the experts in user experience and the end users' perspectives to inspect usability problems and provide findings to further improvements. To apply the first evaluation phase, a low-fidelity prototype was developed, considering the literature of common features existing on smart home and health monitoring systems and the age-friendly guidelines.

Through the expert-based evaluation method, three experts with high expertise in user experience were selected to participate on the heuristic evaluation by Nielsen's guidelines. The experts identified potential usability problems that would probably impact older adults'

experience. Despite the broadly usability rules proposed by Nielsen's heuristics, this study showed that applying this method with evaluators with high expertise in user experience is still relevant to provide substantial and important findings in the evaluation process for age-friendly guidelines. Therefore, it is important to say that this methodology doesn't overpass the importance of user testing studies with the real end users of the product. On this evaluation, it was concluded that findings should be supported with more expert's evaluation and target user testing to provide insights for designers and developers to create design guidelines for more usable interfaces, to address the needs and abilities of the fast-growing population of older adults.

As a future work, besides more expert's evaluation, the design review of the interactive prototype would be applied to individual usability tests to assess its usability and to obtain more detailed users' feedback. The same tasks in Heuristics would be applied to the target users to evaluate the relevance and acceptance of the smart home mobile application. Furthermore, the rest of the smart home system (i.e., Smart TV app and home hub tablet) besides smart phone application would be designed which will follow the same guidelines for an age-friendly system design.

On the design review it was possible to modify important components identified as catastrophic problems on the heuristic evaluation. The health monitoring section was updated as homepage by default, instead of smart home section, as it was considered more relevant for the users. The tab navigation bar was modified, including labeled icons and highlighting them when it is selected. The feedback messages were reviewed to apply plain language, clear and contextualized messages. And the inconsistent components and controllers were updated, such as the windows control. In addition, a new color palette was defined to provide more appealing look and feel. Also, the tablet home hub and the TV interfaces were designed, considering the guidelines established on the design review. Regarding the findings on the heuristic evaluation, with the applied design review it evolved into a more consistent prototype to be evaluated on the second phase on user testing.

As part of the UCD methodology, in user testing was applied the SUS and NPS techniques to quantify the users experience on product satisfaction and to measure user's level of satisfaction. Nine participants between 55 and 69 years of age participated voluntarily on the user testing study. The initial intention on user testing was to conduct individual moderated sessions, to

measure tasks performing and allow detailed analyses of users' difficulties and feedback. However, due to COVID-19 pandemic, the individual moderated sessions could not be applied. In order to perform the usability tests, the procedure had to be modified to remote and unmoderated tests to attend the social isolation protocol due to COVID-19. On the SUS results the system usability was identified as acceptable on acceptability ranges. However, it was concluded that the unmoderated test with a SUS post-questionnaire can be a complex method to apply with older adults. The SUS questionnaire could lead to mistakes and misinterpretation, some contradictory results could be related to this complexity among older adults, and this could lead to a major impact on overall SUS scores (Sauro & Lewis, 2011). In addition, the user testing could be supported with more users to obtain more sustainable feedback. On the NPS results, due to the small sample of participants, it did not provide relevant information for this thesis. Considering the open-ended questions, users considered the system practical, easy to use and useful to support daily activities. Also demonstrated interest on the emergency support feature, considered important to be easily in touch with relatives when needed. However, it is still perceived as an expensive system.

As future work, moderated usability tests should be applied with target users. The same high-level prototype should be used to assess its usability and acceptance to compare with the current SUS score result. The moderated individual tests could provide more detailed feedback of the main difficulties of older adults when interacting with the user interfaces. And also, individual and moderated sessions could minimize misunderstandings and misinterpretations of the SUS questionnaire.

According to this iterative design process, this study contributes with a conceptual idea of an integrated system, applying age-friendly design guidelines on smartphone, tablet and TV user interfaces for a smart home and health monitoring system. The intention is to provide insights for designers and developers to create design guidelines for more usable interfaces to address the needs and abilities of the fast-growing older adult's population.

6. References

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Appendix A – Heuristic Evaluation Guide

Heuristic Evaluation

Project Title:

Evaluate an age-friendly interface design in smart home environments for older adults ageing in place

Project

The main goal of this research project is to design and evaluate age-friendly user interfaces for smart home systems environments for older adults. The system will explore daily activities by monitoring, predicting and reminding functionalities, aiming comfort and independent living for older adults living alone. This project takes into consideration an age-friendly design guidelines and elements (text, size, font, color) of a mobile application that address the user experience of the older adults' population.

The aim of developing an age friendly User Interface design, to a complex smart home and health monitoring system is to enable the opportunity to increase the acceptance of smartphones and assistive technologies by older adults. The results of this project can also provide insights for designers and developers to understand the needs and requirements of older adults, as well the usability and the level of satisfaction while interacting with Information Communication Technologies.

Test goals

Evaluate the user interface usability characteristic according to the principles and guidelines presented by Nielsen, 1994.

Procedure

Evaluate the user interface according to the list of 10 heuristics described on this document. The detailed report form should concern the list of violated heuristics, where each row contains the task number, the heuristic violated,

severity rating criteria and suggested improvements, if it is convenient. It is possible that a single usability problem can be a violation of multiple heuristics.

Evaluators

Each evaluator will receive the heuristic evaluation sheet with the assignment list of tasks. A link for the interactive prototype will be available to complete the tasks.

Scenarios and tasks to be done

1. **Task 1:** check if you are taking your “Aspirina” correctly, that you should take 3 times a day.
2. **Task 2:** add “Dipirona” to your medicine reminder list. You should take 2 pills per day, starting at 10 a.m for one week.
3. **Task 3:** check if you are missing any health check up available.
4. **Task 4:** You forgot the living room lights on, but you are in your bedroom, reading a book. Turn off the lights in the living room.
5. **Task 5:** You are feeling cold in your bedroom and you want to increase the temperature to 25°C.
6. **Task 6:** It’s raining a lot these days and you want to check if you might have any humidity problem at home. Check the humidity of the house.
7. **Task 7:** It’s a rainy day and you are arriving at the supermarket. Check if you left your windows open.
8. **Task 8:** A cake is baking in the oven while you watch TV in the living room. You might open the kitchen window to release the heat. Check if the kitchen window is open.
9. **Task 9:** You are not at home, but you might have left your TV on. Check if the TV in the living room is on.

Measurement criteria

Severity ratings: You can rate each violated heuristic with the severity criteria, from 0 (not a usability problem) to 4 (usability catastrophe problem). You should also report the problem found and might suggest any improvements.

0 = I don't agree that this is a usability problem at all

1 = Cosmetic problem only: need not be fixed unless extra time is available on project

2 = Minor usability problem: fixing this should be given low priority

3 = Major usability problem: important to fix, so should be given high priority

4 = Usability catastrophe: imperative to fix this before product can be released

Usability Heuristics

- I. **Consistency and standards:** Consistent design, standards and conventions in digital products.
 - a. Sequences of navigation.
 - b. Color (categorization status).
 - c. Visual consistency.
 - d. Font size and readability.
 - e. Terminology and language.
 - f. Standards.
- II. **Visibility of the system:** appropriate and clear feedback when the user interacts with the system.
 - a. Appropriate and clear feedback and display information.
 - b. Current status of the system.
 - c. Current location of the user.

III. **Match between the system and the real world:** the image of the system match with the user model. The icons represent the real-world objects and actions.

- a. User model matches system image.
- b. Actions provided by the system should match actions performed by users.
- c. Objects on the system should match objects of the task.

IV. **User control and freedom.**

- a. Support undo and redo actions.

V. **Error prevention.**

- a. avoid user mistakes.

VI. **Recognition rather than recall:** making objects, options, and actions visible.

- a. Recognition vs. recall (menu and commands).
- c. Perceptual procedures.
- d. Hierarchical structure.
- e. Default values.
- f. Concrete examples (DD/MM/YY, e.g., 10/20/99).
- g. Generic rules and actions.

VII. **Flexibility and efficiency to use.**

- a. Enable shortcuts for experienced users

VIII. **Aesthetic and minimalist design.**

- a. Simple and efficiency.

IX. **Help users recognize, diagnose, and recover from errors.**

X. **Help and documentation**

Heuristic Evaluation Sheet

- a. Evaluator name:
- b. Short Bio:
- c. Date: __/__/____
- d. Device:
- e. Access to clickable prototype: [Link to prototype](https://xd.adobe.com/view/7436b63d-e39f-45a8-71b9-09ef74a0d2f1-0207/)

<https://xd.adobe.com/view/7436b63d-e39f-45a8-71b9-09ef74a0d2f1-0207/>

Task	Violated Heuristic	Severity criteria	Problem found	Suggested Improvements
Task 1: check if you are taking your "Aspirina" correctly, that you should take 3 times a day.				
Task 2: add "Dipirona" to your medicine reminder list. You should take 2 pills per day, starting at 10 a.m for one week.				
Task 3: check if you are missing any health checkup available.				

Task 4: You forgot the living room lights on, but you are in your bedroom, reading a book. Turn off the lights in the living room.				
Task 5: You are feeling cold in your bedroom and you want to increase the temperature to 25°C.				
Task 6: It's raining a lot these days and you want to check if you might have any humidity problem at home. Check the humidity of the house.				
Task 7: It's a rainy day and you are arriving at the supermarket.				

Check if you left your windows open.				
Task 8: A cake is baking in the oven while you watch TV in the living room. You might open the kitchen window to release the heat. Check if the kitchen window is open.				
Task 9: You are not at home, but you might have left your TV on. Check if the TV in the living room is on.				

Help and Support

If you need any help, please contact me.

Student: Adriana Marques da Silva

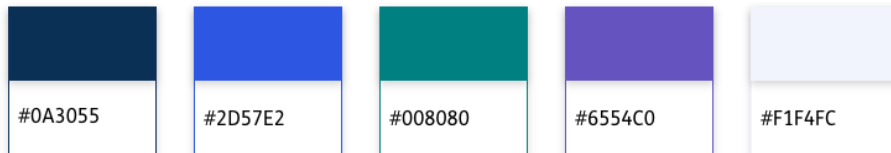
Email: adrianampms@gmail.com

Phone number: 913 140 076

Appendix B – Style Guide

Colors

Primary colors



Secondary colors

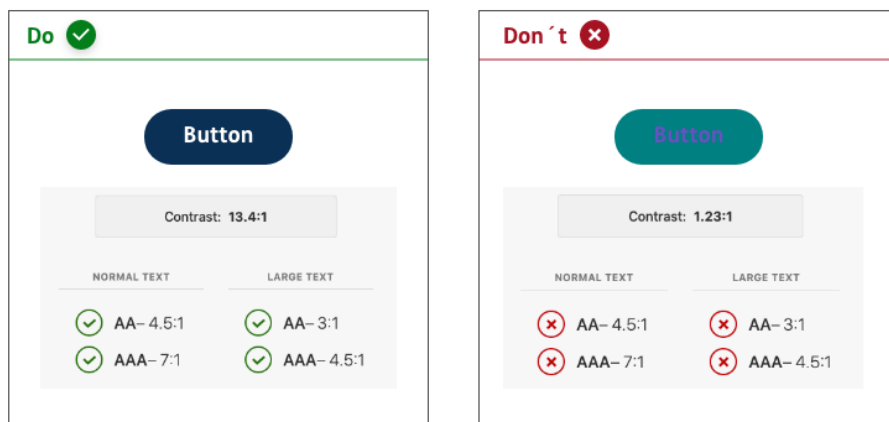


Success

Warning

Error

Color contrast



Typography - FS Me Trial

Title 1 / Bold 25px

Heading 1 / Regular 20px

Heading 1 / Bold 20px

Body Large / Regular 18px

Body Large / Bold 18px

Body Medium / Regular 16px

Body Medium / Bold 16px

Body Small / Regular 14px

Body Small / Bold 14px

Styles

Page Title - Title 1 / Regular 25px - #000000

Lorem ipsum dolor sit amet, consetetur sadipscing elitr

Heading - Heading 1 / Bold 20px - #000000

Lorem ipsum dolor sit amet

Primary Text - Body Large / Regular 18px - #000000

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy

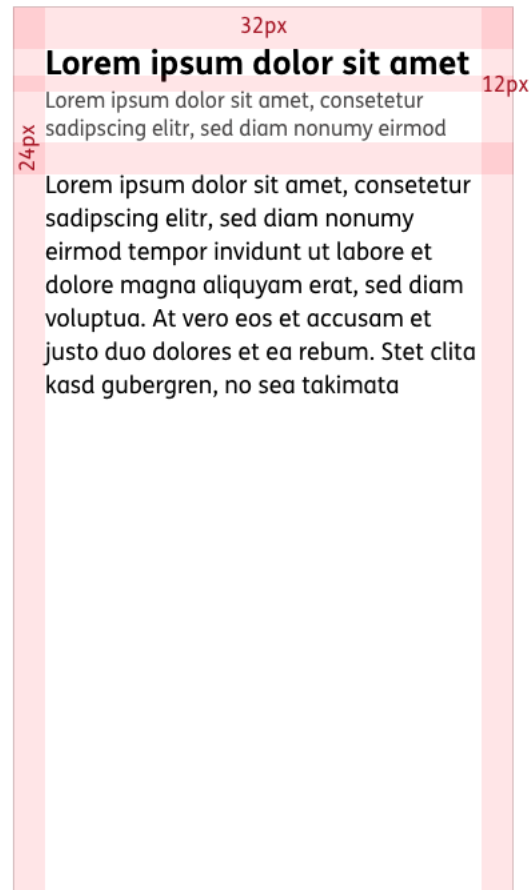
Secondary Text - Body Medium / Regular 16px - #707070

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero

Small Text no action required - Body Small / Regular 14px - #707070

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo

Margins



Primary buttons

Default state



Disable state



Secondary buttons

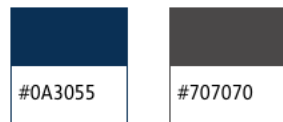
Standard state



Standard state

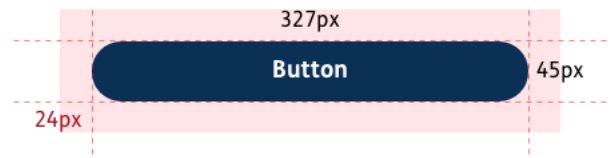


Colors



Margins

Default state



Size

Examples

Large (Default)
327x45

Button

Medium
170x45

Button

Small
120x45

Button

Special buttons

Quick buttons

Examples

Large
60x60



Medium
44x44



Link buttons

Examples

Standard
Font size 16px; Bold

Partilhar 

Icons

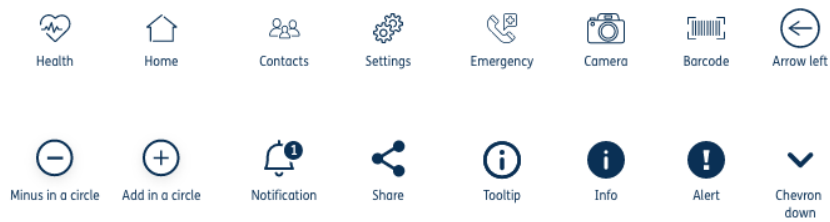
Health Icons



Smart Home Icons



System Icons



Size and margins

Large

48px



48px

Medium

30px



30px

Small

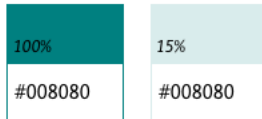
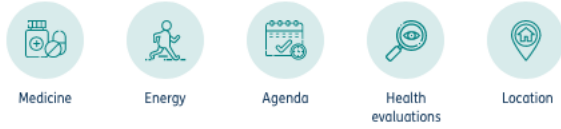
24px



24px

Icon colors

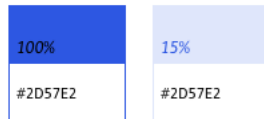
Health Icons



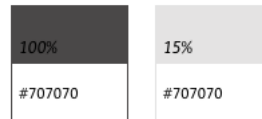
Smart Home Icons



System Status - ON



System Status - OFF



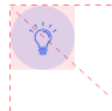
Touch targets

All touch targets for interactive icons should be 48px or larger.

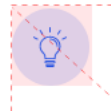
48px



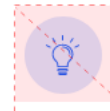
24px



48px



60px

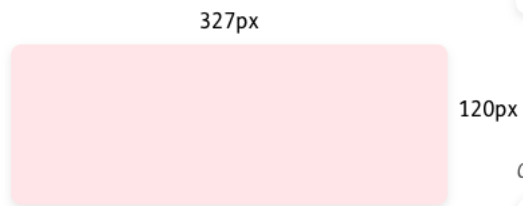
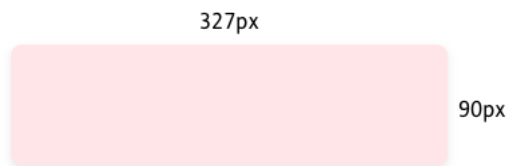
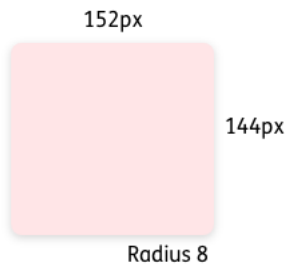


72px

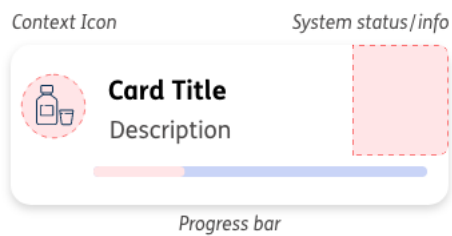
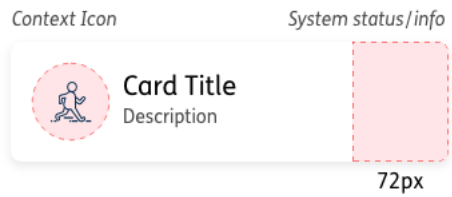
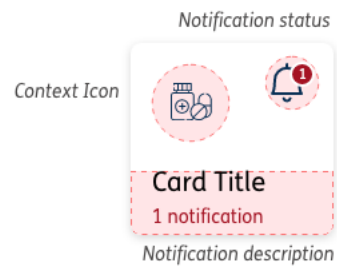
Cards

This component is used to show content and actions on a single topic. Cards can have have flexible layout within a minimum height size of 45px.

Mobile Types



Examples



Size

Minimum
327x45

Examples



Text fields and forms

As mobile screens are small, the text fields will show the label as a placeholder and once the user taps on it that label reduces in size so that input data occupies the main weight. So the users don't get lost on what information to fill.

The diagram illustrates three states of a text field on a mobile screen:

- Placeholder State:** A text field with the label "Label" inside it.
- Active State:** A text field with the label "Label" moved to the top left corner. The input area contains "User input text|". A curved arrow points from the placeholder state to this active state.
- Input text:** A label for the active state.
- Helper text:** A label for the active state.
- Error State:** A text field with the label "Label" moved to the top left corner. The input area contains "User input text|". A red border and a red exclamation mark icon indicate an error. Below the field, the text "Error text. Correct input suggestion." is displayed.

Expand and colapse

Label

▼

Label

▼

Option 1

Option 2

Option 3

Option selected

Label

▼

Option 1

Option 2

Option 3

Size

Examples

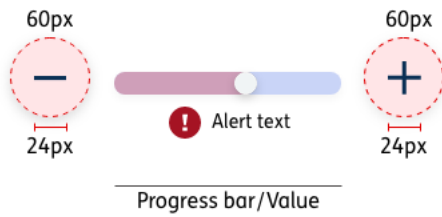
Minimum
200x55

Max
327x55

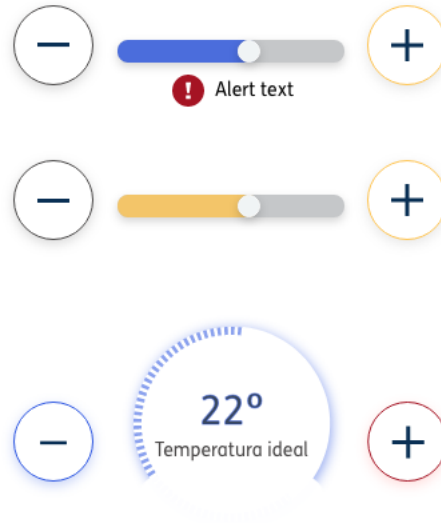
Controllers

Controllers with icon buttons to increase or decrease a value and with enclosed text fields allows the user to input exact values.

Mobile Types



Examples



Size

Minimum
36x36

Examples



Switch buttons

Switch controls can adjust the state of a single setting on or off.

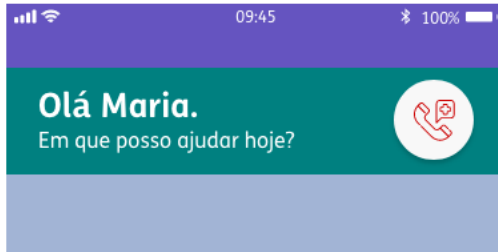


Headers

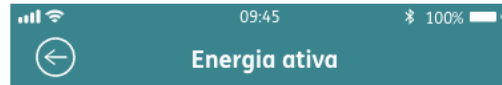
Headers are important components to provide users the current location on the app and also to provide undo, back navigation options and shortcuts to the homepage.

Homepage Headers

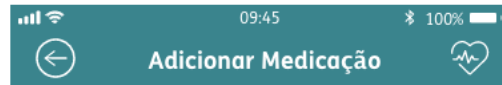
Health Monitoring Header



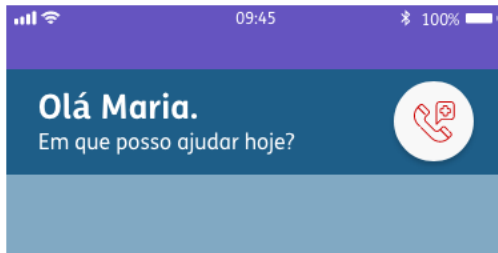
Health Monitoring Header Back



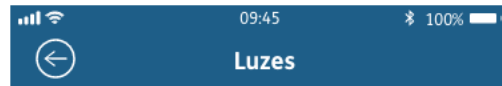
Health Monitoring Header Home



House Monitoring Header



House Monitoring Header Back

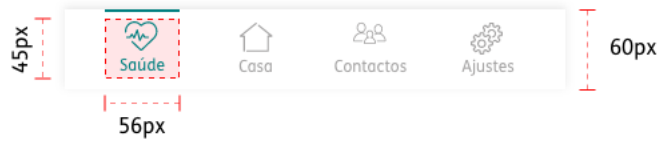


House Monitoring Header Home



Bottom navigation bar

Bottom navigation bar is used to display the most important features in the app. Is an ergonomic and easy way to reach on mobile devices. The icons on the navigation bar should be consistent with the displayed features, with short text labels and should use a highlight color to emphasis the active destination.



1. First active feature



2. Second active feature



3. Third active feature



4. Fourth active feature





Teste de Usabilidade

Mestrado Design de Interação

IADE - Creative University

Introdução ao teste

Você foi convidado a participar de um teste de usabilidade que irá complementar um estudo de mestrado. Este teste é para que você possa fazer o papel de um avaliador de uma aplicação que controla uma casa inteligente. O objetivo é executar um conjunto de tarefas que serão apresentadas, apenas para verificar o quão fácil ou difícil é utilizar esta aplicação, portanto, **não existem respostas certas ou erradas.**

A sua contribuição é essencial para este projeto e, assim, podemos buscar novas soluções para melhorar a qualidade de vida das pessoas em casa, de maneira mais simples e fácil. Este teste é anônimo e é composto por 8 tarefas simples. Todas as tarefas acompanham um link que poderão te guiar para executá-las. Ao fim das tarefas, você deverá responder um questionário final.

O teste será dividido em três etapas:

1. Compreender o cenário.
2. Executar as tarefas na aplicação.
3. Responder o questionário de avaliação.

Lembrando que este teste é um protótipo, portanto, nem todas as ações estarão a funcionar.

Vamos começar?

Cenário

Imagina que a sua casa estivesse equipada de forma inteligente, para interagir automaticamente consigo e facilitar as suas atividades do dia a dia. Que fosse possível, desde acender e apagar luzes automaticamente, para evitar aquela curta caminhada no escuro até a casa de banho à noite, como não ter que ir até outro cômodo da casa apenas porque esqueceu uma luz acesa. Imagina poder ter a casa sua quentinha no inverno e fresca no verão. E ainda acompanhar a sua saúde, suas atividades físicas diárias e até mesmo lhe lembrar de tomar uma medição na hora correta.

Diante deste cenário, você deverá executar as tarefas a seguir.

Lembre-se: **não existem repostas certas ou erradas, isso é apenas a sua avaliação.**

Tarefas

Atenção: ao clicar nos links das tarefas abaixo, poderá aparecer esta mensagem:

Aviso de redirecionamento

A página anterior está a enviá-lo para
<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/?fullscreen&hints=off>.

Clique no link “xd.adobe” para continuar

Se não pretender visitar esta página, pode [regressar à página anterior](#).

1. Consultar medicação

Imagine que você quer consultar as suas medicações e verificar se estão em dia.

Executar Tarefa 1

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/?fullscreen&hints=off>

2. Adicionar medicação

Você vai começar um novo tratamento com Dipirona 500g e quer adicionar à sua lista para não esquecer de tomar a medicação, com início às 10h00, de 8 em 8 horas.

Executar Tarefa 2

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/0d245f85-894f-431e-ac60-39d11cb99e2d/1-Home-Saude-1?fullscreen&hints=off>

3. Consultar atividades físicas

Você quer saber como anda a sua rotina de exercícios físicos diários. Identifique o período do dia que mais se exercitou hoje.

Executar Tarefa 3

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/0d245f85-894f-431e-ac60-39d11cb99e2d/1-Home-Saude-1?fullscreen&hints=off>

4. Consultar avaliações de saúde

Consulte se todas as suas avaliações de saúde estão em dia. E deixe suas avaliações atualizadas.

Executar Tarefa 4

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/0d245f85-894f-431e-ac60-39d11cb99e2d/1-Home-Saude-1?fullscreen&hints=off>

5. Ajustar luzes

Agora, imagine que você está sentado(a) na sala da sua casa e quer deixar as luzes mais confortáveis para assistir à um filme ou à TV.

Executar Tarefa 5

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/3227d95c-8c74-4667-9a43-69a1e90913ef/1-Home-Saude-2?fullscreen&hints=off>

6. Controlar janelas

Ainda na sala, como está um dia frio lá fora, você quer fechar as janelas da sala sem precisar se levantar e ir até lá.

Executar Tarefa 6

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/3227d95c-8c74-4667-9a43-69a1e90913ef/1-Home-Saude-2?fullscreen&hints=off>

7. Controlar temperatura

Ainda com um dia frio, você então quer ajustar a temperatura da sua casa toda para 25° graus, para ficar mais quentinha.

Executar Tarefa 7

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/e23fa207-3893-4acb-80ee-969722d3497f/2-Home-Casa-2?fullscreen&hints=off>

8. Controlar TV

E agora, para assistir o seu filme, você quer ajustar o canal da sua TV para a RTP.

Executar Tarefa 8

<https://xd.adobe.com/view/601d320b-37ce-4c97-4d77-0c7b252e7176-162c/screen/f0776e8f-7067-4ce8-9fc7-a2c0587dad24/2-Home-Casa-3/?fullscreen&hints=off>

Tarefas concluídas!

Questionário final

Para concluir o teste, por favor, responda o questionário final.

Responder questionário

https://uemportugal.eu.qualtrics.com/jfe/form/SV_8hNe0Fm9NSyEinH

Muito obrigada pelo seu tempo.

A sua contribuição é muito importante.

Appendix D – User testing Post Questionnaire



Default Question Block

Em uma escala de **1** a **5**, em que **1** discorda totalmente e **5** concorda totalmente, responda as seguintes questões sobre a aplicação que acabou de avaliar.

Eu acho que gostaria de usar esse sistema com frequência.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu acho o sistema muito complexo.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo

- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu achei o sistema fácil de usar.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu acho que precisaria de ajuda de uma pessoa com conhecimentos técnicos para usar o sistema.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu acho que as várias funções do sistema estão muito bem integradas.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo

- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu acho que o sistema apresenta muita inconsistência.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu imagino que as pessoas aprenderão como usar esse sistema rapidamente.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu achei o sistema confuso de usar.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente

☐ 5. Concordo totalmente

Eu me senti confiante ao usar o sistema.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Eu precisei aprender várias coisas novas antes de conseguir usar o sistema.

- ☐ 1. Discordo totalmente
- ☐ 2. Discordo parcialmente
- ☐ 3. Não concordo, nem discordo
- ☐ 4. Concordo parcialmente
- ☐ 5. Concordo totalmente

Qual a sua idade?

- ☐ 55 a 59
- ☐ 60 a 64
- ☐ 65 a 69
- ☐ 70 a 75
- ☐ 76 +

Quantas pessoas habitam a sua residência?

- ☐ Vivo sozinho(a)
- ☐ Duas
- ☐ Três
- ☐ Quatro ou mais

Em uma escala de **0** a **10**, sendo **0** nem um pouco provável e **10** extremamente provável, qual a probabilidade de você recomendar este produto a um amigo ou familiar?

- ☐ 0 Nem um pouco provável.
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Extremamente provável

Em poucas palavras, descreva o que motivou sua nota sobre a
indicação. (*Opcional*)

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