# Design Science and Augmented Reality in Healthcare

(Wearable Technology)

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**Dissertation submitted to obtain a master's degree in Industrial and Product Design**

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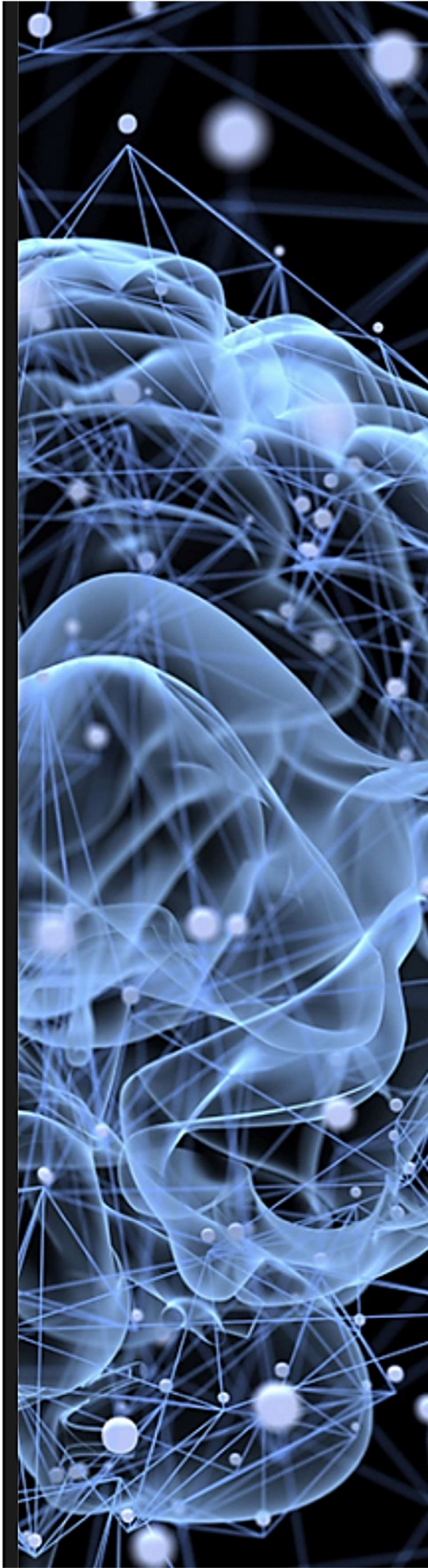


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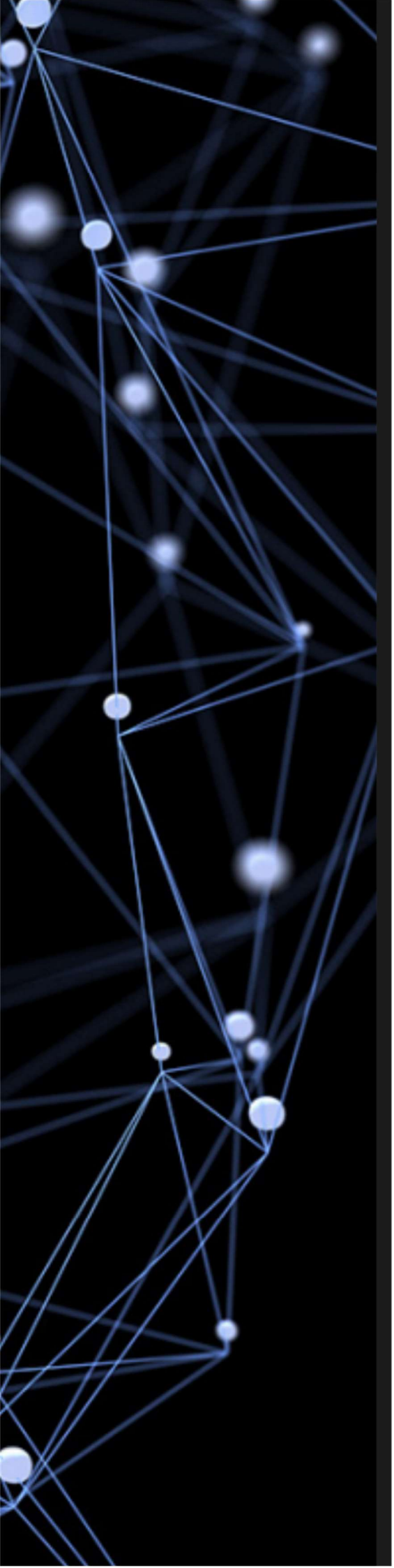

What we call results
are beginnings.
**Ralph waldo emerson**

**ABSTRACT**

Throughout this dissertation, based on the need for research in the biomechanics laboratory of the Institute of Science and Innovation in Mechanical and Industrial Engineering (INEGI), an attempt was made to develop a re-design of an easily wearable and suitable augmented reality headset, as well as their implementation in the context of the healthcare regarding the rehabilitation of patients with alzheimer's disease through the potential of design. Augmented reality is a promising tool for many situations in which rehabilitation is necessary, AR can have a significant impact on those in need of cognitive assistance.

In addition to offering a new point of view through design for augmented reality in the healthcare context since most situations are developed by professionals in the fields of engineering, science of technology and biomedical.

With the results and all the characteristics of the product and material developed, a design solution evaluation model was elaborated, which proved to be viable for production by the biomechanics laboratory of the Institute of Science and Innovation in Mechanical and Industrial Engineering.

It is concluded that it is possible, through an efficient design, to work on product attributes, improve performance processes, know the user experience, in addition to fostering innovation. Innovation must be the bloodstream of patient support products in the context of healthcare, seeking to improve their evolution and transform their aesthetic and comfort potential.

**Keywords:** Augmented Reality; Augmented Reality Headset; Industrial Design; Healthcare; Alzheimer's Rehabilitation

**RESUMO**

Ao longo desta dissertação, com base na necessidade de investigação no laboratório de biomecânica do Instituto de Ciência e Inovação em Engenharia Mecânica e Industrial (INEGI), procurou-se desenvolver um redesenho de um auricular de realidade aumentada de fácil utilização e adequado. bem como a sua implementação no contexto da saúde no que diz respeito à reabilitação de doentes com doença de alzheimer através das potencialidades do design. A realidade aumentada é uma ferramenta promissora para muitas situações em que a reabilitação é necessária, a RA pode ter um impacto significativo sobre quem necessita de assistência cognitiva.

Além de oferecer um novo olhar através do design para realidade aumentada no contexto da saúde, já que a maioria das situações são desenvolvidas por profissionais das áreas de engenharia, ciência da tecnologia e biomédica.

Com os resultados e todas as características do produto e material desenvolvidos, foi elaborado um modelo de avaliação de solução de projeto, que se mostrou viável para produção pelo laboratório de biomecânica do Instituto de Ciência e Inovação em Engenharia Mecânica e Industrial.

Conclui-se que é possível, por meio de um design eficiente, trabalhar os atributos do produto, melhorar os processos de desempenho, conhecer a experiência do usuário, além de fomentar a inovação. A inovação deve ser a corrente sanguínea dos produtos de apoio ao paciente no contexto da saúde, buscando melhorar sua evolução e transformar seu potencial estético e de conforto.

**Palavras-chave:** Realidade Aumentada; Óculos de Realidade Aumentada; Design Industrial; Cuidados de Saúde; Reabilitação de Alzheimer

**ACKNOWLEDGMENTS**

I totally dedicate all my efforts during the accomplishment of this master's degree to my parents Tania Regina Teixeira and Antônio Carlos Teixeira, responsible for all my emotional and financial support until now, without them all this trajectory would not be possible. This dissertation marks the conclusion of a great stage and God's plan for my personal and academic life.

This master's degree was literally a journey, which included a trajectory permeated by innumerable challenges, uncertainties, joys, overcoming and some obstacles along the way, but despite the solitary process that any researcher is destined to, it gathers contributions from several indispensable people to find the best course in every moment of the journey, therefore gratefull Samuel Ribeiro and Catarina Conde for being essential in completing this thesis, in this sense, trying not to forget anyone, I want to express my enormous thanks to everyone involved.

I thank my advisor, Professor Pedro Martins, for all the availability and patience shown throughout this process, always transmitting total confidence in my decisions. I also take the support of course coordinator Jorge Lino, who gave me the necessary support to complete this chapter of life during my period of academic mobility in Finland.

Walking this path was only possible with the support, energy and strength of several people, to whom I dedicate this life project especially.

Thus far the LORD has helped us.
**1 Samuel 7:12**

**ABBREVIATIONS**

AR - Augmented Reality

BLAD - Lisbon Battery for Assessment of Dementia

AD - Alzheimer's Disease

NR - Neuropsychological Rehabilitation

VR - Virtual Reality

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# CHAPTER 1
# INTRODUCTION

## 1. INTRODUCTION

Through the North Star Project that explores the limits of interactive design in Augmented Reality (AR), this thesis fits into the research and development strategy of a Product Design for a headset more adapted to the context of the health area about rehabilitation, study of form and materials in the context of health in the biomechanics laboratory of the Institute of Science and Innovation in Mechanical and Industrial Engineering.

During the development of this thesis I had the opportunity to carry out an academic mobility at the renowned Aalto University, in Finland, where I was able to develop a specific domain of different areas of knowledge, in addition to skills and theoretical context for this thesis that includes some data in the Finnish context that aggregates even more knowledge for this thesis, in addition to the ability to develop cultural intelligence and intercultural sensitivity deserves special mention.

Through this experience I was able to add knowledge with the Institute of Engineering, Management and Architecture in Health (HEMA Institute) which is a research group that focuses on the production and development of health services, from the Department of Industrial Engineering and Management of Aalto University School of Science[1].

Through the DiRVa Project that brings together a multidisciplinary research collaboration and in an international network, committed to building evidence of the value of digital health solutions: HEMA Institute of Aalto University (Engineering, Management and Architecture of Health) together with the most innovative developers in the field digital health solutions in Finland have developed a series of studies that will help us to develop this thesis in terms of contextualizing the theme[2].

This thesis is being developed in an alarming period of social, political and economic impact that the COVID-19 crisis has awakened globally. We are living days that present us with challenges of an unprecedented dimension in our recent history. This is a time when there are many questions and few answers and developing this thesis in this period was challenging, but it allowed for new learning and new adjustments.

This crisis will be another opportunity to demonstrate the importance, relevance, value and capacity as a professional acting and contributing to a new product perspective for a society and health sector more aligned with sustainable issues regarding the use of materials etc.

[1] Aalto University. Healthcare Engineering, Management and Architecture: HEMA Institute. Home page. Available at: <https://www.aalto.fi/en/department-of-industrial-engineering-and-management/healthcare-engineering-management-and>. Accessed on: Dec. 12th, 2020.

[2] Aalto University. DiRVa - Building evidence of the value of digital healthcare solutions. Available at: <https://www.aalto.fi/en/department-of-industrial-engineering-and-management/dirva-building-evidence-of-the-value-of-digital>. Accessed on: Dec. 12, 2020.

## 1.1 THEORICAL STATEMENT

According to the European report on Alzheimer's disease, societies need to prepare adequately for the growing number of people likely to develop dementia (ALZHEIMER EUROPE, 2013). Because of the social cost of dementia, as well as the growing number of people living with the disease, Alzheimer Europe has argued that political structures must change the way care, support and treatment for people with dementia and caregivers is carried out, from diagnosis to the end of life.

In 2017, Alzheimer Europe conducted a study in collaboration with Bangor University and five of its organizational members to better understand the experiences of informal caregivers regarding the diagnosis of dementia in five European countries: Czech Republic, Finland, Italy, the Netherlands and the United Kingdom (Scotland). They work to ensure that Alzheimer Europe's activities, projects and meetings properly reflect the priorities and views of people with dementia.

The most recent of these studies is six years old, Alzheimer Europe has recognized the importance of establishing more recent dementia prevalence estimates, using the most up-to-date academic literature on the topic, developing estimates for different age groups. In doing so, it has been found that there has been a reduction in the prevalence of dementia in the past ten years compared to 2008 estimates. This is probably the result of the effect of public health campaigns and measures, such as better control of cardiovascular factors (hypertension, cholesterol), alcohol reduction, smoking cessation and promotion of physical activity, which address risk factors related to dementia. However, age remains a significant risk factor for dementia, as can be seen in the age-specific table for prevalence rates of dementia in Europe. (ALZHEIMER EUROPE, 2013)

Neurodegenerative diseases are a group of relatively frequent and extremely disabling diseases. They affect individuals of any age group, although some of them (Alzheimer's, Parkinson's, etc.) tend to reach older individuals. With the trend of an aging population, they become a public health problem for the present and for future generations (KOIZUMI, 2007).

Alzheimer's disease (AD) is neurodegenerative characterized by a series of changes in the structure of the brain, lost connections, inflammation and eventual death of brain cells. Such changes lead to memory loss, changes in thinking and other brain functions (STORTI, 2016) that are usually diagnosed with aging, a natural process that occurs gradually causing a series of changes in the body, causing progressive losses in physiological reserves and predisposing the individual at a greater risk of developing multiple pathologies, which, in different areas, can alter their quality of life (KIM, 2015).

Currently, the alternatives of psychological treatments have advanced significantly, with the creation of several protocols exploring the virtual world, efficient in the treatment, including dementias, it is important to highlight the significant role of technologies in this context (DIAS-PEREZ E., FLÓREZ-LOZANO JA 2018).

In the health sector, as can be seen with the growing number of publications on AR for surgery, medicine and rehabilitation, which is the field for this thesis, there is a great demand for solutions capable of improving current clinical practice. According to findings in the literature, the rehabilitation process, regardless of the health area to which it refers, remains a challenge for professionals, patients and their families. To overcome the limitations of traditional interventions, AR technology has been increasingly applied to rehabilitation and begins to provide important tools (DORES, 2012).

Augmented Reality (AR) is a technology that allows a computerized virtual object (image) to be superimposed directly or indirectly in a real environment in real time (AZUMA, 1997; ZHOU, DUH, & BILLINGHURST, 2008).

It is a variant of Virtual Reality that also uses virtual objects, but which differs from this in that AR is a mixed reality that combines the real world with virtual objects, while VR completely immerses the user in a virtual environment created per computer. Thus, AR supplements reality instead of replacing it, bridging the real and virtual world in a perfect way (CHANG, G., MORREALE, P. & MEDICHERLA, 2010). From that, the quality of health care can be improved, and costs reduced with the help of digital solutions and a design that understands the specifics for which it is being produced and understanding that technology will revolutionize health care.

In healthcare, as well as the choices of materials that will be used in the equipment will impact not only the safety of patients that must be emphasized, but also the comfort, confidence and successful use of the equipment. An evaluation model for design solutions was developed in the project and patient safety is a key consideration in the model, considering ergonomic and usability factors. Patient safety means, among other things, eliminating or reducing errors, improving the human-machine interface, as well as cognitive functions related to the product's use behavior, shape study and extending the product's availability and ease of use among professional’s health care and involve patients in their own care.

## 1.2 THESIS SCOPE AND OBJECTIVES

This dissertation had as main objective to investigate the context of the health area for which the product will be used, as well as several design solutions to develop a redesign for the augmented reality device (headset) easily wearable and designed to be used in health, more specifically in the context of rehabilitation of patients with Alzheimer's.

One of the secondary objectives of this thesis is to offer a new point of view through the science of design for an AR in the context of health, since most of the resulting ones are being developed by professionals in the field of engineering and science of science, therefore a creative and dynamic look at the potentials of AR technologies combined with a design reduction in promoting the development of augmented reality is my academic proposal to enrich the visual sensation of using the product that will be

redesigned increasing the user's accessibility and allowing an intuitive and interaction with the product.

## 1.3 METHODOLOGY

The development of this dissertation was accompanied by many methodologies for a better structuring of the research and design process. “The design method for the designer is neither absolute nor definitive, it is something that can be modified if other objective values are found that improve the process. And this is linked to the creativity of the designer, who, when applying the method, can discover something to improve it.” (MUNARI, 2010, p.21 and 22).

The methodology used in this dissertation was structured to organize the actions that guide the creative and design process, helping to divide the process into stages and objectives. Thus, it was decided to follow the following sequence that helped to build the chapter structure:

- Contextualization, study and analysis of the chosen context and user.
- Improvement of mechanical man-machine interfaces.
- Prototype development and shape study.
- Re-Design / improvement of a new augmented reality headset.

To facilitate the investigation, the research was structured by themes.
The bibliographic collection was based on three areas of study: Augmented Reality, Alzheimer's Disease, Design, Ergonomics and Usability Processes, the latter related to product design.

## 1.4 THESIS STRUCTURE

The present dissertation is structured in five chapters.

The first chapter, Introduction, gathers the introductory information to the dissertation theme, objectives to achieve its development, methodologies adopted and the structure of the document.

In the second chapter, a study and analysis of the chosen context and user (patient) for which the product is being developed is carried out, with a review of the literature, which concerns the issues involving the projection of a design product in the context of health being explored knowledge for the projection of the headset under study in this dissertation. Some issues are also mentioned regarding the production of tangible results and the construction of theoretical knowledge, co-produced between the researcher and users, based on real problems.

References are made to the concepts of participatory design widely used in the context of service design and in health, especially when the behavior of a group is fundamental to achieve the expected results. Participatory design assumes that all people who affect or are affected by the investigated theme must be included in the research process, just as design can act to enhance this process.

The third chapter refers to the improvement of mechanical human-machine interfaces with an experimental plan, consisting of the development of material and manufacturing processes. A methodology is applied to assess the user's perception of the material and product developed from the impressions collected through research throughout this, obtaining a direction for the product. In this chapter we will address issues regarding the ergonomics and usability of the product to be developed.

The fourth presents the chapter of the proposed product. The concept, materials, components and manufacturing processes. Finally, an approximate analysis of production costs was made.

In the fifth chapter, the final purposes are made, as well as the tools of this dissertation and future perspectives. Finally, the bibliography and annexes will be exposed, referring to all the supporting documentation for this dissertation.

## 1.5 THESIS ORGANIZATION CHART

The structure of the thesis presented intends to demonstrate the importance of creating a technological product for the context of the health area, optimized and adapted to the elderly public, to provide them with the quality of life and well-being necessary in the life stage they are in, in addition to the rehabilitation of Alzheimer's disease.

For the development of the project, several methodologies and design aspects will be used to help in the redesign of the augmented reality headset. Thus, in a first phase, some research and information collection will be carried out, based on literary research and case studies, related to the theme, to acquire the knowledge for product development and creation. Subsequently, a design solution evaluation model will be used, which proved to be feasible in this context of the corana virus crisis that Portugal is experiencing at the time of preparing this thesis for the production, testing and validation of the designed product, through the prototype that will be carried out for final presentation. Below is an illustration of the thesis:

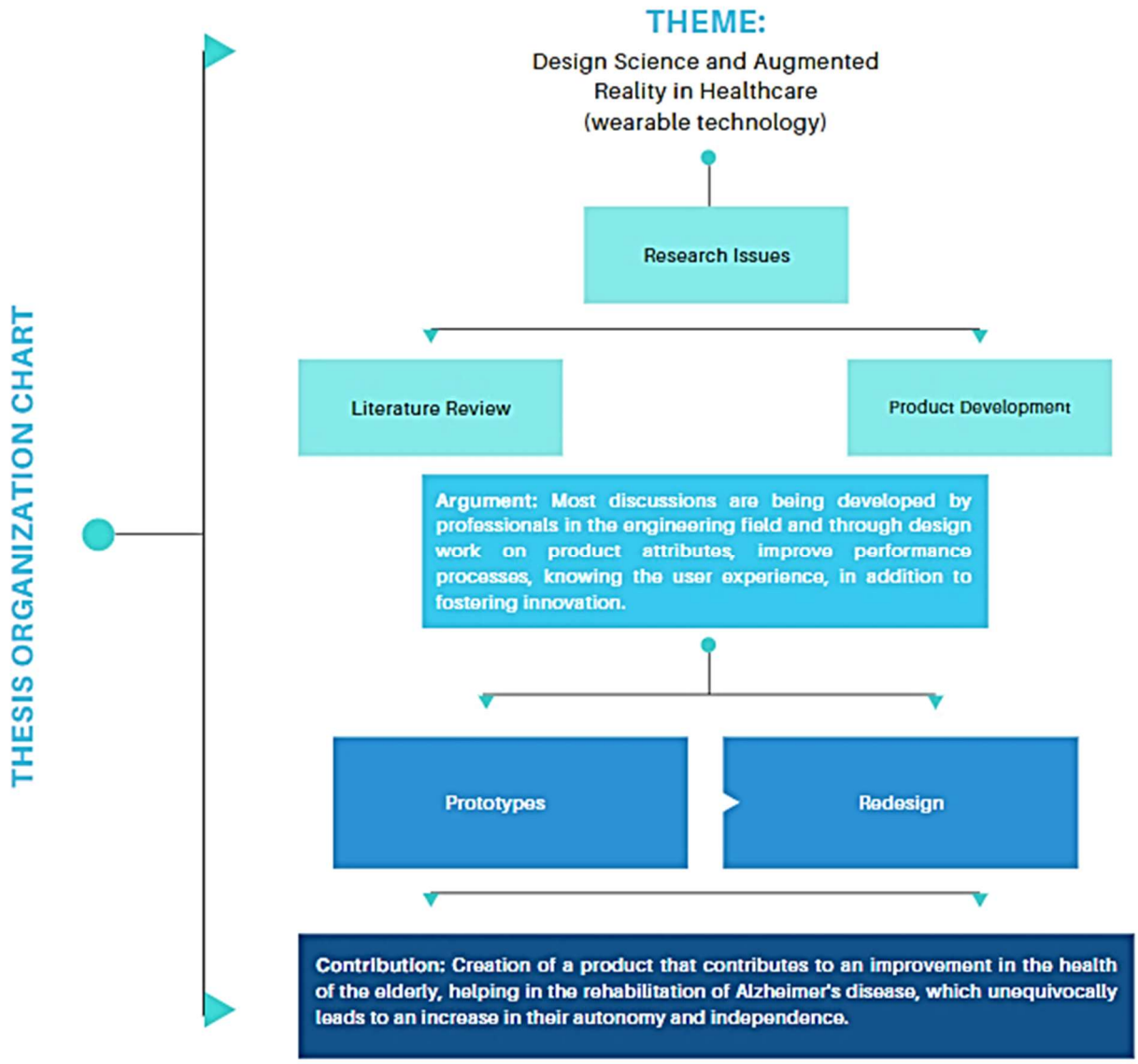
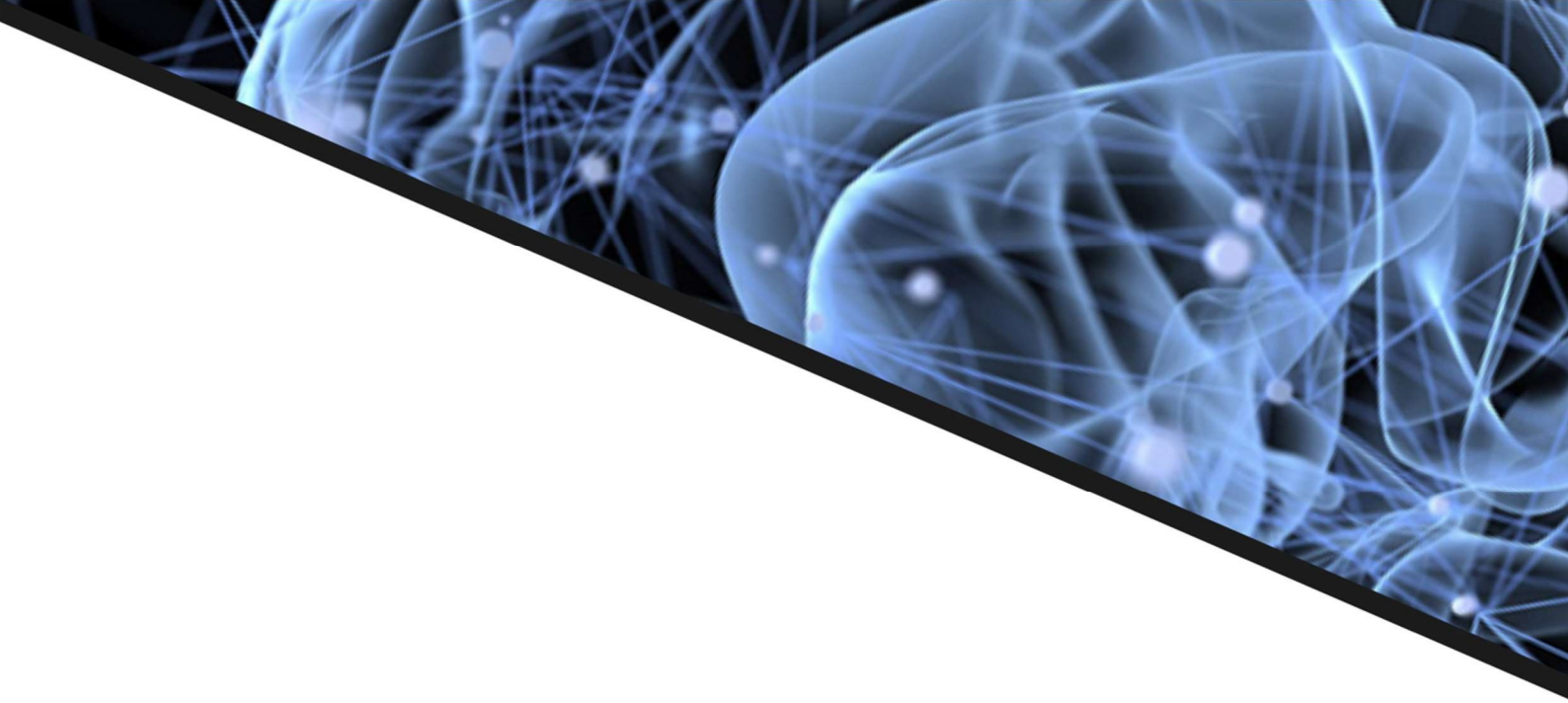



*Figure 1: Thesis Organization Chart*



# CHAPTER 2
# DESIGNING CARE

## 2. DESIGNING CARE

The evolution of the health sector has recently accelerated in terms of methodological and technological design, changing habits, structures and the way users and designers view medical products (CHAMBERLAIN, 2015). In 2017, Markets and Markets reported that the virtual reality (VR) healthcare market increased to $ 976 million, according to Grand View Research, the VR and AR industry will be $ 5.1 billion in 2025.

The digital age opens enormous opportunities to offer health services to patients and going beyond the functional aspect and according to a perspective in which patients are increasingly at the center of the project, Design must also face the sensitive and emotional aspect of the object with the objective of creating a therapeutic product / environment (ULRICH, 2004; DIJKSTRA, 2006). From these ideas for believing that the users' opinions matter, the project being valued as a process and interdisciplinarity brought other fields closer to the act of thinking about design in design.

The concept of health has evolved over time due to many sociocultural changes, such as the aging of the population, but also to alternatives to disease management. Nowadays, care is not only the absence of biological agents that cause diseases, but "it is the result of a harmonious functional physical and mental balance of an individual dynamically integrated into his natural and social environment" (SEPPILLI, 1966).

Therefore, design in the health context cannot be just the application of design methodologies in the project for the medical field, but it must be a multidisciplinary and synergistic process that brings together concepts from different areas of knowledge to guarantee the perfect, aesthetic operation and functional product.

“In recent years, there has been a growing interest in the potential of design and approaches to transform healthcare, where we can draw on a tradition of divergent thinking to address these fundamental but practical challenges for the health of our societies. These challenges are, by definition, "perverse problems", where there is no single true answer and where the strength of design lies in creativity responding to these complex interdependencies” (CHAMBERLAIN et al. 2015).

Thanks to some field-based research experiences involving design evidence, the User-Centered Design and Research through Design methodology shows how an emotional-sensory approach to the design of health products can improve user well-being in therapeutic terms. Through direct observation of users and their interaction with the product to be redesigned, ensuring a greater understanding of a design focused on health care.

But what is needed today when designing health products is an aesthetic that goes beyond the traditional aspect of static form in favor of a new language of form that incorporates the dynamics of behavior (ROSS and WENSVEEN, 2010).

User-centered design processes are obviously focused on user needs. Both analysis and criteria interpretation activities are carried out, where iterative tests and evaluations

are carried out (RITTER et al., 2014). The fundamental concept of this approach lies in the difference between the mental model of the designer and the user.

The user is invited to interact with the system to build and demonstrate a mental model from his previous experience, whereas this model can be completely different from that built by the designer. Through various methods that involve observation and testing, it is intended to bring the model from the designer closer to the user, so that in the model designed, interaction with the system occurs in an intuitive way. It is important to emphasize that in this tradition, design is thought for the user and, although this same user is at the center of the project, he still does not participate in decision making.

The user-centered design modality was used as a development and analysis platform to systematize and to some extent hegemonize technological appropriation, with this approach profile being highly valued in private sector projects, where the focus is more on the final product to be developed and in sales than in the generation of autonomy for the user. According to Foque, dealing with the design problem with a set of direct conditions and a focused design strategy, can be a way to clear the way for a better functional and pleasant final product (FOQUE et al 1995).

Thus, in recent years, Design for Healthcare has changed to an anthropocentric approach, where the exercise of an interdisciplinary experimentation that seeks to operate from the combination of several disciplines, concretely understands the needs of users and provides appropriate responses to their real needs.

Design is a tool of invention, which is why it has always differed from the natural sciences, where an object of study is defined, and its investigation occurs with the aim of discovery. In design, the object of study is not fixed, and research can follow exploratory paths. Such inaccuracy characterizes design as a discipline that is concerned with issues that admit alternative resolutions, and the essential nature of design requires that both the process and the results are open to debate and disagreement (BUCHANAN, 1995: 24, 25).

In addition to reflecting on design centered on the user experience, the involvement of people in the processes is also associated with goals of empowerment and emancipation, favoring self-reflection and stimulating hope and imagination for the future (SANGIORGI, 2011). These double dimensions of understanding and involving people in design for better service experiences is what qualifies the service design's human centering (MERONI and SANGIORGI, 2011).

There are many drivers of innovation and the challenges that the therapeutic product must face in terms of design (aging of the population, technologically advanced health care, intensive care and reduced financing costs). All of this requires strategies, new approaches to care delivery and a radical change in the way we design and use products.

It is important to note that design for health can commonly be used by an approach particularly focused on the aspect of functionality, to the detriment of other factors crucial for an effective interaction of the product with the user (patient). However, it is

known that the relations between user and product involve, simultaneously and synergistically, different ones defined by Overbeeke as an "interaction trinity": cognitive skills, perceptual-motor skills and emotional skills (OVERBEEKE, 2002). Especially the sensory and perceptual aspects, and how positive emotions, such as joy, contentment, love, interest, fun and pride, improve individual and collective functioning, psychological well-being and physical health (FREDRICKSON, 2003).

### 2.1 DESIGN NEUROCOGNITION

Design is one of the most profound acts of humans and is the way in which we intentionally change both the physical and virtual worlds around us. The cognitive neuroscience of designing is a nascent research area that uses EEG, fNIRS and fMRI techniques to study the brains of designers and connect their brain behaviors to their cognitive designing behaviors. We are looking at cognitive behavior that is uniquely indicated for designers and aim to determine whether there are correspondingly unique differences in brain behavior. Projects include investigating brain response differences between designer domains, expertise and gender; effect of design techniques and effects of neurocognitive feedback on ideation fluency.

The drop in the cost of non-invasive brain measurement has opened avenues of research into design neurocognition. In particular EEG and fNIRS, which collect temporal data, are both well suited for design neurocognition studies since design is a temporal activity. fMRI is less suited to study the temporal behavior of designing. It is well suited where high spatial resolution is required. (DESIGN SCIENCE JOURNAL, 2020)

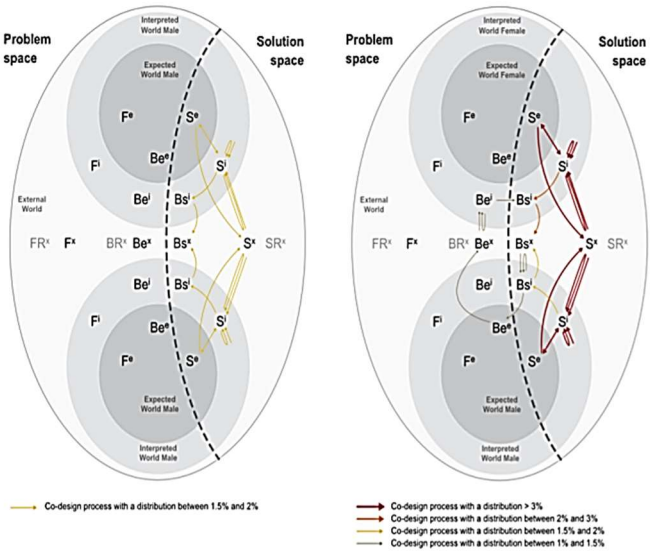



*Figure 1 - (a) Dominant sFBS co-design processes for homogeneous, all-male, teams; (b) dominant sFBS codesign processes for heterogeneous, mixed-gender, teams (Milovanovic & Gero, to appear).*

Significant effort within the design research community has been devoted to design cognition, an area in which researchers attempt to understand the set of cognitive processes underpinning designing. Historically, these processes have been studied using "black box" experiments, where the output of carefully designed studies can be used to infer how internal processes of the mind relate to design activity. However, recent advances in techniques and tools for measuring brain activity provide design researchers with the opportunity to more directly study the internal workings of the brain. We define this emerging research area broadly as design neurocognition. In design neurocognition, techniques for studying the brain are applied to further advance our knowledge of the design process. We are interested in papers from all design domains.

Several neurocognitive approaches for measuring cognitive brain activation have been applied to design: functional magnetic resonance imaging (fMRI), function near-infrared spectroscopy (fNIRS), and electroencephalography (EEG). Each approach offers a unique tradeoff between various properties of spatial and temporal resolution. Using these approaches, researchers can contribute to the understanding of specific cognitive processes of the designer engaged in design activity. (DESIGN SCIENCE JOURNAL, 2020)

A wide variety of design cognition is well suited to neurocognitive studies. In addition to studying designer cognition, neurocognitive techniques can also provide significant value through studies of users of designed artifacts, with the specific intention of informing and improving design knowledge. This thematic collection seeks to capture exciting design neurocognition research across all neuroimaging modalities, as well as to identify and delineate future directions for research in design neurocognition.

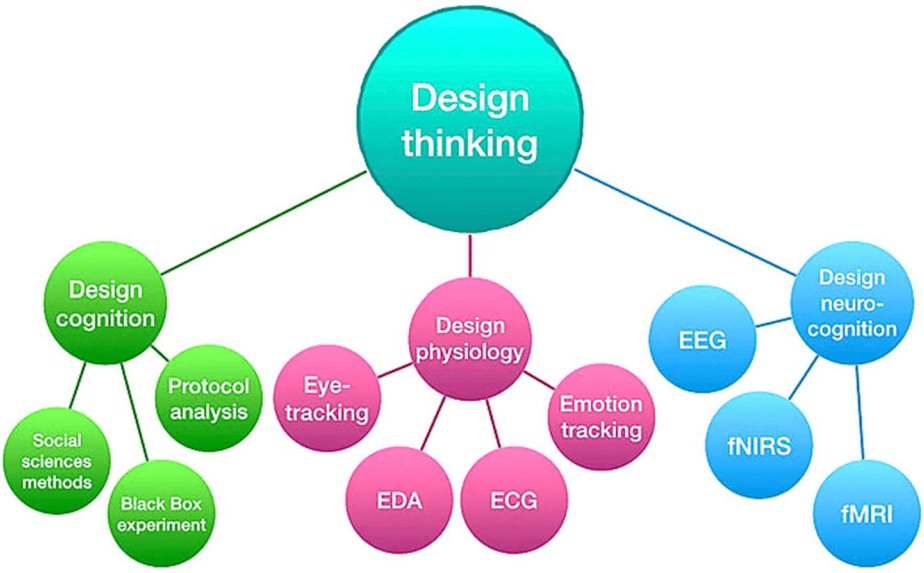



*Figure 2 - Design Neuro-Cognition Esqueme (DESIGN SCIENCE JOURNAL, 2020)*

## 2.2 REHABILITATION IN THE CONTEXT OF ALZHEIMER'S DISEASE

The first part of this sub-chapter leads us to an explanation of the concept of Alzheimer's Disease (AD) and presentation of the disorders associated with it. In a second part we present the treatment of the disease, in a biomedical aspect with the use of technological tools that can directly contribute to the rehabilitation of dementia and dialogues with the use of technological equipment such as the case of this thesis in health context through neuropsychological rehabilitation itself. which according to this literature review was receptive to the use of this technology.

The main objective of rehabilitation is to empower patients and their families to deal with the consequences that Alzheimer's disease brings not only to the patient but to all the people who deal with him. Rehabilitation proposes to teach patients and their family's compensatory strategies and organization of responses, which may facilitate the quality of life of these patients. However, there is little research that analyzes the effects of rehabilitation interventions, especially with Portuguese patients, which was attempted to be resolved by carrying out this literary review in this sub-chapter and with different approaches throughout this thesis.

According to CAMÕES; PEREIRA; GONÇALVES (2020, p. 2) article the Alzheimer's disease is a degenerative disorder of the nervous system, that is, its causes are not really known and are manifested by an abnormally important systematic loss of certain groups of neurons. The term dementia, after qualifying in the principles of the history of neuropsychiatry for a heterogeneous set of mental disorders, is today used solely by reference to a group of cerebral cortex degenerations that are manifested by the progressive and ineluctable loss of intellectual functions: loss reasoning ability, disorders of major neuropsychological functions, such as memory, orientation, language, perceptions of gesture and perception, changes in affective behaviors and behavioral inadequacy to the social context.

Clinically, AD starts around the age of 65 with the presence of abnormal structures, the amyloid plaques, which accumulate in the patient's brain in a progressive and irreversible way, interfering with the normal functioning of cells leading to their death (ADAMS et al., 1998; DESAI & GROSSBERG, 2005; WILSON, 1989).

In other words, we see the progressive failure of all mental activities, to lead in a few years to a vegetative state in which only vital functions and the normal state of consciousness and activity that complement sleep state remain intact.

Therefore, Alzheimer's disease is the center of very active and currently very special investigations linked to the fact that it often equates with an entity initially considered distinct, senile dementia, which occurs in individuals over 70 years old, whose injuries microscopic images are qualitatively similar. This assimilation, together with the aging of the population in the West, makes Alzheimer's disease one of the main problems of our society today.

Although there is no cure for Alzheimer's, there are currently some drugs that stabilize the disease can delay its development by up to five years or more, and a treatment plan is elaborated, where specific care must be broken down according to each case. treatment plan should be according to the evolution of the disease. Before starting any rehabilitation program, it is necessary to define the cognitive profile of each patient, outlining the aspects of cognition that are preserved and the possible deficits that exist. In addition, it is very important to adapt the proposed treatment to the patient's intellectual and cultural level.

Thus, it is important to emphasize the need for plasticity in the development of any technological and innovative proposal, that is, the need for patients to modify their behaviors and living standards to enable adaptation to the disease. Rehabilitation is not only about improving cognitive aspects, but also modifying maladaptive behaviors, professional rehabilitation and psychosocial support.

That is, during the development of the headset, behavioral intervention should be considered, acting on multiple factors, namely: in the adaptation and modification of the environment; in modifying social interactions; in psychotherapeutic treatment; somatic care; family support and treatment and use in health institutions to contextualize product design.

To better visualize the stages of Alzheimer's disease (Adapted from CRUZ, PAIS, TEIXEIRA, & NUNES, 2004; SHIMODA, DUBAS & BARBOSA DE LIRA, 2003):

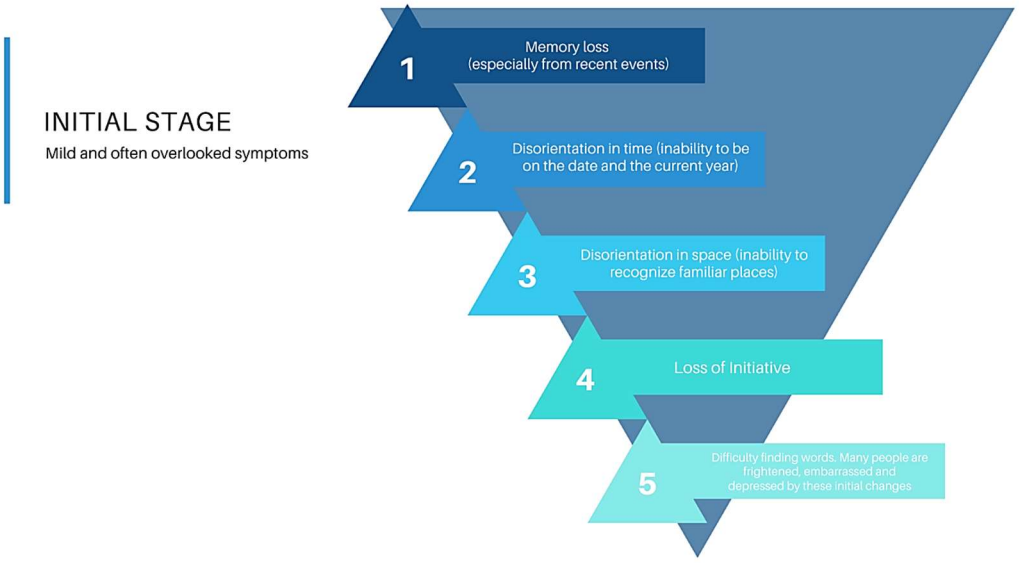



*Figure 2: Alzheimer's initial stage chart*

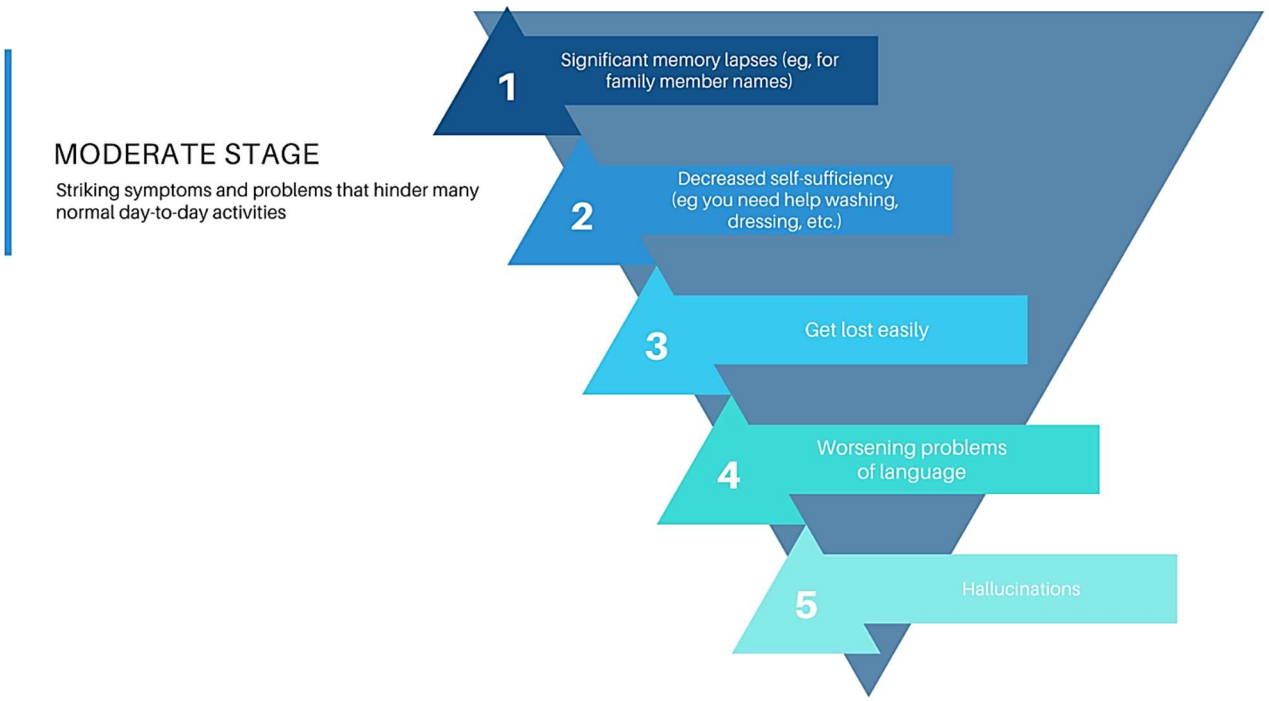



*Figure 3: Alzheimer's moderate stage chart*

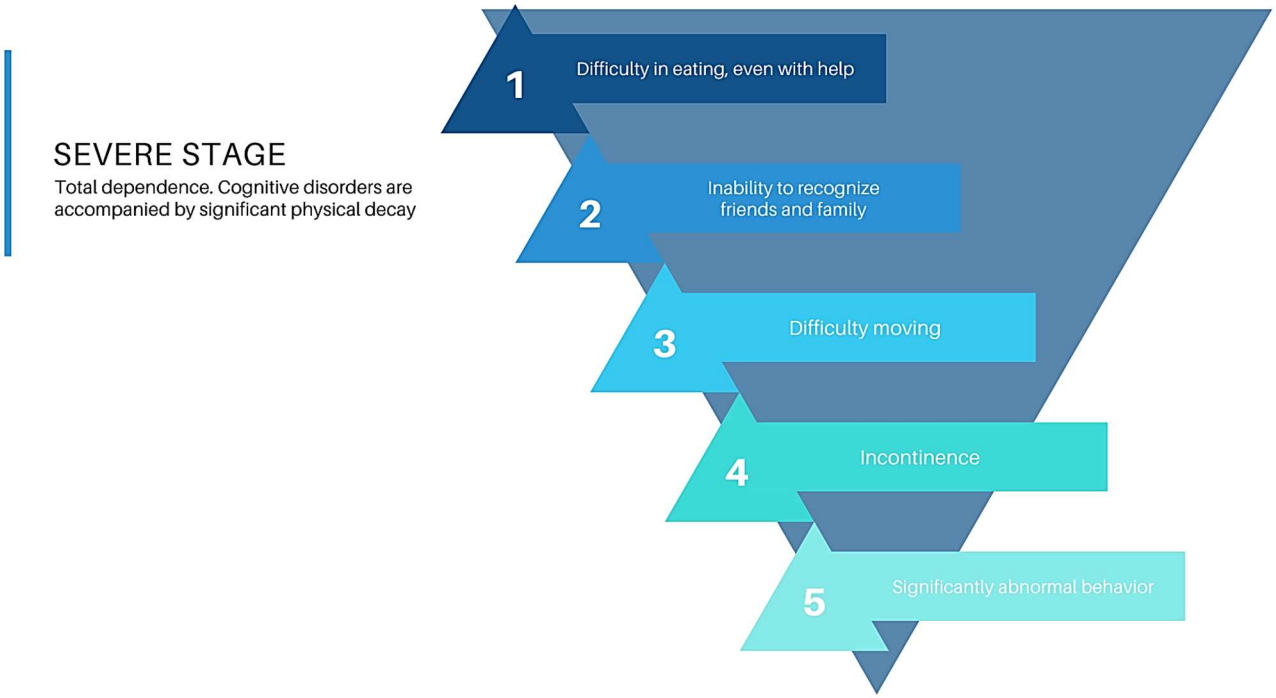



*Figure 4: Alzheimer's severe stage chart*

The analysis of these phases allows making a diagnosis that is essentially clinical and makes it easier to understand the context for which the product is being developed, adapting to the desired needs.

As the disease progresses, neuropsychological changes include, in addition to memory loss, aphasia, visual-spatial defects, acalculia, changes in abstraction and judgment (ADAMS et al., 1998; CUMMINGS & BENSON, 1992; DESAI & GROSSBERG, 2005).

The language of a patient with AD is quantitatively impoverished and incoherent, leading, in a more evolved phase, to the possible appearance of logoclonia (Adams et al., 1998; Camões, 2006; Mahendra & Arkin, 2003). Another frequent change, during the evolution of AD, is the presence of agnosia. In some patients it has been described as an early feature, but it is generally considered to be a feature of the latter stages of this degenerative process (ADAMS et al., 1998; LISHMAN, 1987).

A Portuguese study stands out in this scenario of assessing changes cognitive functions. The Portuguese researcher GUERREIRO (1998) developed a work to bring some progress to the diagnosis of dementia (eg, in Alzheimer's disease), mainly in cases where mental deterioration was incipient and difficult to diagnose. Among other instruments, it used the Lisbon Battery for Assessment of Dementia (BLAD), which allows the neuropsychological assessment of various cognitive functions. The author found that AD could present three neuropsychological profiles (mild, moderate and severe) with no direct relationship with the time of evolution or the age of installation.

Still in the Portuguese scenario, despite not having many studies within this society SANTANA (2015) states that the main characteristics of demographic trends in Portugal are the “continued increase in average life expectancy at birth, the reduction in infant mortality, the increase in emigration, the abrupt fall in fertility and the consequent aging of the population” (SANTANA et al., 2015, p.3).

BISPO (2018) also mentions these reasons as dominant for an aging Portugal, where disability becomes increasingly common. The proportion of people aged 65 or over has progressively increased, in 2018, 20% of the total Portuguese population was elderly and the number is expected to increase to almost 40% in 2080 (NATIONAL GEOGRAPHIC, 2018). The figure 5 shows the aging rate of the Portuguese population in the years 2001, 2010, 2013, 2015 and 2019 and the estimate for the year 2080 (PORDATA, 2019; NATIONAL INSTITUTE OF STATISTICS, 2017).

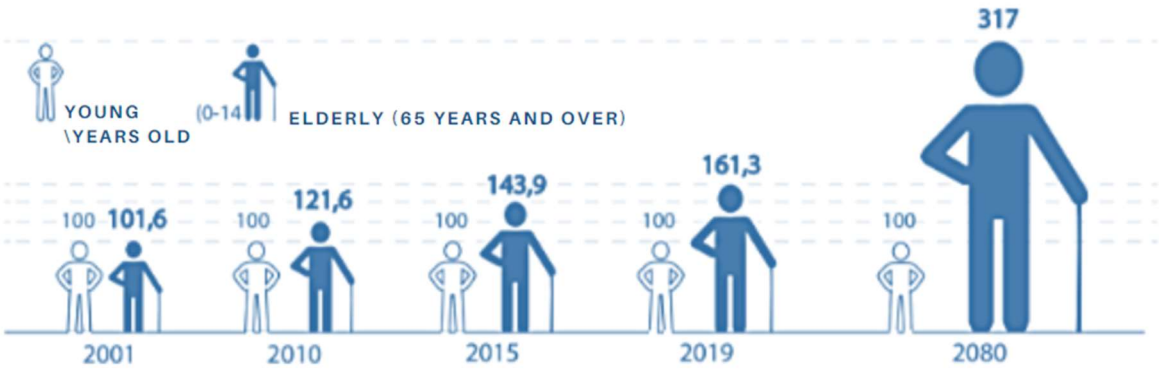



*Figure 5: Infographics representing the aging index of the portuguese population (OECD, 2017)*

With the focus on Portugal, estimates made in 2012 pointed to a 29% of people with dementia of 1.71% of the population, when the European average would be 1.55% (Alzheimer Europe, 2014). In 2017, Portugal was the 4th OECD country with more cases of people with dementia per 1000 inhabitants, about 20, preceded by Germany, Italy and Japan, the latter with around 23 people per 1000 inhabitants (OECD, 2017).

Neuropsychological Rehabilitation (NR) is an active process that aims to empower people with cognitive deficits caused, by injury or illness, with a good level of social, physical and psychological functioning (MCLELLAN, 1991). According to WILSON (1996), NR, in addition to treating cognitive deficits, also proposes to treat changes in behavior and emotions. The objective of cognitive rehabilitation is to allow patients and family members to live, deal with, reduce or overcome cognitive impairments resulting from neurological damage, making them have a better life, with fewer disruptions in the activities commonly performed (WILSON, 1996).

In this way, rehabilitation implies maximizing cognitive functions through psychological well-being, the ability to perform activities of daily living and social relationships (CLARE & WOODS, 2001). In addition, NR also seeks to reduce the deficits that cause social exclusion and isolation, dependence and discrimination (KITWOOD, 1997).

Bolognani and team (1999) evaluated the effects of NB in nine individuals with dementia for six months. The results indicated stability, or a small decline, showing a positive effect of the rehabilitation performed, without changing the medication of these patients. Another study, carried out by Clare and Woods (2001), demonstrated an improvement in the memory of patients after the implementation of NR, remaining so for six months after the end of rehabilitation. In summary, NR is a biopsychosocial treatment that involves patients and family members, where it is proposed to teach patients, family members and / or caregiver's compensatory strategies, enabling the improvement of cognitive functions and quality of life.

Bearing in mind that in Portugal there is no study of neuropsychological rehabilitation of various cognitive functions in AD, there are only studies looking at the differences between patients undergoing a rehabilitation program compared with patients not

undergoing any intervention and to ascertain whether rehabilitation has an impact on cognitive functions of patients with AD. However, this study is not of great relevance for the construction of a new product design.

In this step we will discuss the medical and therapeutic advances in the development of a headset for patients with Alzheimer's, as it can work to restore patient's memory. Scientists believe that directly illuminating areas of the brain damaged in Alzheimer's, through the nose and skull, can reverse the disease (ASHWINI SAKHARKAR, 2020).

In research by Vielight, a leader in brain photobiomodulation (PBM) technology, it is claimed that light enhances the mitochondria that provide energy to cells through a process called photobiomodulation and stimulates the brain to activate immune cells known as microglia, which fight against diseases and try to get rid of them. The innovation was announced after the first major test to see its effectiveness, and the headset improved writing and reading skills, restored memory, improved rates of sleep, anxiety and stress, reduced tantrums and increased development cognitive.

*Figura 6 - The device delivers 40 Hz gamma waves directly into the skull using LEDs on a headset (Vielight, 2020).*

Initial experiments showed the ability of this headset to reverse the symptoms of Alzheimer's disease, get rid of toxic proteins accumulated in brain cells and increase the cells responsible for memory, remembering that this information from parallel products will be used as design inspiration for the product that will be developed throughout this study. If successful, technology will be the first to really contribute to reversing the disease/. This clinical trial is timely in the context of many unsuccessful attempts by pharmaceutical companies and devices to demonstrate acceptable efficacy and safety to treat the disease (ASHWINI SAKHARKAR, 2020).

Now, patients need to rely on drugs that have only managed to delay the onset of dementia. "Photobiomodulation introduces the therapeutic effect of light on our brain,"

said Dr. Lew Lim, Vielight's CEO and inventor of the device, to The Telegraph. “It activates the body to restore its natural balance or homeostasis. When we do that, we invoke the body's innate ability to heal" (ASHWINI SAKHARKAR, 2020).

Other forms of rehabilitation and treatment using a headset were carried out in a workshop with doctors to select appropriate environments that would be calming. Each participant used an AR (augmented reality) headset to visit five virtual locations. These included a rural area, a sandy beach, a rocky beach, a cathedral and a forest. Patients can choose their environment on their own (ASHWINI SAKHARKAR, 2020).

The team monitored several 15-minute RA sessions and analyzed feedback from patients and their caregivers. Some patients wanted to be in an environment repeatedly, while others wanted to explore more. Ang's team reported that AR helped participants to recall old memories. He did this by offering new stimuli that he could not otherwise achieve due to illness or inaccessibility (THE TELEGRAPH, 2020).

Caregivers were able to learn more about patients' lives, which improved their social interaction. In an art session, a few weeks after a session, a patient recalled the experience and then made a drawing by the sea. This suggested to researchers that RA had a positive impact on his mood - along with his ability to take advantage of the creative process. The RA experience can clearly have positive benefits for patients with dementia, their families and caregivers. According to Ang, it provides a richer and more satisfactory quality of life than that available, with many positive results.

Improving quality of life reduces levels of anxiety, depression and hostility within the wards, the study concluded. Ang has already tested VR technology in patients with dementia in day care centers and residential care centers. He believes that additional research will assess the elements of the virtual environment that can make VR so effective and shed light on how to use it more effectively. As it becomes easier to produce augmented reality environments, creators can make customized settings for the patient. (THE TELEGRAPH, 2020). However, this sub-chapter highlights the need for more diverse joint involvement of people with dementia in all aspects of research, to better delimit the real design needs for the product, but in view of the pandemic moment in which it is being developed this study carried out a comprehensive literature review to minimize possible negative impacts.

## 2.3 INCLUSIVE AND EPATIC DESIGN FOR ELDERLY

Considering the perspective of aging in society, this sub-chapter sets out the definitions of inclusive design and empathetic design, the models and approaches adopted in these new perspectives, considering the social model as an important design variable in contemporary times. Population aging has been a challenge for all countries. The increase in life expectancy increased the number of design approaches and projects for this audience, in addition to design concepts permeated by a new, more humanized ethic, with a focus on product design for the elderly. To this end, it presents the concepts of inclusive and empathetic design, new models of analysis and discusses the importance of elements in inclusive Healthcare Design for the Elderly.

Historically, two perspectives or models of disability can be defined: the medical model and the social model. The first, practiced between 1900 and 1970, held people accountable for their disabilities and saw them as medical curiosities or aberrations, excluded them from basic social circuits such as markets and services and removed their rights. In the social model, practiced since the 1970s, disability is seen because of a society that does not offer adequate products and conditions. Thus, the concepts of universal design (MACE et al., 1991) and inclusive design (COLEMAN & PULLINGER, 1993) emerge in the early 1990s, with the aim of making common products, spaces and services accessible to the maximum of people possible, considering the social context in which they are inserted and minimizing the exclusion of certain population groups (BISPO, 2018; LOPES, 2016; CLARKSON et al., 2003).

The concepts emerged simultaneously with a growing interest in user-centered design. One of the great motivations of this new way of thinking about design was the reality of population aging and the failure of design to respond positively to problems related to disability (CLARKSON et al., 2003).

The prolongation of life and the change in the social profile has led to debates about the new elderly, rethinking diseases and well-being, weaknesses and autonomy. The aim is to reduce the degree of exclusion and provide a better quality of life to an increasingly significant portion. This context became a challenge for several academic areas and design was impacted by this new ethics.

Also, according to Clarkson et al. (2003), this new user-centered design approach marked the transition from product development where a factor of technical and functional performance was valued to a perspective that favors more human aspects such as emotional involvement, lifestyle, personal aspirations and focusing on the anti-stigmatizing characteristics of products that promote the social integration of the individual. A perspective that seeks to bring design closer to people and their real needs.

The challenge is to use design as a tool that meets social and political expectations of equity and inclusion, creating conditions for all people to have an autonomous and fulfilled life for as long as possible. This control of the very life that design can provide, benefits not only the person who becomes more capable, but also the rest of society (COLEMAN, 1999).

Universal Design emerged in the early 1990s in the United States with a User-Centered focus. The U.S. was the first country to guarantee design as a civil right for people with disabilities. Accessibility is understood as the right to create a barrier-free environment, explains Fletcher et al (2013). The term "Design for All" is a philosophy that aims to design products, environments and systems oriented to human diversity and inclusion to facilitate equal opportunities. It has its origin in northern Europe, in the Scandinavian civil service of the 50s and 60s, with the aim of promoting social integration.

The term inclusive design emerged in the mid-1990s, in the United Kingdom, going back to the experience of the 1960s related to projects and social needs. Population aging and the integration of people with disabilities were the cause of the emergence of Inclusive Design (CLARKSON and COLEMAN, 2013).

Inclusive Design is not a new genre of design or a new specialty, but an approach to address the needs of a wider audience and not design for subgroups such as the elderly and the disabled (CLARKSON and COLEMAN, 2013).

Considering reduced functional capabilities is critical to these three theories of design. It is common for many authors to consider these terms as synonyms because they appeared at the same time and in the same spirit. The goal is to make the artifacts accessible and usable for anyone or a larger number of users, comment Elton and Nicolle (2010). It is an exercise in otherness, valuing diversity and emancipation. These new conceptions about the user, subject, human being, in the project scope, allowed the emergence of new approaches and analysis models.

Three main approaches can be highlighted for this inclusive design project with different focuses and orientations MONGE (2003). With an approach that considers the vision of the business, CLARKSON et al. (2016) relate the widest possible range of users of a product to the increase in its commercial success, highlighting the importance of a correct understanding of users. STEINFIELD & TAUKE (2002) highlight a social point of view, where the suppression of discrimination that design can originate is valued, considering the participation of all members of society.

The third approach, closely related to the previous one, considers the stigma that certain products can cause in the user. It values the person's independence and the importance of products that do not seem designed just for disability (GREEN & JORDAN, 1999).

Although when addressing the theme of stigma and how design can contribute to its deconstruction is related to people with disabilities in a comprehensive way, the most prominent population groups are the elderly, especially with deterioration of various cognitive functions such as Alzheimer's disease. “What matters is that an individual not only survives but maintains themselves. Health seen then as a synonym for wellbeing, for living well” (TAVARES, 2013, p.298).

However, as is possible see in figure 6, old age can be understood as a complex process marked by changes, with a significant reduction in functional capacity (motor, sensory

and cognitive), thus, the biological characteristic allows to verify the signs of senility (CAMARANO and PASINATO, 2004).

Capacity, in this model, is one of the fundamental attributes that a person needs to access, use a product and perform an activity. Disregarding these capabilities makes the design process exclusive (ELTON and NICOLLE 2010).

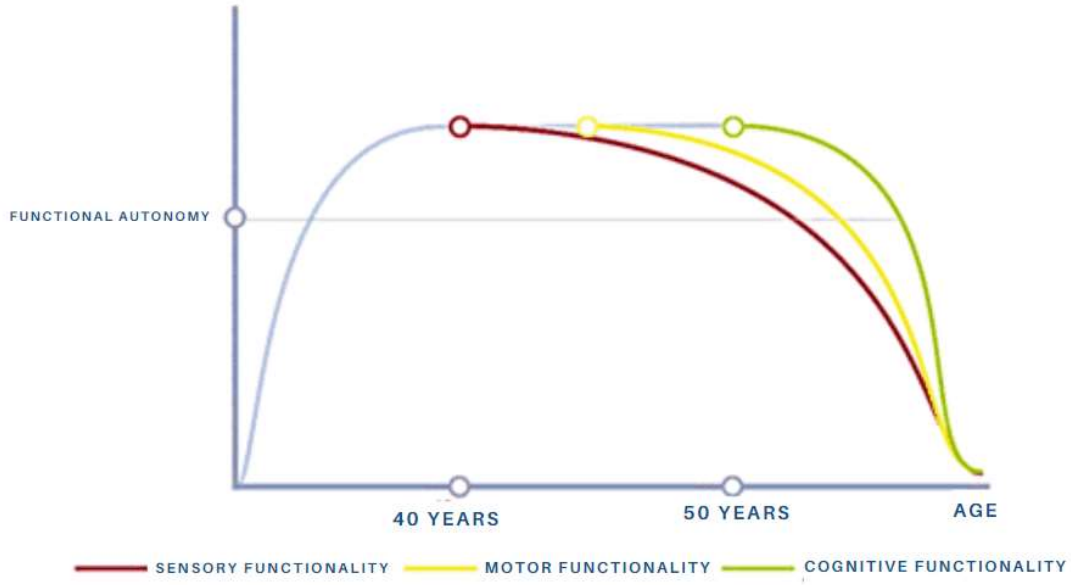



*Figure 7: Features and the Aging Process (GURGEL e SISTO, 2010).*

In old age, it is common to increase the risk of mental illness that affects memory, judgment and control of emotions, causing a cognitive deficit in elderly people with slowness and loss of precision (GURGEL and SISTO, 2010). Therefore, a product that requires activities that involve a high degree of complexity, memory and learning must consider this functionality.

In products and services, there is currently a strong need for identification and emotional meaning of the user with the product (KOSKINEN and BATTARBEE, 2012, p.37) and increasingly the importance of the relationship between people and objects, that is, quality the experience that the object provides stands out in the expectations of users when purchasing a product.

> "Far beyond the ephemeral world of technocentric design, a rich and interactive domain hides based on a deep human need: the need for empathy" (CHAPMAN, 2005, p.18).

Empathetic Design consists of the ability and capacity to perceive people's experience and thoughts emotionally, without having had the same experience, that is, it intends to understand the user, putting himself in his place (BATTARBEE, 2004, p.2). It is a user-centered design that, through observation and interaction with the user, discovers their needs and experiences. However, as already reported several times throughout this thesis, due to the pandemic crisis and the impossibility of developing a participant project previously proposed, the ideal considering the product profile in which the

empathic design is being developed in this thesis, prioritizes feelings about the product regarding the designer's perception and the appeal that the product will have.

This parallel showed the impact of this new vision, putting itself in the user's shoes and imagining the easiest, most comfortable and quickest way to use the product and, above all, prioritize harmony, simplicity and intuition. In this way, empathic design becomes a tool or technique used based on the experiences of the public, to achieve new goals and improve their products (BATTARBEE, 2004, p.1). The use of this approach becomes a great differential, as it brings a series of benefits to customers. By motivating the adoption of users, it leads them not only to the full use of the tool, but to the learning of new features and the concepts involved. The simplicity built into the concept, makes the tool more useful and applicable in everyday life.

Thus, the experience that empathic design provides is divided between aesthetic experience, emotional experience and the meaning of experience (DESMET et al, 2007, p.1). This means that the experience starts from the appearance of the product and service to the emotional impact, ending with the contributions that provide its effectiveness.

The concept of empathic Design applies to the final product and service, with regard to rehabilitation, the fact that there is the creation of a more futuristic, organic product, moving away from the typical hospital image looking like an innovative object, contributing to the inclusion and identification of the user with the product and service, as the user becomes more integrated with the advances of society and evolves at the same time.

> "Emotions are inseparable and a necessary part of cognition. Everything we do, everything we think is affected by emotion, often subconsciously. In turn, our emotions change the way we think and serve as constant guides to appropriate behavior, moving us away from the bad, guiding us to the good" (NORMAN, 2004, p.7).

This notion of the meaning transmitted, through a given object, depends both on the experiences lived by the user in relation to that object, as well as on its context, environment, culture and sensitivity (BATTARBEE, 2004, p.1), that is, just as each object can convey a different meaning depending on these factors, the user can also respond differently to each product or equipment, given their experience (DESMET & HEKKERT, 2007, p.7).

The creation of a more familiar, innovative product and without the hospital aspect, current in current health products, is important to create motivation for its use and for the elderly not to feel out of place, but integrated and supported. With the creation of an empathic design, which considers the emotional aspects of the user, as well as his experience with products whose objectives are the same, it helps to motivate and captivate the user in the continued use of the product. This relationship between the elderly and the product not only leads to huge improvements in the health of the elderly,

but also contributes to the feeling of being integrated into society and part of the technological future.

To create a coherent and appropriate product, the needs of the user, in this case of the elderly, must be understood, in which the loss of capacities leads to the need to consider several characteristics in the execution of a product, as represented in the table below:

*Table 1 -Loss of capacities and ergonomic needs (adapted from MCGOWAN, 2011)*

| LOSS OF CAPABILITIES AND CHARACTERISTICS TO BE TAKEN INTO ACCOUNT WHEN EXECUTING THE PRODUCT | |
|---|---|
| VISUAL PERCEPTION | NEED FOR MORE LIGHTING AND INTENSITY, IN ORDER TO BE ABLE TO SEE PROPERLY, BECAUSE AN ELDERLY PERSON NEEDS TWICE AS MUCH LIGHT |
| MOTOR AND TACTILE PERCEPTION | SENSITIVITY AND TACTILE ABILITY DECREASE |
| FORCE | STRENGTH IN ARMS DECREASES BY UP TO 16% FROM 60 YEARS |
| MOTION CONTROL | MOVEMENT CONTROL DECREASES, WHICH MAKES THE ELDERLY SLOWER IN MOVEMENTS THAT INVOLVE HOLDING, REACHING AND REPETITIVE MOVEMENTS |
| INFORMATION PROCESSING | THE INFORMATION PROCESSING TIME INCREASES |
| MEMORY | THE ABILITY TO MEMORIZE AND MEMORIZE EXCHANGES OF INFORMATION DECREASES |
| CARDIOVASCULAR CAPACITY | DOWN TO 70% |

The main objective through these different approaches mentioned above is the creation of a product that can efficiently support the elderly in rehabilitation, given their loss of natural aging capabilities and due to Alzheimer's disease, contributing not only to a healthier life, but also for a life with more autonomy and independence.

In addition, there is another major objective in the creation of this product / service design, the integration of the elderly population in new technological advances so that they too can enjoy all the benefits that result from it. Although a large part of the elderly population is not familiar with the technologies, a strong theme of this project leads to the need to adapt and allow for the learning of these new services, that is, this product takes into account all these factors and intends to solve them having take into account a design with technology and that is, at the same time, intuitive in its use.

Therefore, for this investigation it was necessary to acquire solid theoretical knowledge to compensate for the lack of the practical component due to the pandemic context in which it has already been explained previously. Therefore, it was essential throughout this investigation to permeate the following topics: Product Design, Inclusive Design, Empathic Design, Interaction Design, Interface Design, Ergonomics, Sustainability, Health and well-being.

## 2.4 TECHNOLOGY AND PRODUCT

Technology is changing the face of health as we know it. Virtual and Augmented Reality, which were previously associated only with the games and film industries, is becoming a real factor of change in the health domain.

When we talk about technological revolution, the notion of Internet of Things, or Internet of Things (IoT), is one of the main issues. A phenomenon since the last few years, but that continues to develop and is shaping our future in a completely new way. Its possibilities are innumerable, the Internet of Things is transforming our relationship with technology, changing the way we interact with the world and, mainly, the way the world interacts with us. It is a concept capable of changing not only how we live, but also how we work and in the case of this study assist in the rehabilitation of people with AD.

Promoting innovation through technology is one of the biggest challenges as a designer, developing the integration of technologies to products. In this sub-chapter it is considered that this integration between technology and product as the result of a technology development process that must be used in a product development process.

The technological revolution today, increasingly makes possible the connection between the virtual world and augmented reality close to people, between people and products and between products themselves. More and more products will be interconnected, figure 8, and in 2020 the number of interconnected products increased by around 50 billion, demonstrating the constant technological evolution and increasing use of intelligent products (MORGAN, 2014 apud SMITH et al, 2015, p. 43; BASENESE, 2014, apud SMITH et al, 2015, p.48). In a very simple way, Internet of Things is the way physical objects are connected and communicating with each other and with the user, through intelligent sensors and software that transmit data to a network as if it were a large nervous system that makes possible the exchange of information between two or more points. The result of this is a more intelligent and responsive planet.

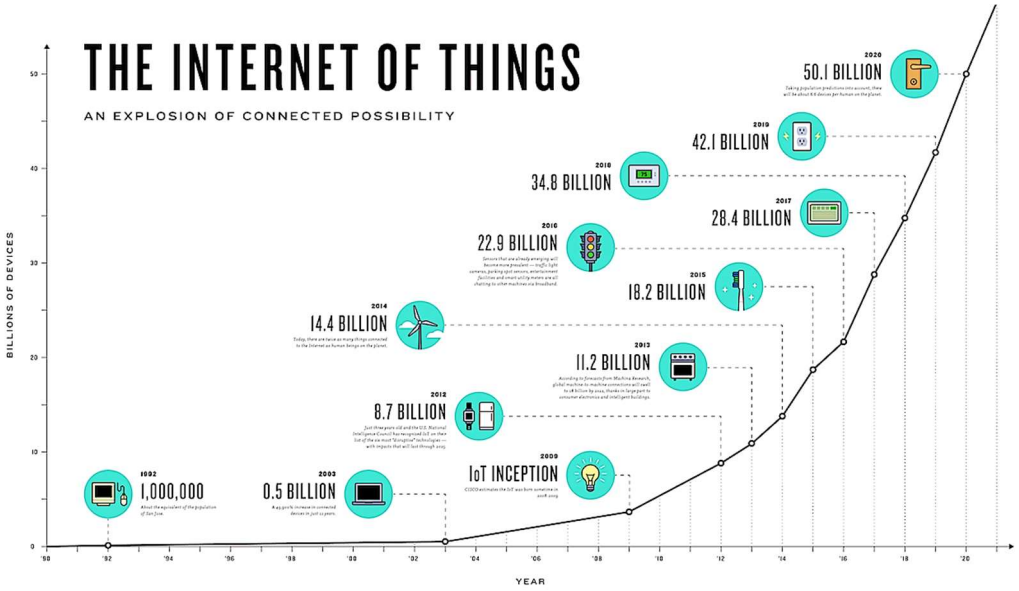



*Figure 8: The evolution of connections via Internet of Things (Brandon, 2015)*

Technology refers to tangible elements, such as machinery and equipment, and intangible elements, such as knowledge that are related to the establishment of favorable conditions for product development (Kurumoto, Caetano, & Amaral, 2007). These elements deal with know-how and how to do, which are the necessary technology to develop a certain product, that is, what to do.

Cooper (2006) and Sheasley (2000) define the development of a new technology as the process of converting ideas into technological platforms. It is a process composed of a set of knowledge acquisition activities that will serve as a basis for the development of a new product or a new process.

For Kaplan and Tripsas (2008) technology is not only the knowledge used in the elaboration of a product, but also includes the physical manifestation of that knowledge incorporated in a physical artifact, such as the activity of making a prototype, a test bench and other artifacts.

Now we can better understand how these things work, and how they work together to better serve us. The interconnection between the real world and the virtual world has become possible through the internet of things, one of the most debated concepts over the last few years and today. (PELLET, 2015, p.59). The internet of things, IoT, is the intelligent link that unites everything in the world, from people, to products and information, more precisely:

> "(...) is based on the assumption that smart devices can find application contexts autonomously, namely, through the Internet in order to establish collaborations with other smart devices and services, creating a collaborative network of value in a given operational context." (GONÇALVES & MACHADO, 2016, p.16)

By making products smarter, by contributing to automation with more capabilities, more adapted and with more information, the internet of things has seven characteristics, highlighted in figure 9.

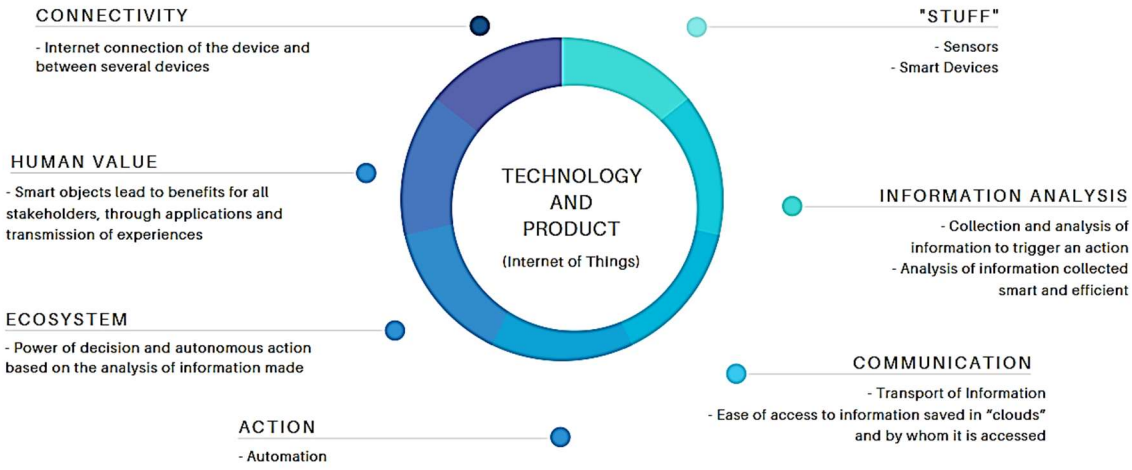



*Figure 9: The seven characteristics of IOT (adapted from ASHTON, 2016, S.P.).*

Technological advancement and the use of intelligent products, which use the internet, brought new mechanisms, techniques and sensors, with the ability to collect information on positioning, mapping, movement and space, and enabled the development of products adapted and customized to the needs of users with disabilities or restrictions, physical, sensory and cognitive, allowing, for example, to move and relate better with the environment around them. (ROE, 2007, p.5).

These capabilities of these intelligent products and equipment are contributing to a better efficiency, effectiveness and adaptation, providing a better quality of life for the user. However, this effectiveness is only possible if both the product and its interface are designed for a positive user experience.

The internet of things is increasingly affecting all aspects of people's daily lives. (SARMA, 2016, s.p.) When applied and used in health, users can benefit from a service with more quality and more adapted to their needs, contributing to better monitoring of health and preventive care. (CRITICAL SOFTWARE, 2017, s.p.).

Currently, the internet of things has a great impact and a fundamental role in this new phase, which is designated as the 4th Industrial Revolution or Industry 4.0, being a concept that enables and contributes to the integration of economically sustainable and innovative technological solutions, being, therefore, the great concept in the present and future. (GONÇALVES & MACHADO, 2016, p.16).

Therefore, it is necessary to start with a more intuitive product, simplifying the functions and adapting to the necessary needs. The internet offers immense benefits and it should be emphasized mainly the fact that it allows the faster and more efficient customization of products and services to its users, in this case the elderly, who would benefit in their daily life, with a more adapted and functional product. The Internet, although it is no

longer something foreign to the elderly, certain products continue to be a complex system.

Design is understood as the creation of a product or service based on information about the user's needs, which define its production process (ROYAL ACADEMY OF ENGENEERING, s.d., p.67). Being one of the specific areas of Design, Product Design consists of creating a product based on a specific service and the needs of a user. “A product is something sold by an enterprise to its customers” (EPINGER & ULRICH, 2012, p.2), therefore, it must correspond to the needs and benefits of each user in the best possible way.

Product design is not only an area of study, but also encompasses a wide range of other areas and it is important to understand that product design does not only depend on the creation of the model, but also ally the development of the image, management and strategy that will be addressed throughout that investigation.

However, the main dimension for the integration between technology and product is knowledge. There will be integration if the knowledge generated by the product development area is applied to the new product. Therefore, in a practical work we must evaluate integration as the result of the cycle of knowledge generation, knowledge retention and application of knowledge (Iansiti, 1998).

## 2.5 WEARABLE TECHNOLOGY

As currently introduced in the subchapter prior to technology, it has achieved great proximity for the user, being a number equal to that of the wardrobe, having to enter a primary need. In technology and clothing, there are two distinct areas, although they are currently in constant cooperation.

We tried to go through this subchapter, a path that instigated us during research without base on the author's textile formation, about the influences of technologies on the body, since the clothing technology itself is a layer that is located on it, therefore, we cannot disregard all the aspects that involve it.

Wearable Technology is the incorporation of advanced electronic devices in clothing, footwear and accessories. Often associated with health monitoring or physical exercise performance solutions, Wearable Tech is gaining more and more market share. Presented in 2013, in agreement with the consultancy Visiongain, the movement was close to US $ 4.6 billion (MJV Team, 2014).

Although it looks somewhat futuristic, the wearable technology itself is not a novelty. In the 1980s, some watches already came with calculators attached, but it was in the 2000s that the footwear and fitness fashion industry started creating solutions in applications that monitor heartbeat and other data related to physical exercise. Since then, several technological combinations in clothing and accessories have been growing every day.

Initiated as a wearable computer concept, a wearable system was originally understood in a basic way as pieces to be used on the human body or pieces of clothing to support technological devices. Subsequently, or more practical and refined concept of wearability, addressing issues of comfort, lightness, breathability, care and maintenance (SUH 2010 apud FRANCO, 2013). Our current sense of wearability will be most useful for applying electronics or computers to the use of connected electronic components. Thus, the clothing itself would carry only as transmission lines and textile-based connectors, so that it is still usable, flexible and washed (FRANCO, 2013).

Wearable computing is the combination of clothing and accessories with electronic and digital technologies. Steve Mann (1995), who coined the term Wearable Computing, states that the personal computer has failed to achieve its goal of being fully integrated into the user's daily life, which could be done through a wearable device.

Wearable devices are configured as auxiliaries that work silently and in complete harmony and symbiosis with the body: monitoring, analyzing, recording, organizing and producing data about the daily lives of these bodies. Bracelets, watches, and smart clothes can now monitor and offer different information, such as heart rate, step count, temperature, and other data left as traces of intimacy, provided by contact with the user's body. Lifelogging, or life data are basically ways of recording, by digital means, aspects of our daily lives. (DUQUE, 2019, p. 9)

It is necessary to work with wearable technology, not only making it a provider of technical and impersonal information in the ways of capturing or organizing data about the body but giving aesthetic values to this type of data. We must reflect on these mechanisms of production of memories and intimacies about the body in the current context, a question little explored by artists, designers and other thinkers involved with the issues of technological clothing.

For MCLUHAN (1964, p. 140), clothes are an extension of the skin. We believe that clothes and accessories, when combined with technologies, go further, as they can manufacture new human subjectivities / behaviors. MCLUHAN (1969) proposes that the instrumentalization of man is an extension of himself, so clothing is an important instrument of analysis for us to understand the human being. To understand the human body in the contemporary world, it is necessary to place it in a context in which there are needs created and demanded by self-surveillance, the exposure of intimacies on social networks, the connection with other bodies.

The main technical and ergonomically made clothing technologies capable of providing comfort and functionality to the wearable or health care product are defined based on the practical needs of each system. Professionals in interdisciplinary areas involving technical, ergonomic, electronic and programming knowledge can develop wearable technology for health care from electronic devices produced with or lesser size, weight and possible resistance, which have impermeable or attached characteristics and human activities. The field of smart clothing is characterized by the merger of two distinct fields: functional clothing design and portable technology. These two fields will be developed

separately, but both are necessary for the success of smart clothing design (KUMAR, L. ASHOK; VIGNESWARAN, 2015).

A smart dress can be used for a variety of purposes, such as healthcare, surveillance of babies and children, soldiers on the battlefield, as well as in extreme sports. Through sensors, we can capture information from the individual himself and from the environment in which that person is located. An example is the Valedo system by Hocoma AG, which consists of a medical device for back training, which allows the patient to adapt to the patient and allows the person to obtain increased motivation through increased feedback in real time based on trunk movements. The transfer of the movements of the trunk of two sensors is used for a motivating playful environment and guides the patient through exercises designed specifically for low back pain therapy (KUMAR, L. ASHOK; VIGNESWARAN, 2015).

This possibility of production in textile electronics (e-textile) facilitated the development of smart clothing as it became a potential alternative for a wide range of personal applications, including security and entertainment, as well as applications that require privacy. The basis for smart clothing is ordinary clothing, which is augmented with electrical or non-electrical components and the fabric can also be intelligent (KUMAR, L. ASHOK; VIGNESWARAN, 2015).

Providing a new culture in clothing, the technology provides freedom and comfort for the individual who monitors their daily habits through textile structures connected to applications for managing the control of personal information. Through the identification of computational technologies and the efforts made to solve the feasibility problems of the application of wearable technologies in health care. Identifying a gap that allows the elaboration of projects of clothing products contributing to treatments.

According to Li et al. (2016), individuals' confidence in using technological health care devices negatively affects their privacy risk in the context of the wearable health device. Since portable health devices provide services in real time through a sensor used on the body, the product of portable health devices can be considered both as health information and sensor hardware. Therefore, the intention of individuals to adopt portable health devices positively affects their adoption behaviors.

Wearable technology has distinct advantages in improving the efficiency of health care and reducing its cost. Therefore, individuals' perception of privacy plays an important role in the adoption of health information technology that includes portable health devices. According to Chiauzzi, Rodarte and Dasmahapatra (2015), the correct use of wearables requires an ability to understand and use personal health data, the user experience must apply principles of mathematics and evidence-based behavioral science to promote continued engagement. As portable devices are electronic devices, high technology and fashion items, manufacturers must focus not only on functionality as well as differentiation and high compatibility, but also on attractive design.

The lack of reliability is a serious obstacle that needs to be removed long before a device can be considered for any medical application, as for patients and doctors, privacy and

personal security remain problematic. Thus, affirm Piwek et al. (2016) that these systems will be strengthened by the “Internet of Things” (IoT) - the network of interconnected sensors, inserted in everyday spaces and objects that communicate with wearable technology and provide an additional layer of information for users.

The study by Chan et al. (2012) investigates the theme smart wearable systems: current situation and future challenges - “Smart wearable systems: Current status and future challenges” - present a study that aims to provide an overview of the status and future perspectives in the research and development of related wearable systems health care. The field of wearable systems includes technologies capable of monitoring the elderly or patients undergoing surgical operations using advanced sensors that can be applied in case of respiratory diseases in children or soldiers on the battlefield for example.

To expand the study to the daily lives of people with the possibility of continuously using the devices attached to clothing or accessories and to continue the study for a week or a month for example, we suggest the continuation of this research. There are great possibilities for combining technology with clothing and designers should explore this market, which covers needs such as comfort, sustainability, energy reuse, physical and chemical protection of the body that can be obtained through advances in new textile products, such as, smart fibers, conductive threads and technological textiles.

However, textile design enters the field of so-called wearable technologies by adding a computational component to clothing. There are several denominations like wearable computer, wearcomp and wearable technology. Seymour (2008) created the term fashionable technology in 2000, which refers to the intersection of design, fashion, science and technology.

According to Donati (2004), wearable technology must incorporate the personal space of the wearer without limiting their body movements, in addition to performing some type of "computational performance" in the artistic sphere or it works.

> Wearable computers (or wearcomps) are technological devices that congregate from computerized elements inserted in the weaves of fabrics to communication objects attached to the body through clothes. According to Steve Mann, one of the most important experts in this area, the wearcomps are attached to the individual's body and act interactively with him. They can perform one task while the person wearing them acts on another. [...]. Wearcomps take advantage of the functionality of computers and still have interconnectivity with the person wearing them. (Avelar, 2009, p. 148).

For the author, the understanding of wearable encompasses both those of textile support (clothing) and rigid structure apparatus. Examples of wearable technologies produced with hard materials are Google Glass and Android Wear (the smartwatch or "smart watch" that works in conjunction with the Android smartphone). These are mobile devices from large computer, telecommunications and sports corporations.

Wearable technologies are part of both computing and mobile communication due to their connections with bodies in motion. “The wearable device, when designed in an integrated manner with the user's own movement, is inserted in their daily activities in a relationship established by proximity and physical contact” (Donati, 2004, p. 96).

If, on the one hand, wearable technologies with a rigid structure appear on the market from large companies, on the other hand, those that have textile support are related to academic institutions or independent research.

However, wearables, by promoting the convergence between fashion, design and technology, enable new ways of interacting with the user and, consequently, the subject with the world increasingly taken by virtual data.

## 2.6 ERGONOMICS AND USABILITY PROCESSES

The AR glasses / headset are not just for games as we commonly associate, they also have the potential to redefine how we work, interact and how is the case with this thesis in the treatment of diseases or the way it behaves during a treatment and can be totally influenced by augmented reality, in order to offer the most appropriate form of treatment, in this context it is necessary to research ergonomics and usability for the product. The term ergonomics derives from the combination of two words derived from the Greek, "ergon" which means work and "nomos" which means laws. Thus, ergonomics studies the relationship between human beings, namely their interactions and activities, including their manifestations or involvement in a given situation or, in this case, a product, that is, “In most situations, the term ergonomic is related with the idea of promoting user comfort” (REBELO, 2004, p.15).

For contextualization DUL and WEERDMEESTER (2004) state that ergonomics developed in the Second World War when there was a union of professionals in the areas of technology, humanities and biology to solve problems of military equipment. From this perspective, the focus arises that the project must be developed from man, that is, the work project must adjust to human capacities and limitations. The design project, in this case, refers to projects of machines, equipment, systems and tasks. Within this very broad role of ergonomics are the virtual systems applied to various products that, as much as other work projects, need efficiency, quality and need to satisfy their users. Out of that need comes usability.

For JORDAN (1998) the term usability can be considered when it is easy to use a certain product. Remembering that the construction of a system with usability depends on the careful analysis of the various components of its context of use and the active participation of the user in the design decisions of the interface / design.

In other words, usability would be the main highlight of this project if we had not been limited by a pandemic moment in which Portugal was seriously affected, limiting the

possibilities of practical research. However, the factor of this design project focuses on the use of an interactive and intuitive design.

Ergonomics must take into account all the evolution and morphological deformation of people, depending on their problems, questioning their usefulness and usability, and, according to BRADLEY, et al. (2013), in the article “Applied Ergonomics”, utility is related to the functionality of the product and what it has to offer, as benefits for society, and should, therefore, provide something better, necessary and innovative, before the that already exists, while usability focuses on objectives related to the effectiveness, efficiency and strengths of a product, taking into account the application of the product in a real situation to analyze it (BRADLEY et al, 2013, p.298).

Punctuating the relationship established between user, task, interface, equipment and other aspects of the environment in which the user uses the system / product. There is, however, a “basic configuration” from which an interface or projection can favor the establishment of usability in the user - system / product relationship. This configuration is made respecting usability criteria proposed by several authors and institutions in the last decades, which I will make a brief review in the next lines.

NIELSEN (2003) considers the usability of a system, associated with its acceptance, or its ability to satisfy the user's needs and requirements. To have usability, three factors are necessary: the user, the human-machine interaction and the interface itself. Jakob Nielsen is one of the leading usability experts in the United States, is the author of a classic book on the subject, Usability engineering, from 1994, in which he proposes a set of ten usability heuristics (NIELSEN, 1994) important for the development of this project:

- Visibility of the state of the system;
- Mapping between the system and the real world;
- Freedom and control to the user;
- Ergonomic principles;
- For Human Computer Interfaces;
- Ergonomics and Usability;
- Consistency and standards;
- Error prevention;
- Recognize rather than remember;
- Flexibility and efficiency of use;
- Aesthetic and minimalist design;
- Support for the user to recognize, diagnose and recover errors;
- Help and documentation;

Another well-known author in the field, Ben Shneiderman, proposes eight “golden rules” for the design and evaluation of interfaces in his classic book Designing the User Interface (SHNEIDERMAN & PLAISANT, 2004):

- Pursue consistency;
- Provide shortcuts;
- Provide informative feedback;

- Mark the end of the dialogues;
- Provide simple error prevention and handling;
- Allow the cancellation of shares;
- Provide control and initiative to the user;
- Reduce the load of working memory;

Based on the ideas of the authors mentioned above, it is possible to establish and use some of these relationships between aspects of the systems' operating context and the ergonomic criteria to prioritize in a project activity and / or usability evaluation of the product in which this thesis is being developed.

Issues that must be related and taken into account are the level of education and socio-cultural context associated with a socio-economic dimension that allows the user / patient to have a previous contact with information technologies and emerging technologies, when it is not a generation naturally disconnected from the technologies information, that is, when users are experienced in their tasks, but new to using the system, the compatibility criterion should be prioritized.

As well as paying attention to the progression of the disease when it has not yet decisively inhibited the cognitive component and even considering the acceptance of technology, which in this case can be facilitated with a certain enthusiasm in experimenting, that is, in the case of the elderly, the more exposed a more intuitive and easier technological backgroung will be to use the headset.

The user, including novices and intermittents, who is performing critical tasks, subject to errors with important repercussions (for example, in using the software to improve work activities), all the criteria of error management necessarily apply, when the user, including beginners and intermittent, is performing information search tasks, information density should be a priority criterion in the project / evaluation. Readability is an important criterion when the task is reading or as users include elderly people.

When professionals use application / product systems to perform their tasks in situations of intense and sometimes repetitive work (such as medical or nursing staff), all the brevity criteria necessarily apply. When the functions of a system can be used for different tasks, in different situations, by users from different professional cultures, the criterion of flexibility must be considered as a priority.

Having a broad view of the ergonomics applied in this project about planning, design and evaluation extending to all aspects of human activity. In general, the areas of specialization of ergonomics used are:

- Physical Ergonomics - referring to human anatomical, anthropometric, physiological and biomechanical characteristics, and how they relate to the physical activity in which the headset is involved. Important topics include modes of use, lifting material, repetitive movements, possible disturbances related to use, layout of the place of use, safety and health.

- Cognitive Ergonomics - referring to mental processes as perception, memory, reasoning and motor responses. We also studied how these processes affect interactions between people and other elements of use. Relevant topics are mental workload, decision making, human-computer interaction, stress and work training in ways that can relate to the human-system project.

HENDRICK (1993) shows us that Ergonomics has at least four components:

- Technology of the Human-Machine Interface: studies the physical part with its characteristics and the application of this data to workspaces and control design. Representing the beginning of ergonomics, it is still the focus of professional ergonomics.

- Interface Technology Man-environment: studies the relationship between environment and man. Its importance has been increasing with the awareness of the importance of sustainability.

- User-System Interface Technology: referring to the cognitive aspects of human performance, the cognitive nature of use.

- Technology of the Organization-Machine Interface, or Macroergonomics: it focuses on the study of the interface of the entire organizational system and the design of the use system with the technology used, to improve the man-system functioning.

According to BEVAN, KIROKOWSKI and MAISSEL (1991) there are three ways in which usability can be measured:

- The product-oriented view: evaluates the product's ergonomic attributes;

- The user-oriented view: assesses the user's mental effort and attitude;

- The view of user performance: evaluates how the user interacts with the product, with an emphasis on ease of use or acceptability;

Definitions inherent to the concepts:

- User - person who interacts with the product;

- Context of use - users, tasks, equipment (hardware, software and materials), physical and social environment in which the product is used;

- Effectiveness - degree of achievement of the objectives achieved by the expected users;

- Efficiency - amount of resources spent by users to achieve their goals;

- Satisfaction - degree of acceptance of the product by the user. The system consists of users, tasks, equipment (software, hardware and material) and the physical and organizational environment that influence the interaction, that is, for there to be usability, three factors are needed: the user, the human-computer interaction and the interface, itself;

Usability optimizes the interactions established by individuals with interactive products (PREECE; ROGERS; SHARP, 2005). It is divided into the following goals:

- be effective - how good a system is at doing what is expected of it;

- be efficient in use (efficiency) - how the system assists the user in performing tasks;
- be safe in use (safety) - protect the user from dangerous conditions and undesirable situations;

- be of good use (usefulness) - when the system provides the right type of functionality, so that users can do what they need or want;

- be easy to learn (learnability) - how easy it is to learn to use a system;

- be easy to remember how to use it (memorable) - easy to remember how to use the system, after you have already learned how to use it, especially for systems that are not used frequently (PREECE, ROGERS, SHARP, 2005);

Another important concept to highlight is Ergodesign, the union of Ergonomics with Design, explained by GRANDJEAN (1984): "if an application of the principles of Ergonomics to the Design process is implemented, the result must be an attractive and also friendly product". Machines, equipment, workstations and work environments that integrate Ergonomics with Design contribute to the quality of life, increase the well-being and performance of products. (MORAES, 2004)

For YAP, VITALLIS and LEGG (1997), Ergodesign means the fusion of theoretical and practical focuses of the two disciplines: Ergonomics and Design. As systems become more complex, it becomes increasingly difficult to establish differences between the two disciplines. Ergodesign has a creative macro-economic approach that seeks to reconcile human and system attributes simultaneously with the conceptualization and development of design. As a technology, Ergodesign has an orientation that makes it an

important tool, both in scope and in the efficiency of implementing Ergonomics in the design and development of products, equipment and systems.

The forerunner of this approach that unites Ergonomics and Design was Henry Dreyfuss. For some authors, the oldest reference to the term “human factors” is present in the works of Dreyfuss, which date from the 1930s. MORAES (2004) highlights that Dreyfuss was the first industrial designer who actively implemented the application of anthropometry in the design of products, besides presenting a pioneering propensity to know the behavior of consumers. Since the beginning of the work in the Dreyfuss office, Ergonomics has been included in the design process and all designers recognized it as a fundamental part of product development.

Something in common with all Dreyfuss projects was his intense concern for the user through a variety of projects, which included vehicle consultations and equipment for the US army, Dreyfuss was a pioneer in the application of anthropometry - the coding of human dimensions in industrial design. Because of this concern and this work, the Dreyfuss team developed the models of the typical Americans "Joe" and "Josephine", which were used in the design of aircraft seats, forklifts, tools and other utility objects. Human factors - such as reach, grip and many other physical and mental aspects of using an object - have become a key component of the industrial design process and profession since Dreyfuss published the first diagrams in his autobiography Designing for people, in 1955. However, despite being born from the concern to meet the functional needs of the human operator within the human-task-machine system, Ergonomics, over time and technology, started to place the user as the center of attention, giving rise to the call "User-Centered Approach" so important in this thesis.

## 2.77 MATERIALS AND SUSTAINABILITY

Planet Earth has fragile and sensitive natural resources that are systematically affected by human negligence. In the last fifty years, the population has increased by about 50% and, in parallel, the use and extraction of natural resources has also increased to 100%. This means an exponential increase in consumption, which is very worrying. The fact that the state of the planet was transmitted and communicated and shown to the world increased the creation of new laws and strategies that contributed to a better environmental impact, as well as to the continuity of the success of companies and their products (CHAPMAN, 2005, p .1 - 3).

Sustainability is very important for the consumer today, called “Future Earth”, it is a ten-year initiative to support research that results in the knowledge necessary to respond efficiently to the impacts of environmental changes global (JUNG, 2012). The idea is to provide the basis for sustaining the transformation in search of the planet's sustainability for the coming decades. Thousands of researchers worldwide are being mobilized by the initiative, at the same time it is a great responsibility as a design professional to develop products in accordance with these issues to offer sustainable solutions.

Design, as already exposed in previous chapters, is a creative professional activity that aims to develop products and services through human needs. Within the contemporary and social well-being. Sustainable Development has concepts from different disciplines and human knowledge. Thus, this subchapter aims to systematize the concept of Design for Sustainability, demonstrating its interdisciplinarity regarding the use of materials.

Interdisciplinarity has been present since the beginning in the history of Sustainable Development in which there are a variety of concepts from different disciplines. Contemporary Design is increasingly involved with the concepts of Sustainable Development, innovation and social well-being, especially given the demands of society and the market. System-product life cycle analysis and design are paramount in any product or service project development. To systematize the concepts used in the field of Sustainable Design, bibliographic research and systematization of information3was carried out, aiming to contribute to this project practice.

Initially, the necessary concepts for the domain of design for sustainability can be listed, namely: Sustainable Development; Green Economy; Ecodesign or Ecoconception; Eco-efficiency; Sustainable consumption; Environmental impact; Industrial Ecology; Environmental education; Interdependence of products and services. These and other concepts and principles continue to emerge in view of the complexity of the theme and the socioeconomic and environmental challenges imposed on designers. It is emphasized that interdisciplinarity, according to Fortes (2012, p. 1), "does not cancel the disciplines, but asks that they dialogue with each other in an educational perspective in search of innovation". Therefore, concepts, definitions and principles of relevant authors were researched and systematized in a conceptual map.

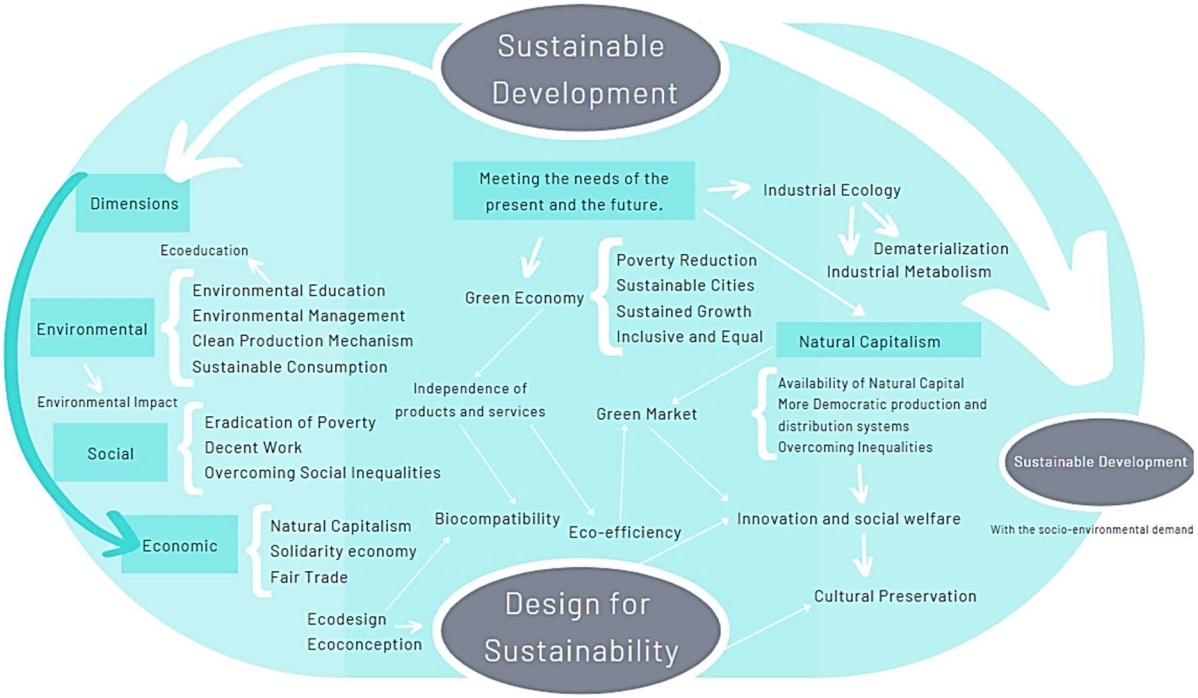



*Figura 10 - Conceptual Map (adapted from Fortes, 2012, S.P).*

The concept of sustainable development first appeared in 1987. It was defined by the World Environment Commission by the UN, under the direction of Gro Harlem Brundtland. The Brundtland commission defined Sustainable Development as "one that meets the needs of the present without compromising the ability of future generations to meet their own needs". (BRIAN, 2008, p.20). This concept has been refined over the decades that separate the United Nations Conference on the Environment, in 1972, held in Stockholm and Rio + 20, in 2012, in Rio de Janeiro. Epistemological developments in which new concepts emerge, such as that of the Green Economy that prioritizes the eradication of poverty, food security, solid management of water resources, universal access to modern energy services, sustainable cities, management of oceans and improving resistance and disaster preparedness, as well as public health, human resource development and sustained, inclusive and equitable growth that creates jobs, including for young people. (UN, 2012, p.6).

As for biocompatibility, according to Manzini and Vezzoli (2002, p. 33), it is the realization of a production and consumption system based on renewable resources and that its removal does not exceed the limits of the productivity of natural systems and that its elimination in the ecosystem is totally biodegradable, separated according to their capacity for renaturalization. In fact, only products and services that are effectively compatible with existing renewable resources can be realized within the framework of biocompatibility.

Industrial Ecology considers a productive system to be a subsystem of the biosphere (lithosphere, hydrosphere and atmosphere). An organization of flows of matter, energy and information. In this sense, two key concepts are considered: industrial metabolism that is based on the conservation of matter. Because the amount of matter that transits in the biosphere remains constant, not disappearing after its disposal, only losing its economic value; the dematerialization of production that is based on the quantitative reduction of matter, increasing the productivity of resources. (POLIS ESTUDOS, 1998).

Realize a closed system of production and consumption, reusing and recycling all materials that would form technocycles (technological cycles) with a tendency to autonomy in relation to natural cycles. This objective is still impossible to achieve even in a theoretical way, as it is impractical that technocycles do not interfere with anything in the biosphere. In other words, always, and even in an insignificant way, there is an environmental impact on production and consumption systems.

In figure 47, one can visually perceive such paths for environmental sustainability in which, from the combinations between cultural changes (socio-cultural dimension) and technological changes (technical dimension), new possible sustainable solutions can be characterized. This plan defined by the axes - technological change and cultural change - indicates three orders of articulations, namely: how to assess when solutions can be considered sustainable; what are the meanings and implications of the various combinations between technical and socio-cultural innovation; and what are the ideally practicable paths to achieve sustainability (MANZINI; VEZZOLI, 2002, p.41).

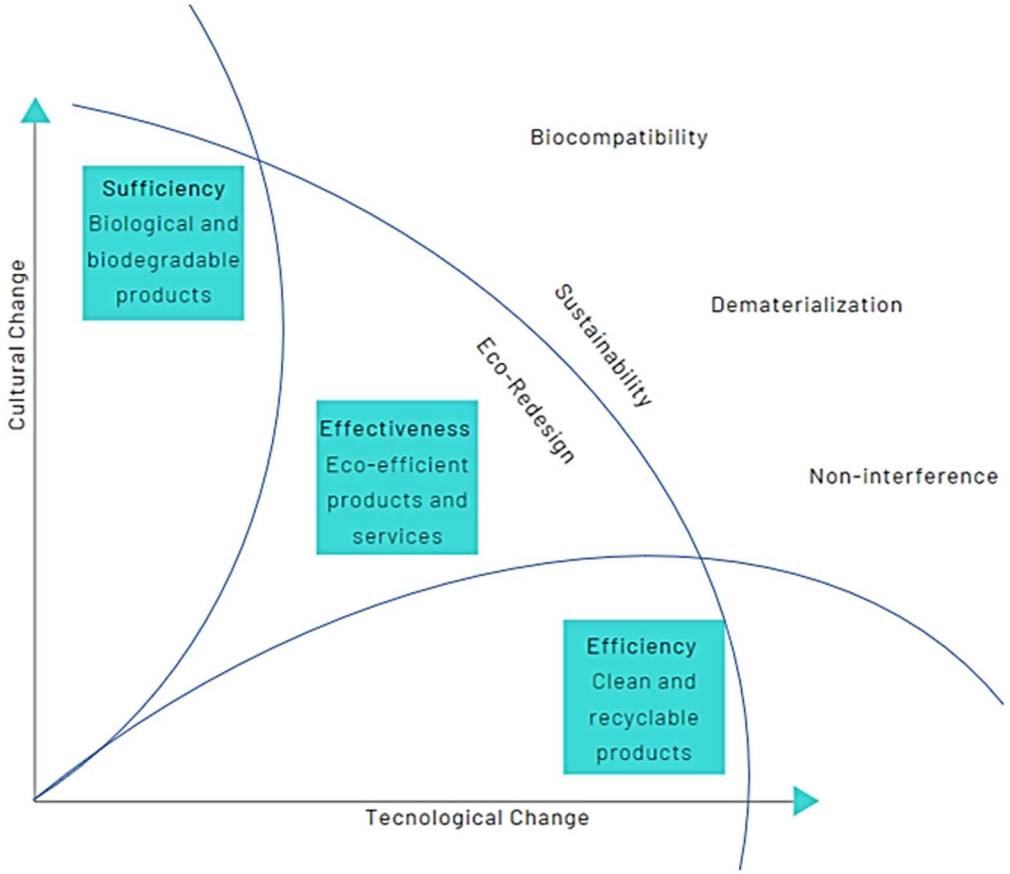



*Figure 11: Based in Manzini e Vezzoli (2002, pp. 36-41)*

Eco-efficiency is the widespread concept for providing services with economically and environmentally correct performance, according to the World Business Council for Sustainable Development. For Larica (2003), it is the increase in productivity and profitability in organizations based on the reduction of environmental impacts.

Ecodesign, whose first definition was given by Victor Papaneck, works to reduce the impact of human beings on the planet. For Kazazian (2005, p.36), ecodesign is part of a process that seeks to make the economy “lighter”. Also called ecoconception that deals with reducing the impact of a product on the environment, conserving its qualities of use (functionality, performance) to improve the quality of life of users. "According to this approach, the environment is just as important as technical feasibility, cost control and market demand". Ecodesign, as a global approach, requires a new way of conceiving, considering all stages of the life cycle of a product or service. It should be noted that in an ecoconception, a cooperative process begins with a chain of actors in a transversal and multidisciplinary approach.

Sustainable Consumption stems from the perception that if everyone consumed as much as the citizens of rich countries, natural resources would soon run out. “Use of services and products that respond to the basic needs of the entire population and provide an improvement in the quality of life, while reducing the use of natural resources and toxic materials, the production of waste and pollution emissions throughout the life cycle, without compromising the needs of future generations” (UN Commission on Sustainable Development).

Environmental education, according to Sachs (2004, p. 39), is essential for development, as it contributes “to cultural awakening, awareness, understanding of human rights, increasing adaptability and a sense of autonomy”, self-confidence and self-esteem. It cannot be considered a panacea, but it must be part of a set of development policies.

For Manzini (2003), Design for Sustainability considers environmental issues and the study of the life cycle in Product Design. In this context, the aim is to balance the production system with the needs of social well-being, optimizing the processes and the useful life of products, with the aim of reducing environmental impacts.

For Vezzoli (2010, p.45) in a broader sense it can be defined as “a practice of design, education and research that, in some way, contributes to sustainable development”. In the development of sustainable products, there is the problem of the duration of these products in the environment from their conception to their disposal or reuse / recycling and the issue of managing this entire process. Durability, as Kazazian (2005, p.45) supposes an obsolescence management that can be objective (motivated by technical advances) or subjective (motivated by appearance dictated by fashion). Increasing the life span of a product with quality is a timely strategy for a company.

The product seen as a system is a crucial point to understand, study and analyze its life cycle. The product "is interpreted in relation to the flows - of matter, energy and emission - of the activities that accompany it throughout its life". (MANZINI; VEZZOLI, 2002, p.91). the life cycle of a product can be understood as a set of processes grouped according to Manzini and Vezzoli (2002, p.91) in: pre-production; production; distribution; use; discard. Design for sustainability is a method or strategy that combines innovation with the sustainable development of a product, throughout its life cycle, from the extraction of resources to the end of the product's life. Thus, sustainability is divided into three essential elements, that is, users, the planet and profits, that is, it is reflected at a social, environmental and economic level (D4S, 2015, p.21). Each of these elements has strict criteria essential for the success of a product, equipment or service, which must be considered:

- Social Level

**Usefulness** - it is important to define what benefits and contributions the product and its features can bring, both for the user and for society. (FALCATO and BISPO 2006, p.46)

**Usability** - it should be noted whether the product has exceeded the user's expectations, that is, if it has achieved its goals through the effectiveness, efficiency and satisfaction that the product brought during its use in real life, that is, in its day -to-day. (FALCATO and BISPO 2006, p.46)

**Inspiration** - the ability of a product to motivate the user to continue its investment and use must be understood, considering the cost of the product and costs throughout its use, that is, considering the quality and price.

- Environmental Level

**Consumption of resources** - referring to the sustainable and balanced consumption of materials, water, labor and other natural resources, in relation to the country;

**Control of residues and waste** - the extent to which the product motivates and leads to the waste or residues, which may contaminate the land, air or water, to be controlled, as well as considering the expenses of the products and resources used in carrying out the even and even in its use;

**Energy Efficiency** - minimizing energy consumption throughout the product's life cycle.

- Economic Level

**Commercial viability -** it is the way in which the product, compared to the investment in its implementation and throughout its life cycle, offers a profitable return adequate to the investment made;

**Technical feasibility -** is related to the effectiveness of the product and that leads the consumer and user to show confidence and support, so that the necessary production and volume of the product can continue;

**Compatibility -** the ability of a product to work together with other products, in compliance with legal requirements and cultural expectations (WALLER, BRADLEY, HOSKING, & CLARKSON, 2013 p.297);

The inclusion and insertion of a social group, such as the elderly, in technology presents benefits both for companies and for the elderly themselves, who will have a more customized service, avoiding social exclusion and increased problems due to poor adaptation and inclusion of products. With a product and service that adheres to sustainable design, the benefits increase at all levels, both for developers and for the users themselves, in this case the elderly.

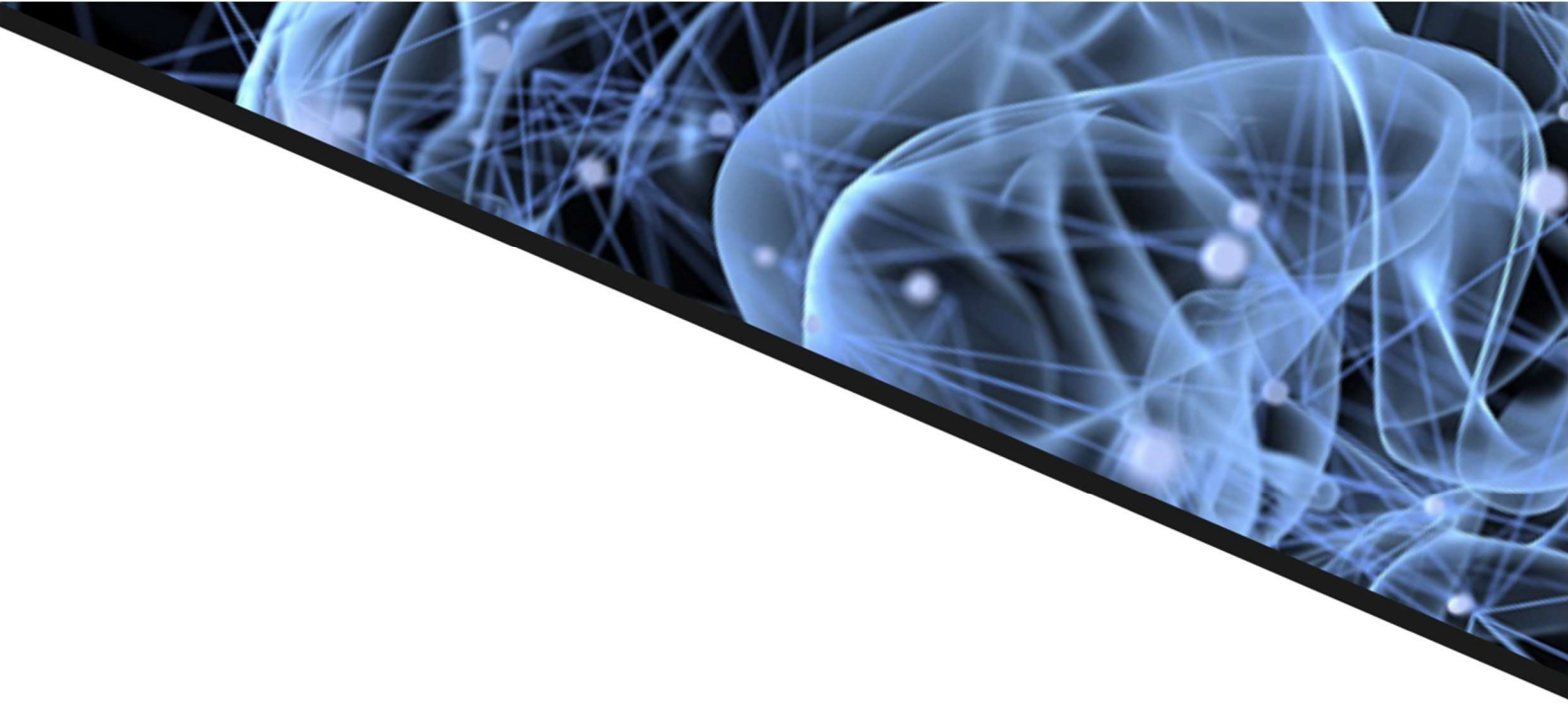
During my period of academic mobility in Finland as mentioned in the introduction to this thesis, I had the opportunity to visit some filaments factories with great innovations in materials that will help the industry to be more environmentally friendly. More and more we see new startups being formed in Finland with corporate social responsibility. Several Finnish organizations have been intrigued by the issue of a sustainable raw material for filaments for years, including Finland's VTT Technical Research Center and Aalto University. In conversation with Professor Pirjo Kääriäinen of Aalto's design-oriented filament innovation, he estimates that seven or eight different projects are underway, and some of them have already left the laboratory.

Based on the content exposed, these things are essential to define the materials to be used in the developed product keeping the original model material, PLA, which represents polylactic acid and one of the most used materials in 3D FDM printing, which uses filaments as raw material. PLA plastic has very interesting characteristics, such as high hardness, gloss and ease of printing.

For the internal comfort of the headset, the VarioShore TPU was defined as the best rubberized filament, allowing users to vary the material density by adjusting the temperature and material yield (speed and height of the layer). At temperatures between 200 and 250 °C, materials will begin to expand to about 1.4-1.6 times their original volume. This means the material can be printed at low flow rates (60-70%) to compensate for active foaming, which in turn results in parts created too soft.

*Figura 12 - soft touch characteristics of varioShore TPU.*

*Figura 13 - latest innovative 3D printing filament by colorFabb*



# CHAPTER 3
## PRODUCT DEVELOPEMENT

## 3. PRODUCT DEVELOPMENT

The product developed during this project is aimed at the elderly user with AD and the medical support team in the context of the health area. It is intended to contribute to a rehabilitation in an easy and effective way, through a technological product that fits the intended functions and considers ergonomic and usability issues as well as its intuitive and innovative potential with the use of technological materials that promote sustainability and other pertinent aspects. The product resulting from this entire project aims to respond to needs and gaps in the current augmented reality headset.

Following the steps of the new product development process ensures success in creating, validating and introducing new design solutions. The creation or redesign of a product can be a complex process, but it must be structured, going through several stages from the conception of the idea to the launch of the product on the market. In business science, the term is new product development (NPD), and there are several possible methods for turning ideas and solutions into successful products. It is necessary to think, of the consumer's needs, as we have discussed throughout the previous chapters and of the trends available in the market, material and economic viability, sustainability, among several other aspects that we will address from this chapter.

The objective throughout this chapter will be to translate a redesign from the user's need into an appropriate product, reinforcing that only a structured process can guarantee the success of innovation, considering aspects such as strategic design and attention to the stages of the development process new products to avoid mistakes.

Therefore, we present an architecture to integrate all aspects previously discussed that discuss design requirements and good aesthetics through the following steps below:

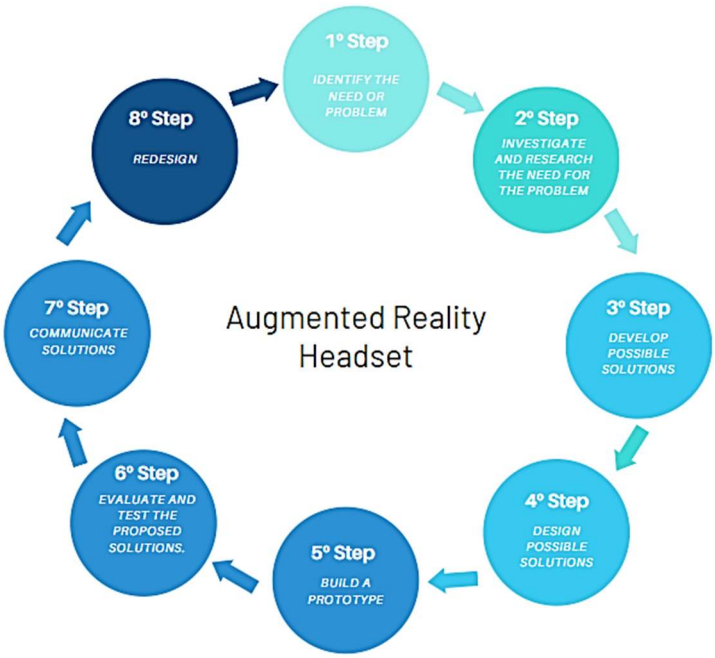



*Figure 14: Product Development Scheme*

Clarkson et al., (2016) argue that it is necessary for the product to reconcile the following characteristics: be functional, responding to the needs and requirements of the target audience; simple to use, becoming more satisfying and avoiding feelings of frustration and exclusion; desirable, a characteristic that can be reached through different paths, from the stimulation of the senses, such as touch or smell, to the perception of opportunity for an improvement in the user's quality of life.

### 3.1 NEED AND PROBLEM

Thinking about improving the quality of life of people who have Alzheimer's Disease, some technologies are being developed to facilitate the rehabilitation of patients as well as promoting the innovation of equipment for use in the context of health, this being an augmented reality headset to assist in health treatments, called assistive technologies, these devices provide the expansion of some functional skills that make a big difference in people's lives. The following questions were shown to be necessary to impact the product redesign:

- How can Product Design contribute to an increase in the independence and autonomy of the elderly in rehabilitation?
- What are the elderly's difficulties regarding the use and interaction with the product?
- Considering the loss of skills of the elderly, how to contribute to their social integration?
- How is the use of technological devices by the elderly characterized?
- How should we integrate the senior generation in new technologies? What would be the benefits of this integration?
- Considering the elderly public, which is not yet integrated in new technologies, and the way in which the product is used, which must be done in an intuitive way, what functions the product should have and how to clarify them to be easy to use and understand?
- Should the product have more than one function?
- How can a product be created that contradicts the hospital image of common products?
- In the case of creating a non-hospital aesthetic and image, how can you highlight your goals and make them reach the right audience?

Health is indispensable for everyone, as well as the inclusion of the elderly in more adapted and optimized health technology systems, to contribute to a more autonomous and more independent healthy life, for a longer time. It is therefore necessary to intervene, through the creation of a product that allows rehabilitation using the capabilities and benefits of technology, through automation and the existence of an application, leading to the integration not only of the elderly but also of the health team, achieving both the carrying out activities.

That is, the elderly enjoys a system adapted to him that gives him support and remembers important actions, while the medical team through an effective design has a high level of rehabilitation and care equipment.

Making decisions about specific user needs is extremely important for the development of this project, focusing on those unique needs that the product will address will ensure that you have a solid foundation, as the needs of the users on which this research focuses will form a core of its product differentiation strategy.

The initial headset showed ergonomic and material problems and mainly in the form of interaction, when using it. Another of the problems that stands out is the fact that the elderly is not included in the technological advancement, which brings countless possibilities and benefits, which leads them to look for ways of inclusion and integration that allow them to enjoy their qualities and a way of easy and intuitive. Thus, the elderly, instead of being left behind, will also be included in the innovation of the systems developed for the health area.

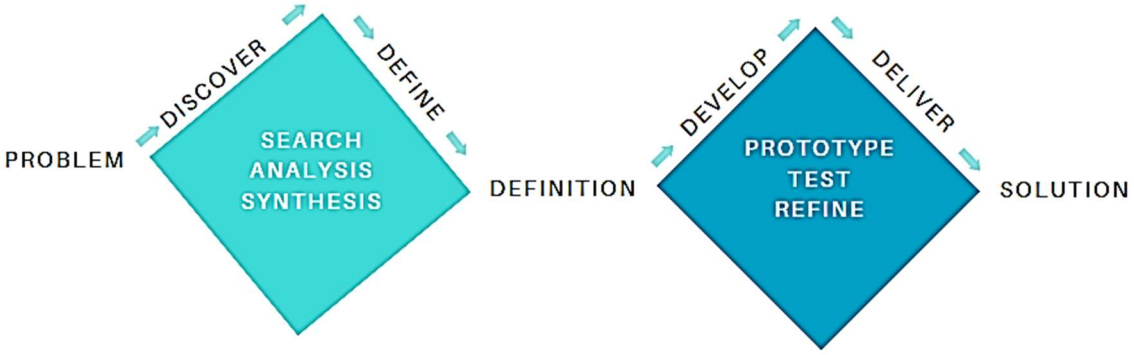



*Figure 15: Product Development from the Problem*

### 3.2 POSSIBLE SOLUTIONS

2018 was heralded as an important year for Augmented Reality. The interest and investment of leading technology companies signaled that augmented reality could finally match the hype and enter the mass market. Unfortunately, the lack of interest from users and persistent problems with hardware and software meant that 2018 was another year of setup. Even the first Magic Leap[3] developer kit did not live up to expectations. However, the enthusiasm of influential companies and ambitious startups has not gone away, and by 2024, the AR market is expected to exceed $ 50 billion.

[3] American startup company that launched a virtual retina monitor on its head, called Magic Leap One, which superimposes computer-generated 3D images on real-world objects.

The year of 2019 AR overcame its technological hiccups and brings an expanded world into focus. The future of AR involves not only startups, but also incumbent operators like apple and microsoft are also making great moves in this field. AR's business applications are growing in terms of data visualization, conferencing and operator support and are expected to continue to grow.

Based on a market study, below will follow a selection of some models of headset and smart glasses that point to paths of analysis of products currently on the market, being necessary to obtain as much information as possible, in order to understand exactly the pros and cons of each of the products, in order to understand which gaps exist in the products taking into account the context and for which it will be used, finding opportunities for innovation and improvement. As there was neither the possibility nor access to most products in real time, this analysis will be made based on articles of a critical and comparative nature of the products and based on videos and real comments from consumers on Youtube.

The criteria used for the analysis of the products are based on:

- Product characterization - synthesis, brand, dimensions;
- Ease of use - intuitive use for the user;
- Ability - that is easy to handle and accessible;
- Comfort - good materials that do not cause discomfort;
- Product capabilities - functions;
- Mechanisms - possible alerts or signaling;
- Technology - internet connection and automated systems;
- Design - Minimalist and Innovative;

Therefore, it was necessary to create specific criteria to evaluate the various products on the market, based on the objectives of this project. Positive properties and product factors were considered, those that understood and answered the identified needs, in the theoretical investigation. Thus, the criteria for evaluation and comparison between products are as follows, represented below:

*Tabela 2- Evaluation for existing products on the market*

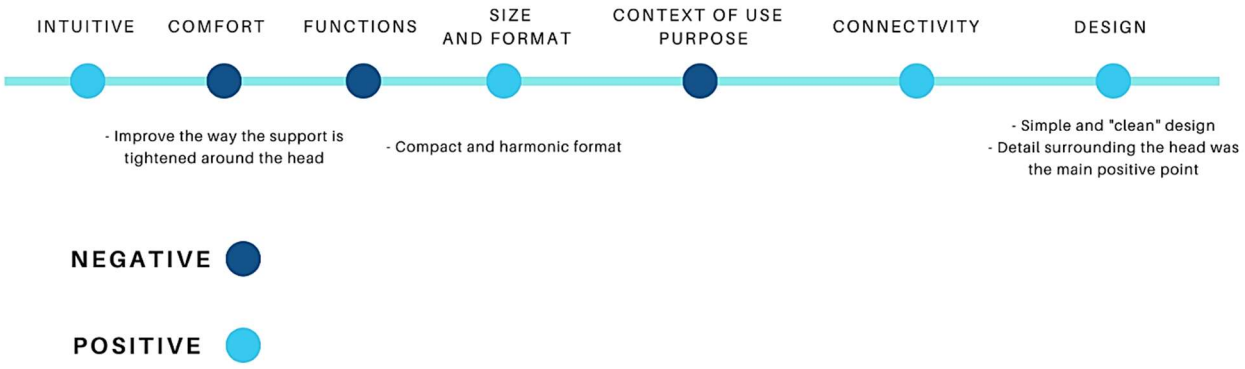
| | POSITIVE | NEGATIVE |
|---|---|---|
| IINTUITIVE | EASY TO UNDERSTAND HOW IT WORKS; OBVIOUSNESS | DIFFICULT TO UNDERSTAND HOW IT WORKS; COMPLEXITY |
| COMFORT | ACHIEVE A GREATER SENSE OF IMMERSION, EASE OF HANDLING TAKING INTO ACCOUNT THE PROBLEMS OF THE ELDERLY | DIFFICULT TO HANDLE AND USE GIVEN THE PROBLEMS OF THE ELDERLY |
| FUNCTIONS | FUNCTION MOST SUITABLE TO THE HEALTH SECTOR OR THE NEED OF THE ELDERLY | FUNCTION NOT SUITED TO THE NEEDS OF THE ELDERLY; DOES NOT HAVE ANY MECHANISMS OR SYSTEMS TO SUPPORT ELDERLY |
| SIZE AND FORMAT | CHECK THAT THE NOSE SPACE IS LARGE ENOUGH, THAT THE STRAPS ARE ADJUSTABLE AND MADE OF A SOFT AND PLASTIC MATERIAL, PRODUCT WEIGHT | RIGID AND COMPLEX FORMAT; HEAVY. |
| CONTEXT OF USE / PURPOSE | IF THE PRODUCT IS DESIGNED FOR USE IN THE HEALTH CONTEXT | IT WAS NOT DESIGNED FOR THE HEALTH CONTEXT |
| CONNECTIVITY | WIRELESS SYSTEM | CABLES AND CONNECTIONS |
| DESIGN | MINIMALIST AND FUTURIST | COMPLEX AND ROBUST |

In each product, at the end of its description, a quick evaluation of the product will be carried out, through a frieze that represents all the points present in the criteria table, to understand its positive and negative points. Thus, the positive points will be marked with the light blue color and the weak points with the dark blue color.

**Microsoft**

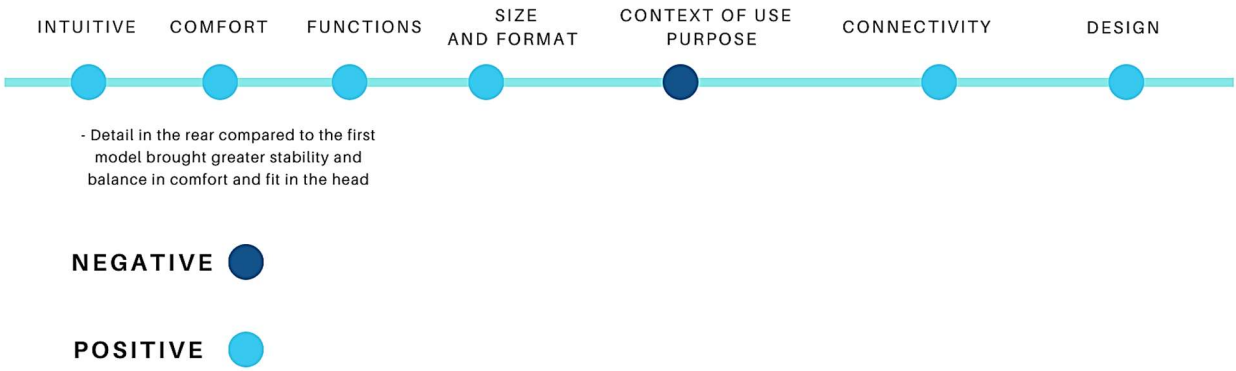
Microsoft refers to itself as 'the leader in mixed reality'. Mixed reality refers to the combined power of augmented and virtual reality when deployed in the real world. Its main HoloLens headset is generally considered an AR device. The first iteration of HoloLens went on sale in 2015 at a price of € 2,719. While the price limited its adoption in the consumer market, the product offered high quality AR and demonstrated Microsoft's success in developing the technology. Also in 2015, Microsoft launched a catalog of mixed reality experiences on its Windows Mixed Reality platform. Users can access mixed reality content, including games, 360 ° videos, social media and events (MICROSOFT, 2015, s.p.).

*Figure 16: Headset Hololens 1 (MICROSOFT, 2015, s.p.)*




The announcement of the second version of HoloLens, HoloLens 2, was launched in the first quarter of 2019. The product is lighter than its predecessor and will feature a custom Holographic Processing Unit incorporated with a powered coprocessor. This will allow the headset to view data locally without communicating with the cloud, accelerating object recognition and increasing use in business applications. (MICROSOFT, 2019, s.p.)

*Figure 17: Hololens 2 (MICROSOFT, 2019, s.p.)* *Figure 18: Hololens 2 (MICROSOFT, 2019, s.p.)*



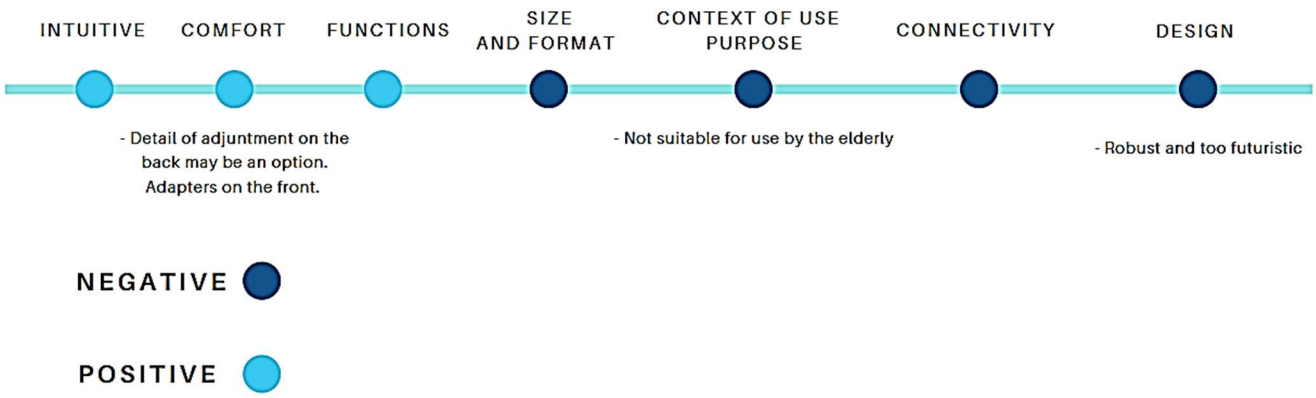

**Magic Leap**

In 2018, Magic Leap finally launched a tangible product. Although the Magic Leap One headset has made the improvements expected from previous alternative HMDs, it certainly hasn't impressed the tech community. Then, to make matters worse, Magic Leap lost a € 480 million military contract with Microsoft (MAGICLEAP, 2018, s.p.).

*Figure 19: Headset Magic Leap One (MAGICLEAP, 2018, s.p.)*

Even so, Magic Leap is still widely considered 'the one to watch' in this context. The startup expanded its partnership with AT&T to build solutions for companies. The first three sectors to be benefited will be manufacturing, retail and health. In other words, the Magic Leap is diversifying, and AT&T will also provide the 5G connectivity needed to deliver high-quality AR content (MAGICLEAP, 2018, s.p.).

*Figure 20: Magic Leap One (MAGICLEAP, 2018, s.p.)*



**Asus**

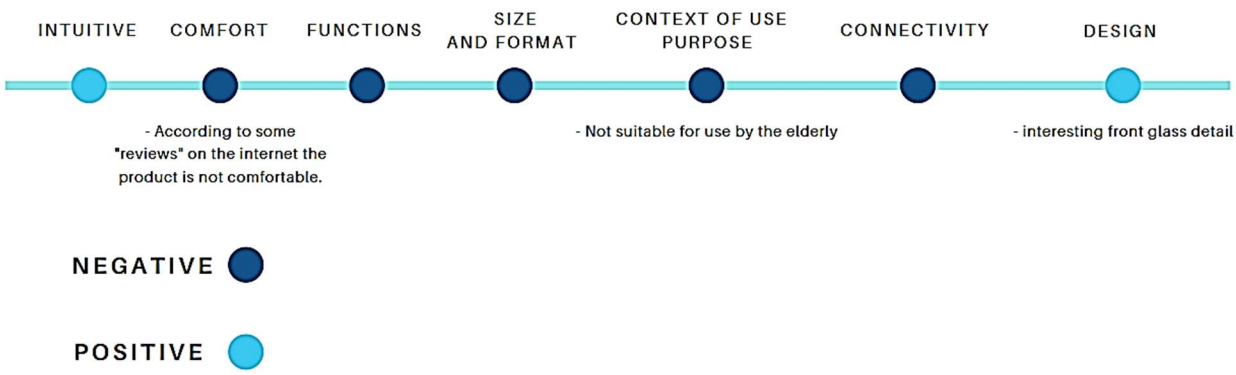
The Asus Augmented Reality Headset has moved the technology business sector as a major potential launcher to provide consumers and brands with an affordable way to incorporate AR into their daily schedules.

According to Asus CEO Jerry Shen, the Asus Augmented Reality Headset is set to be more interactive and intuitive when compared to existing virtual reality headsets on the market that simply provide an experience but leave little room for user interaction (Asus, 2018, s.p.).

*Figure 21: Headset Asus (ASUS, 2018, s.p.)*

As Asus has a history of incorporating solutions that work well with Microsoft's software environment, the Asus Augmented Reality Headset is certainly a victory for business professionals and consumers looking to experience RA technology (Asus, 2018, s.p.).

*Figure 22: Vista Frontal Headset Asus (Asus, 2018, s.p.)*



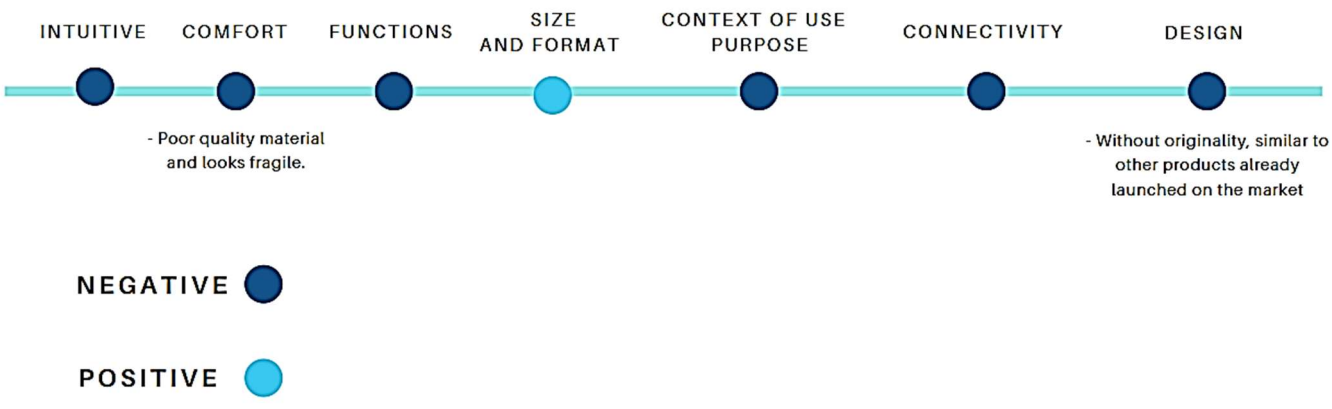
**Lenovo**

Lenovo unveiled its new family of AR headsets designed primarily for business applications. Positioned as a potential competitor to Microsoft's HoloLens, Lenovo's ThinkReality head mounted monitors will feature software and hardware developed by Lenovo for workers who can take advantage of AR in various industries (Lenovo, 2019, s.p.).

*Figure 23: Headset Lenovo frontal (Lenovo, 2019, s.p.)*

The first member of the family is the ThinkReality A6 AR headset, which is powered by a combination of Qualcomm's Snapdragon 845 application processor and an Intel Movidius VPU. A two-part solution, Movidius VPU is in the headset itself, while the more powerful Snapdragon SoC is in a separate 'Android computing box'. The HMD offers 1080p resolution per eye, as well as a 40-degree diagonal field of view (Lenovo, 2019, s.p.).


*Figure 24: Headset Lenovo vista lateral (Lenovo, 2019, s.p.)*



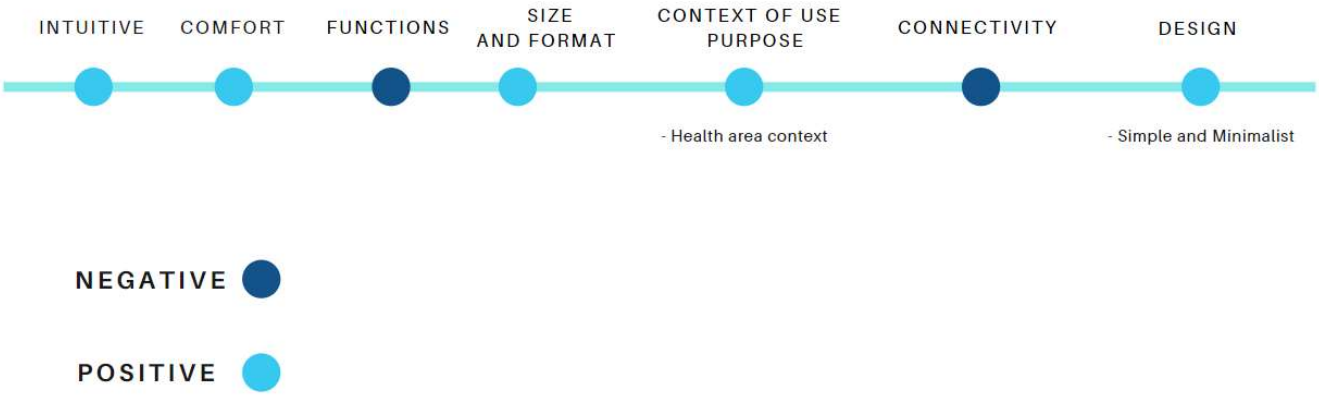
**Dream World**

Augmented reality is still incredibly expensive and offers limited use for most ordinary people. DreamWorld wants to help solve this by lowering the price and, at the same time, providing good AR fun (DREAMWORLD, 2018, s.p.).


*Figure 25: Headset DreamGlass AR (DREAMWORLD, 2018, s.p.)*

Your attempt to do this is the DreamGlass AR headset. It has a 90-degree field of view with 2.5K resolution. There is also 3DoF head tracking and hand gesture recognition, so you can partially interact with your new, augmented world (DREAMWORLD, 2018, s.p.).

*Figure 26: Headset DreamGlass AR (DREAMWORLD, 2018, s.p.)*

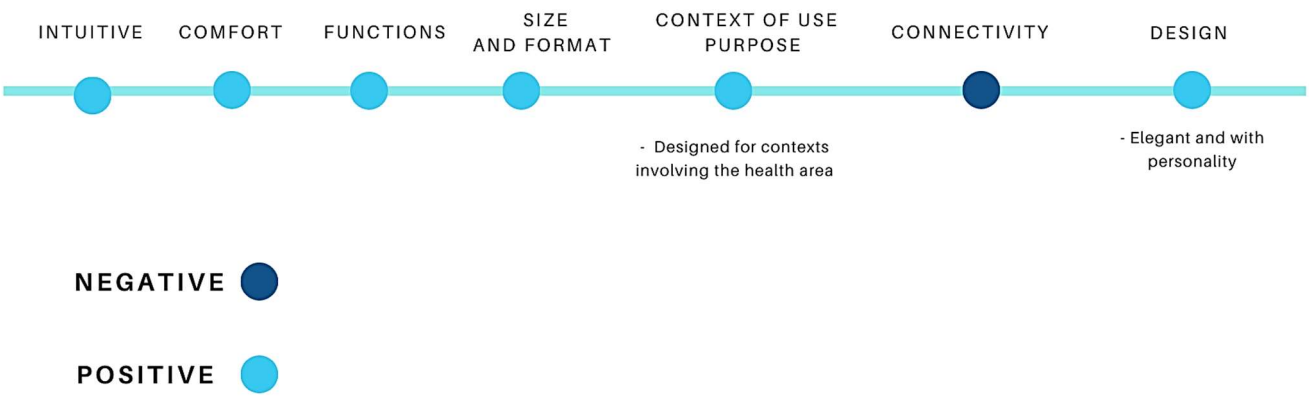


**Meta View**

*Figure 27: Headset Meta 2 (Meta View, 2016, s.p.)*

Meta, maker of the augmented reality headset Meta, was sold to a new company called Meta View. The new company will be led by former Qualcomm executive Jay Wright and is building "a complete hardware and software solution for a specific use case", rather than a generalist RA headset (Meta View, 2016, s.p.).

*Figure 28: Headset Meta 2 (Meta View, 2016, s.p.)*



**Niantic**

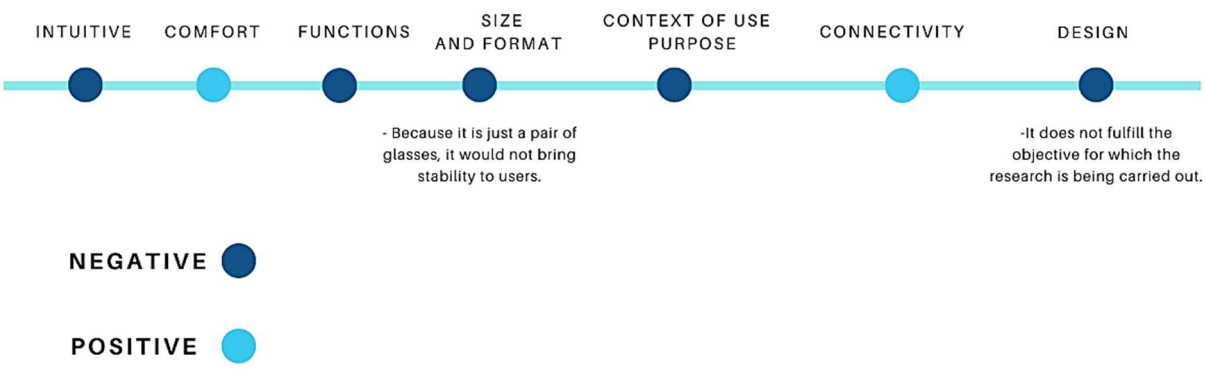
Niantic, a by-product of Google, was founded in 2010 to 'enrich our experiences as human beings in the real world' with augmented reality. The company's real-world platform manages shared communications, security, mapping and RA functionality. According to Niantic, it is the only 'planetary scale' augmented reality platform in the world. In the summer of 2016, Niantic launched the game that would quickly become the poster child for augmented reality. (Qualcomm Technologies, 2016, s.p.)

The popular Pokémon Go brought AR to the market and remains the most successful AR game ever made. Niantic Labs has partnered with technology company Qualcomm to produce a new line of smart glasses; Augmented reality hardware designed to show digital information to a user through screens and speakers built into a pair of glasses.


*Figure 29: Snapdragon XR2 Headset (Qualcomm Technologies, 2016, s.p.)*

AR games are an economy and popular games change the public's awareness of technologies, which in turn makes business adoption broader, more viable and affordable (Qualcomm Technologies, 2016, s.p.).


*Figure 30: Snapdragon XR2 Headset (Qualcomm Technologies, 2016, s.p.)*



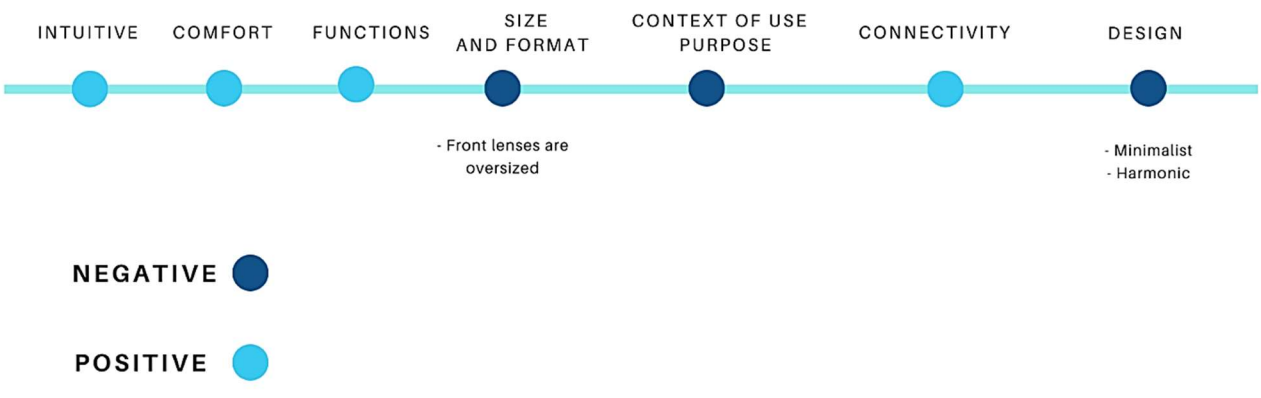
**Ximmerse**

Ximmerse is a technology company that aims to explore the low-cost mass market in the field of Augmented Reality and Virtual Reality. Ximmerse has also created many mobile device solutions. They are known in the field as an innovative technology company with a promising future in the field of AR and VR solutions. (Ximmerse, 2019, s.p.)

*Figure 31: Rhino X AR (Ximmerse, 2019, s.p.)*

In addition, with the recent YouTube video introducing the Rhino X AR headset, they have sparked many interests among AR enthusiasts. They provoke viewers by showing a variety of experiences, such as tactical training with firearms, multiplayer games and more. The product design is also slightly introduced in the video, which looks wonderful. The launch of Rhino X is a great achievement for the company. Not only is it aesthetically amazing, but it also has some notable features. (Ximmerse, 2019, s.p.)

*Figure 32: Rhino X AR (Ximmerse, 2019, s.p.)*



**Zappar**

Created in 2011, Zappar aims to democratize AR through a free application and a simple SaaS model for brands that want to build AR solutions. The company has partnered with Unilevel, Warner Bros and AXA, and has worked with several influential brands like Coca Cola and Sony. The ZapWorks platform from Zappar allows marketers, designers and developers to create interactive experiences that are accessed through digitizing zapcodes via mobile. (Zappar, 2020, s.p)

Zapcodes can transform products, packaging and passive printing into multimedia channels that drive engagement and unlock value for brands. At Augmented World Expo 2017, ZapWorks was elected the Best Authoring and Publishing Tool. (Zappar, 2020, s.p)

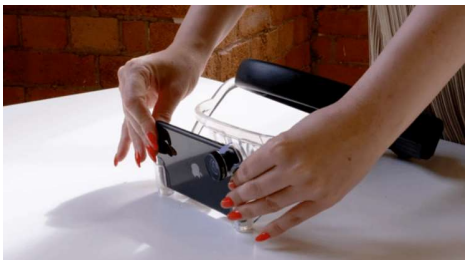
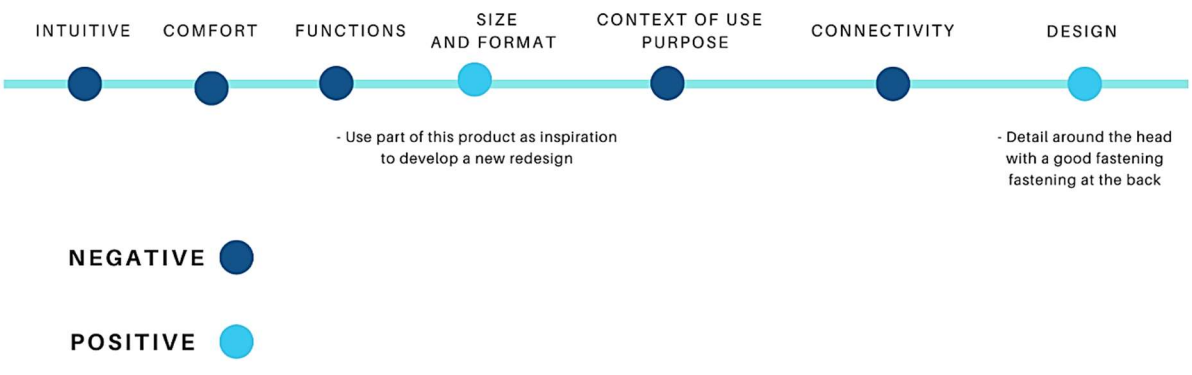


*Figure 33: Heasetd ZapWorks (Zappar, 2020, s.p)*

*Figure 34: Headset ZapWorks (Zappar, 2020, s.p)*

*Figure 35: Headset ZapWorks (Zappar, 2020, s.p)*



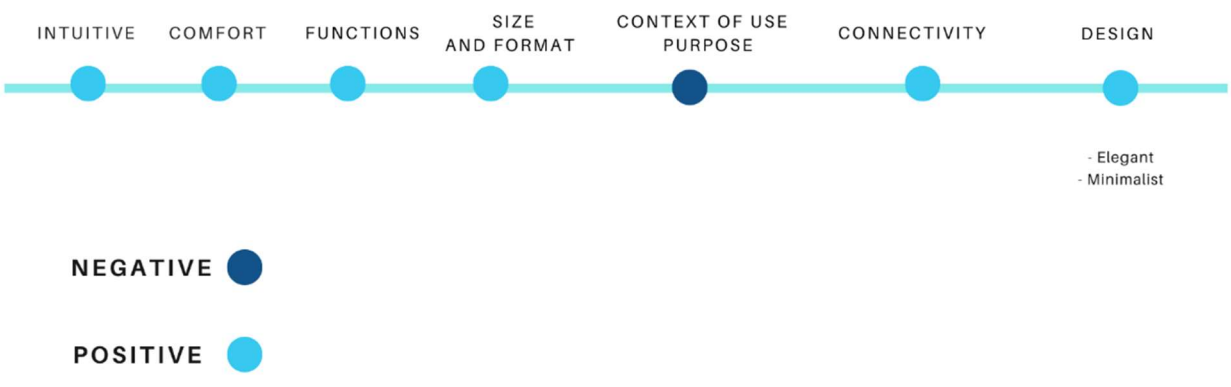
**DreamGlass Air**

AR DreamGlass Air glasses use AR to provide users with a private viewing experience that includes a 100 ”2.5K screen on a generous 90-degree FOV, multiscreen functionality, stereo sound and compatibility with a multitude of devices. Powered by its own dedicated battery (capable of up to 5 hours of playback), DreamGlass Air connects to smartphones and tablets, computers and game consoles to create a large AR-based screen on which you can enjoy content privately.


*Figure 36: Headset Dreamglass Air (DREAM WORLD VISION, 2020, s.p)*

Unlike other existing AR headsets, such as Microsoft HoloLens 2 or Magic Leap One: Creator Edition, DreamGlass was specifically designed to function as a private screen instead of a dedicated computing device. As a result, the headset does not include any form of on-board interactivity. Instead, it serves as a complementary tool for existing devices (DREAM WORLD VISION, 2020, s.p).

*Figure 37: Headset Dreamglass Air (DREAM WORLD VISION, 2020, s.p)*



**Yanko Design**

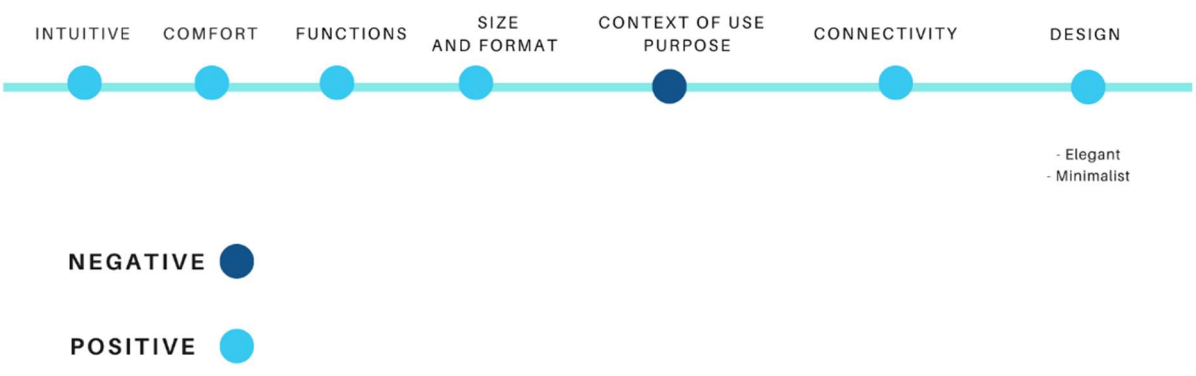
Designer Jonggun Kim sees something very important with the adoption of AR and VR on a commercial level in large proportions, as it is less likely that we will adopt it if it is foreign to our current lifestyle. No one carries (or needs to carry) an RV or AR headset with them, so the only way to make them more widespread is to actively integrate them into your lifestyle (YANKO DESIGN, 2020, s.p).

*Figure 38: Headset Prism (YANKO DESIGN, 2020, s.p)*

*Figure 39: Headset Prism (YANKO DESIGN, 2020, s.p)*

No one carries an augmented or virtual reality headset, but there is a large part of the population that carries headsets with them. Realizing this, the Prism is an AR headset that turns into a pair of innocuous headphones. With a HUD that slides up and down, you can turn the Prism from an immersive RA audiovisual experience.

*Figura 40: Headset Prism vista lateral (YANKO DESIGN, 2020, s.p)*



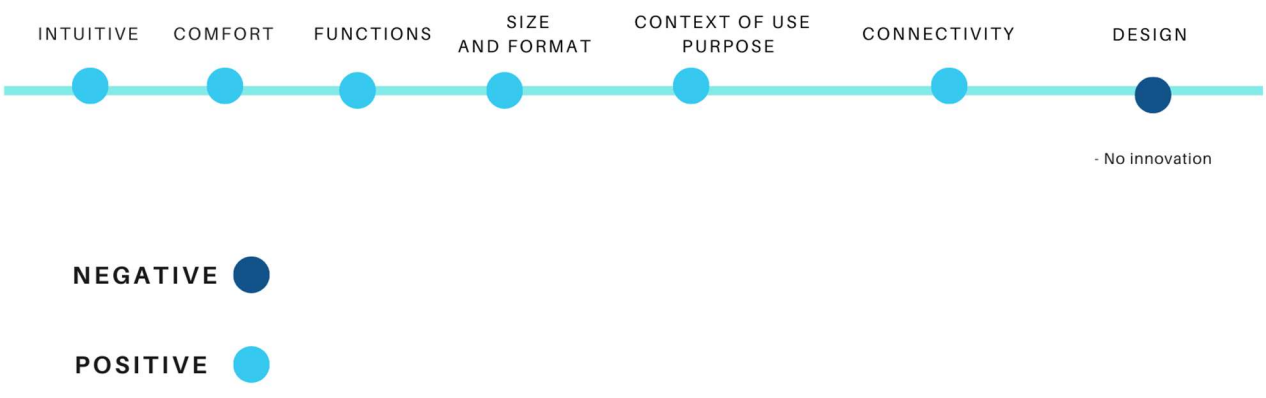
**LightSpace**

LightSpace is working on a new RA headset design - using a freeform optical combiner that is integrated into a safety protective glass, easy to sterilize. The idea came up in the context of the coravirus in partnership with AR developers and doctors redefining the ways of using the AR headset (LIGHTSPACE, 2020, s.p).


*Figure 41: Multi-focal Stereoscopic 3D (LIGHTSPACE, 2020, s.p)*

As a result, the headset will provide capture of patient data and visualization of 3D patient medical data sets (x-ray computed tomography, test results and more) directly from the database in a virus-contaminated environment, without the need for use complicated document blocks to sterilize (LIGHTSPACE, 2020, s.p).

*Figure 42: Multi-focal Stereoscopic 3D (YANKO DESIGN, 2019, s.p)*



**Nreal**

Nreal has released its new standalone augmented reality headset, launched in the fourth quarter of 2020. The new headset is a business version of the company's Nreal Light AR eyewear design for the consumer market. Nreal will compete with other headsets in the corporate market, such as Microsoft's HoloLens 2 (NREAL, 2019, s.p).

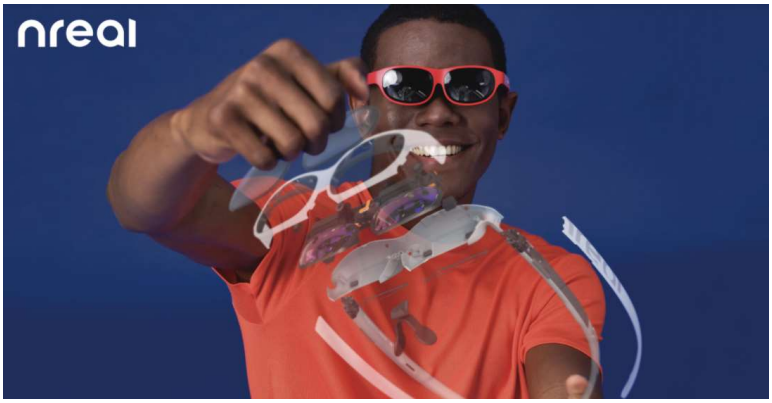
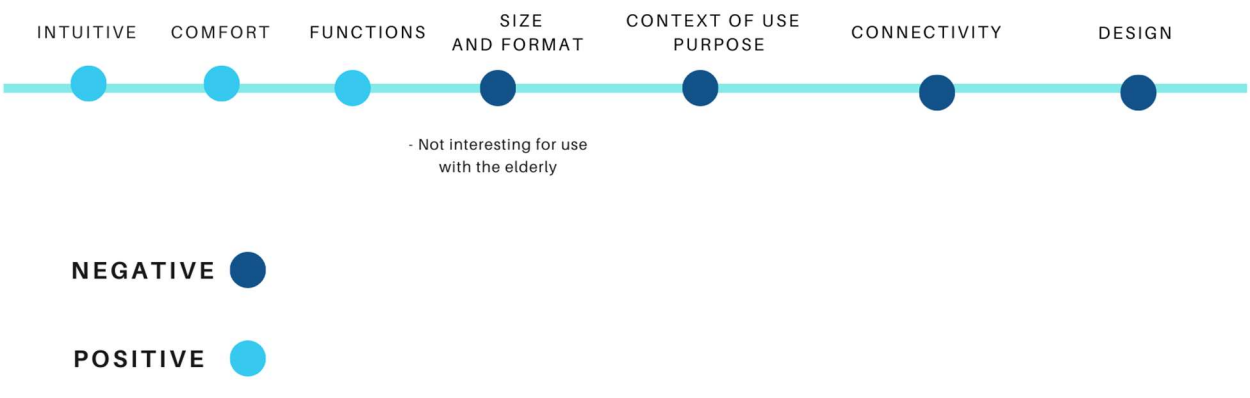



*Figure 43: Headset Nreal (NREAL, 2019, s.p)*

The consumer version of Nreal Light, priced at $ 499 compared to Hololens 2 targeted at Microsoft companies, priced at $ 3,500, or the Magic Leap 1 at $ 2,295, Nreal Light is much closer to the market of mass, despite offering a lower resolution, lack of wireless connectivity and less varied content (NREAL, 2019, s.p).


*Figure 44: Headset Nreal vista lateral (NREAL, 2019, s.p)*

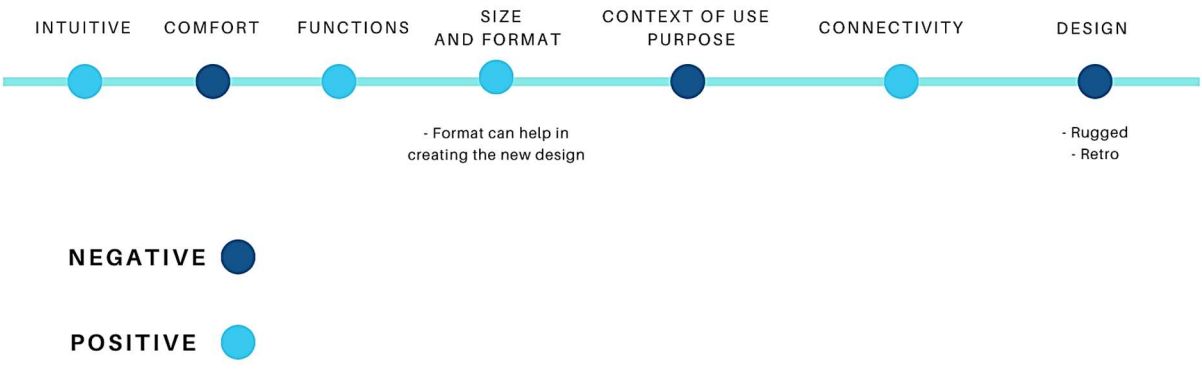


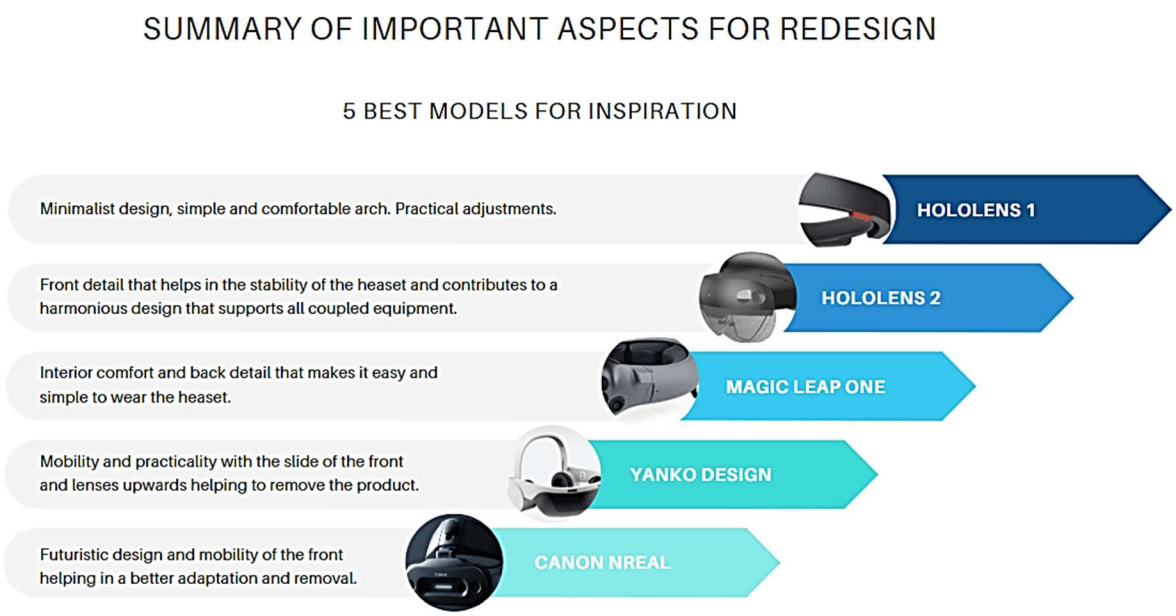
**Canon**

In early 2020, Canon unveiled the MREAL Display MD-20 with a business focus like the previous version, which is an augmented reality headset. The MREAL S1, on the other hand, is more of a virtual reality headset that has a pass-through AR feature. This was accomplished through the inclusion of stereoscopic camera sensors that are located on the front of the device and with virtual reality screens to offer users a "mixed reality".


*Figure 45: Headset MREAL Display MD-20 (CANON, 2020, s.p)*

*Figure 46: Headset MREAL Display MD-20 (CANON, 2020, s.p)*






Thus, after the market study it was concluded that:

- Most headsets still have a very similar image in terms of design, which makes their function clear with aesthetics adapted to the user's expectations of use for each specific context;

- Most of the most accessible headsets are those with a common and simple design, such as figures 19, 20, 26, 29, 30, 31, 32 and 33, the majority being similar in shape without major innovations. The more expensive and soon more elaborate models offer more attributes, both aesthetic and ergonomic, as well as mechanisms for inspiration;

- The models Snapdragon XR2 Headset (figures 25 and 26) and Nreal (figures 39 and 40) are not very useful for the study of shapes that will be developed in the next subchapter, with simple glasses format without the necessary stability around the head in view of all the problems reported in previous studies that the elderly may suffer from Alzheimer's disease, the ideal is the product to be built with a stable support on the head and not just being glasses;

- The detail of the Prism headset (figures 34, 35 and 36) in which it has a "glide system" turning an arc in the head is interesting and will be studied as a way of generating greater adaptation, comfort and even flexibility to the product to be built. However, there are still many criteria to be developed in view of the needs of elderly users that must be considered;

- The last researched headset (figures 41 and 42) despite its robust appearance has several positive features that will be addressed in the study of shapes in the next subchapter, it has a futuristic image, but at the same time fits into the product profile already used in health context, which would not be surprising to elderly users possibly adapted to the hospital or clinical environment;

According to the Statista Research Department, estimates suggest that by 2021 the AR and VR headset market will reach around 5.5 million units. Forecasts project massive growth in headset sales in the coming years, with both combined technologies estimated to sell more than 26 million units a year by 2023. With market revenues expected to grow to around $ 19 billion by 2021, developing a good solution mainly for the health context is very important and urgent (Statista Research, 2021).

### 3.3 STUDY OF SHAPES

The North Star Project is an open source RA headset originally developed by LeapMotion (now UltraLeap) in June 2018. The project has had many variations since its inception, both by UltraLeap and the open source community.

The headset is almost completely 3D printable, with a handful of components like reflectors, circuit boards, cables, sensors and screws that need to be supplied separately. Fortunately, with the help of Noah Zerkin, all parts for making North Star headphones are easily accessible through Intelligent Prototyping.

The Northstar Project has had its fair share of revisions and updates since the original open source files were released. To clear up any ambiguity from the start, Release 1 was an internal release. Version 2, the first public open source version (sometimes called the initial version), was in 2018. Version 3 came in 2019 and improved the mechanical design in several ways. As shown in the table below, the newly launched Deck X is probably what new users will want to start with. It uses an integrated circuit board to reduce the headphone cables to just two (USB 3 / mini DP), combining USB devices in a custom USB hub + Arduino module.

Project North Star calls itself the world's first serious open source headset project. An elementary component is the Leap Motion Sensor, which uses two thermal cameras and three infrared LEDs to determine the position of the hands. The cameras record 200 frames per second and the associated software calculates the 3D position of the hands in the images with functionalities necessary for the experiments.

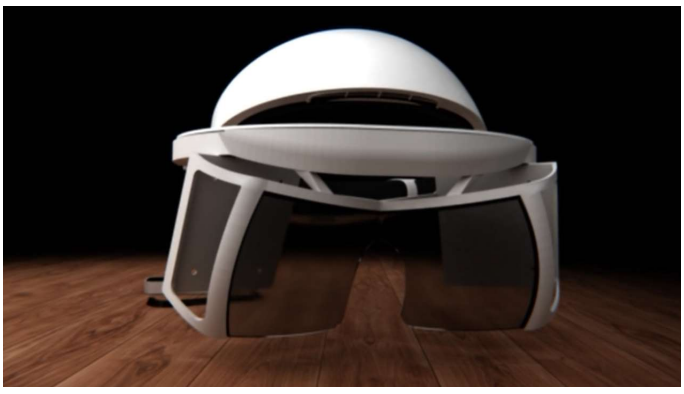


*Figure 47: Headset North Star (LEAPMOTION, 2021)*

All the information needed for printing and assembly was found on the Leap Motion home page and it was possible to start immediately. The files contain good material with all the items needed to print.

*Figure 48: Headset North Star (LEAPMOTION, 2021)*

Although it is extremely bulky, it is quite light. The visual quality of the lenses is good, especially if the space is slightly darkened. Users who generally must wear glasses can wear them without discomfort or loss of focus.

Bearing in mind that the North Star Project is an ongoing prototype, in which the efforts of this thesis are to improve it for its proper context of use, the product is not marketable, and the functionalities are currently limited to the possibilities of Leap Motion, which is a sensor in the glasses. Regardless, it is a good way to gain some experience with augmented reality.

Through the Reddit platform, which is an aggregation of social news, in which users can post content links on the web such as posts and images, in which other users can then vote positively or negatively, a discussion channel about the Project was created. North Star where I got technical information on the critical points.

Just like the GitHub platform, which is a distributed version control system, used mainly in software development, but can be used to record the history of edits of any type of file, in the Leapmotion / Project North Star forum there are updates for several problems as well as solutions.

After an analysis of all the weaknesses and strengths regarding the headset design above, shape and size, among other aspects follows some positive and negative points that we will consider in the redesign of the new headset in the table below:

*Table 3 - Evaluation for existing products on the market*

| | POSITIVE | NEGATIVE |
|---|---|---|
| VIEWERS | TWO SMALL MONITORS | X |
| COMFORT | X | UNCOMFORTABLE WITH THE NEED FOR ADAPTATION |
| WEIGHT | X | HEAVY WITH NEED TO EXCHANGE MATERIALS |
| SIZE AND FORMAT | X | VERY BULKY |
| ERGONOMICS | X | NO ERGONOMICS |
| CONNECTIVITY | X | MANY CABLES AND CONNECTIONS |
| DESIGN | X | COMPLEX AND ROBUST |

The challenge is to find something that strikes a balance between performance and form factor, as some changes would enrich the product design to be developed as:

- Built-in cameras facing inwards for automatic and accurate alignment of the enlarged image with the user's eyes, as well as eye and face tracking.
- Head mounted ambient light sensors for 360-degree lighting estimation.
- Directional speakers close to the ears for discreet and localized audio feedback.
- Electrochromatic coatings on reflectors for electrically controllable variable transparency.
- Micro-actuators that move screens in fractions of a millimeter to allow variable and dynamic depth of field based on eye convergence. The field of view could be further increased by moving to slightly non-ellipsoidal "freeform" shapes for the reflector or by slightly curving the screens themselves (as in many modern smartphones).
- Mechanical tolerance is of utmost importance and, without precise calibration, it is difficult to align everything. Expect a post about our efforts here, as well as the optical specifications themselves next week.
- In this augmented reality system there are two 120 fps, 1600 × 1440 screens with a field of view that covers more than one hundred degrees combined, along with 150 fps hand tracking in 180 ° x 180 ° field of view.

Putting these points mentioned in this headset, the resolution, latency and limitations of the field of view of today's systems disappear and we face the question that lies at the heart of this effort: What and how would be the best way to reconstruct?

With the objective of understanding in concrete the creation of the product, in this specific case the redesign process of an augmented reality headset until the final shape, this chapter focuses on images, drawings, sketches and even collages the concept design and inspiration of the product that will be defined in the later chapter.

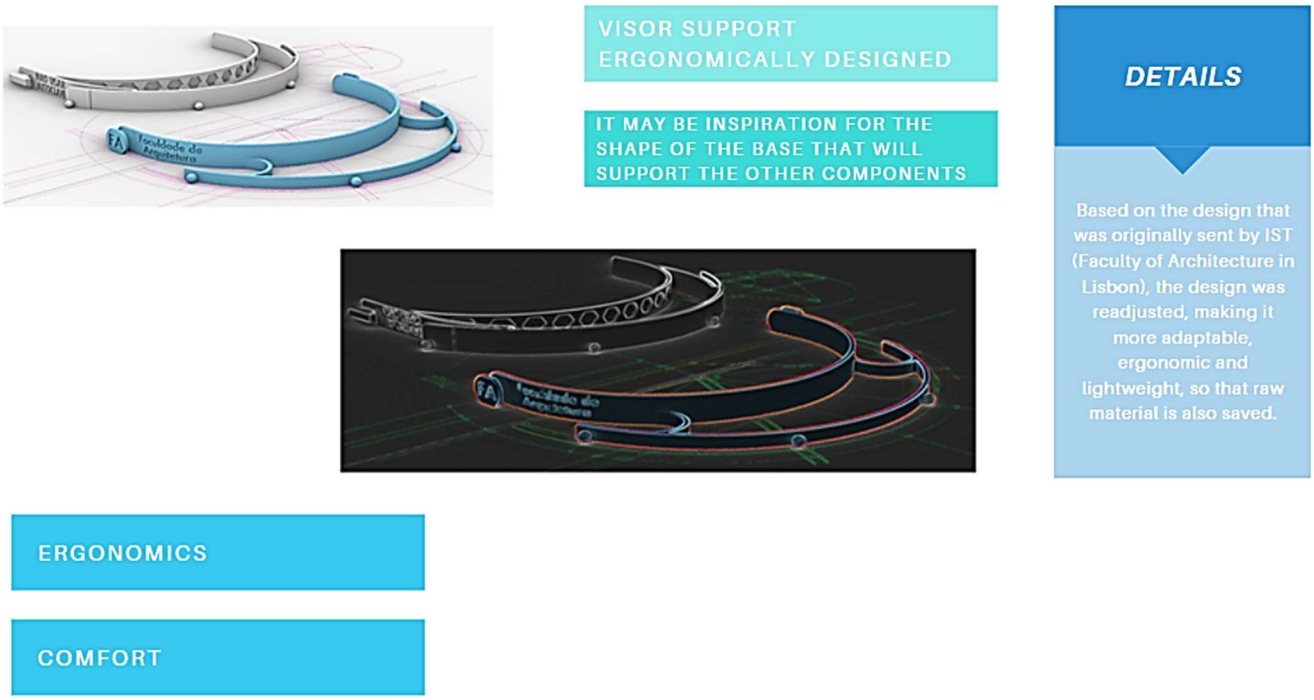



*Figure 49 – Visory Support (Lisbon University, 2019, s.p)*

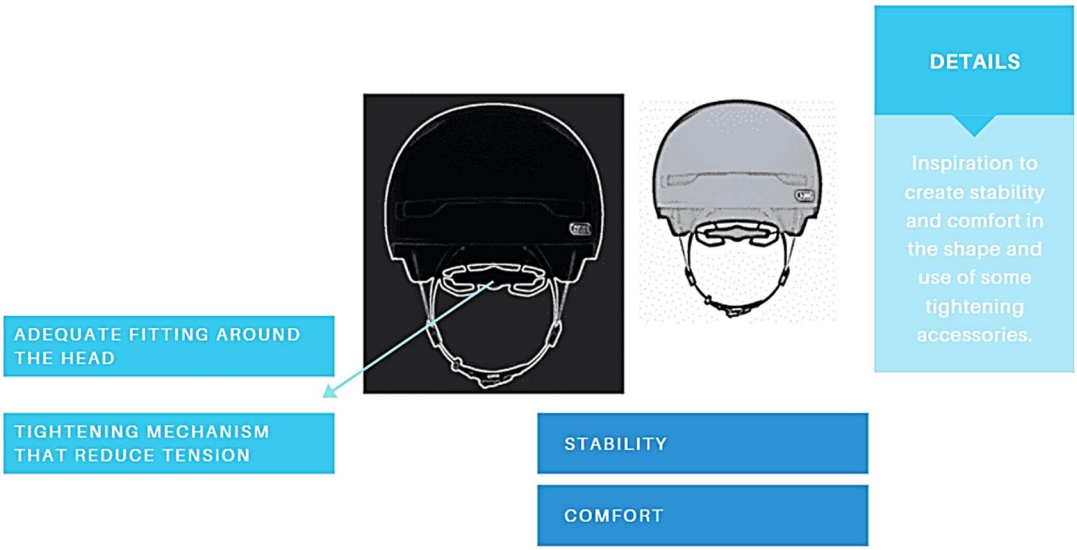



*Figure 50 – Tightening Mechanism, 2021, s.p*


*Figure 51 – Go Pro Camera Accessory, 2010, s.p*


*Figure 52 – Ergonomic stem, 2009, sp*

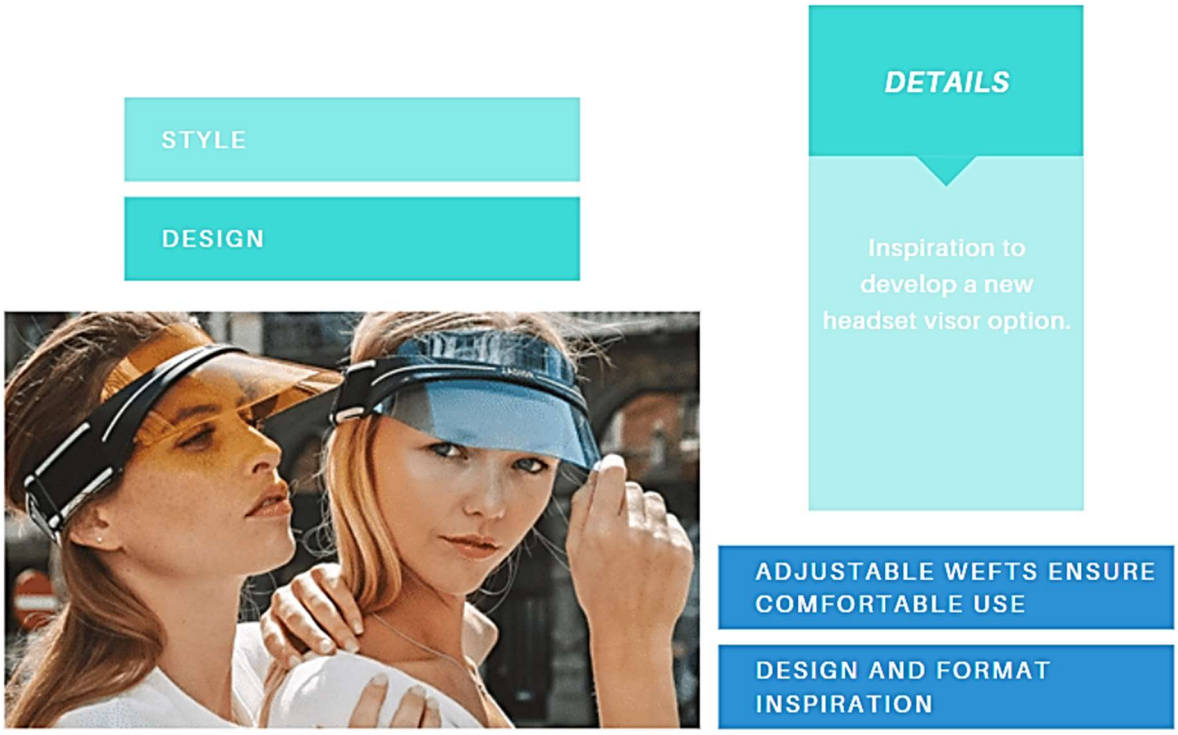



*Figure 53 – Channel Headset Visor, 2012, sp*

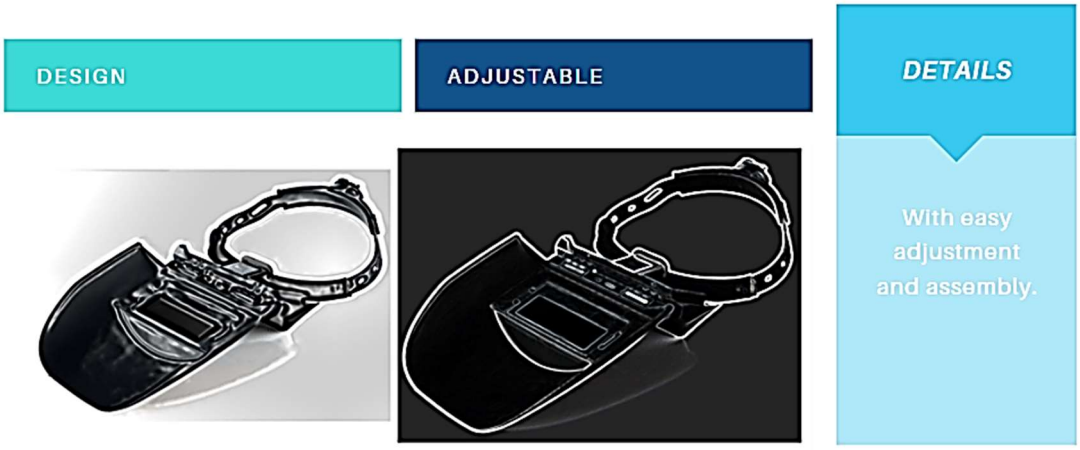



Figure 54 – Adjustment and Assembly, 2019, sp

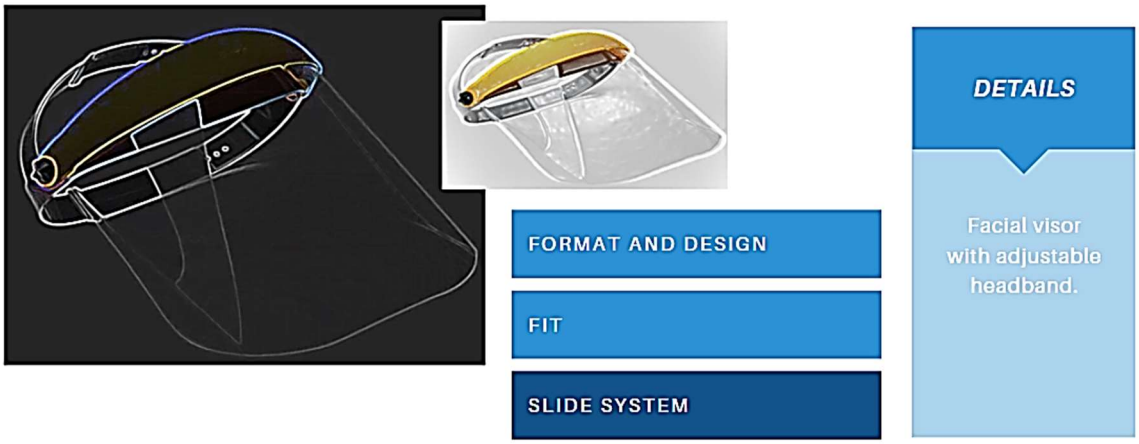



*Figure 55 – Facial Visor, 2019, sp*

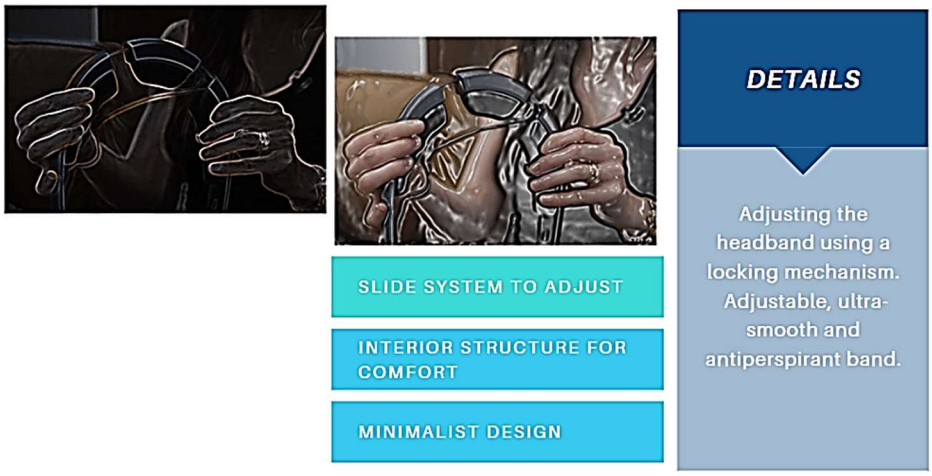



*Figure 56 – Slide System, 2019, s.p*

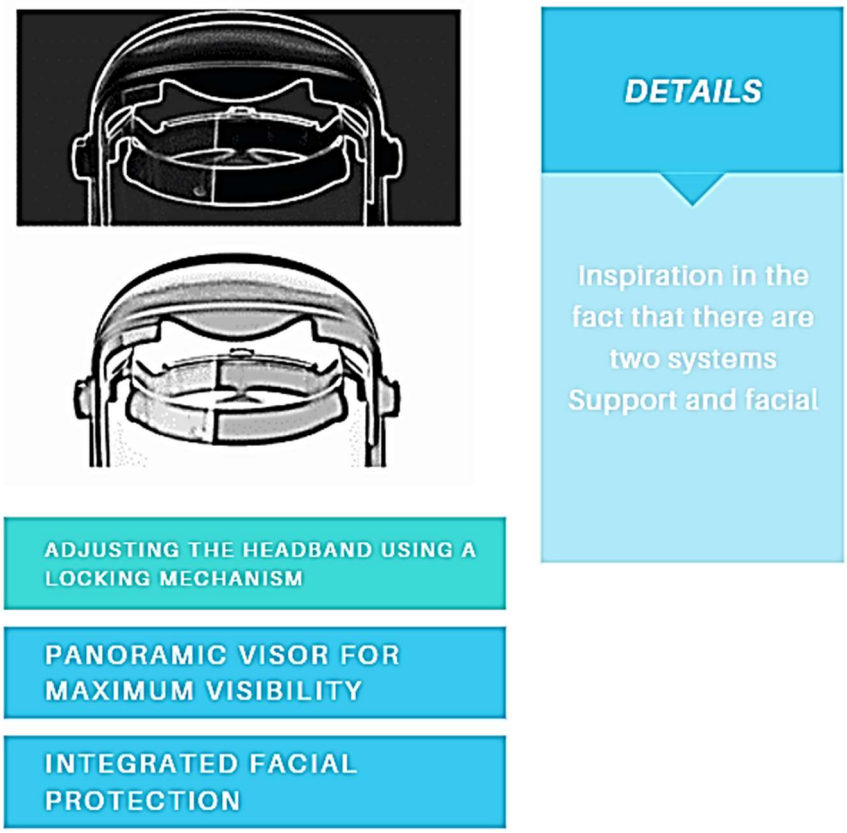



*Figure 57 – Adjusting Headband, 2010, s.p*

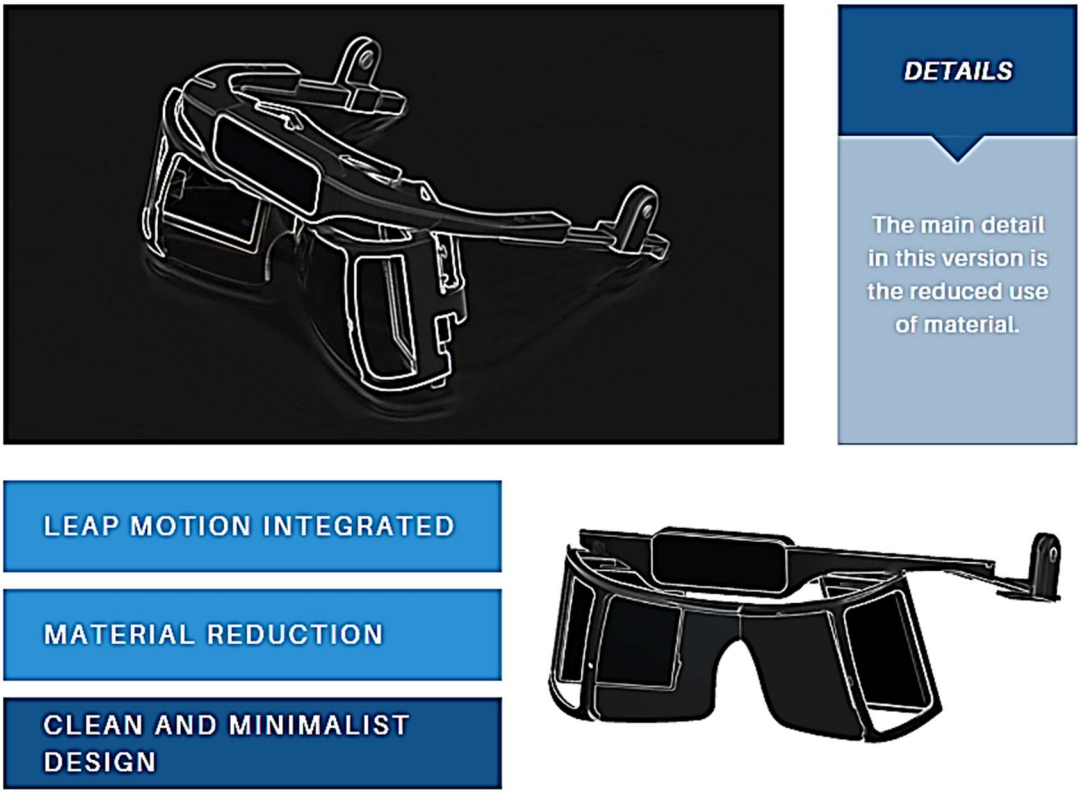



*Figure 58 - North Star Headset, 2021, s.p*

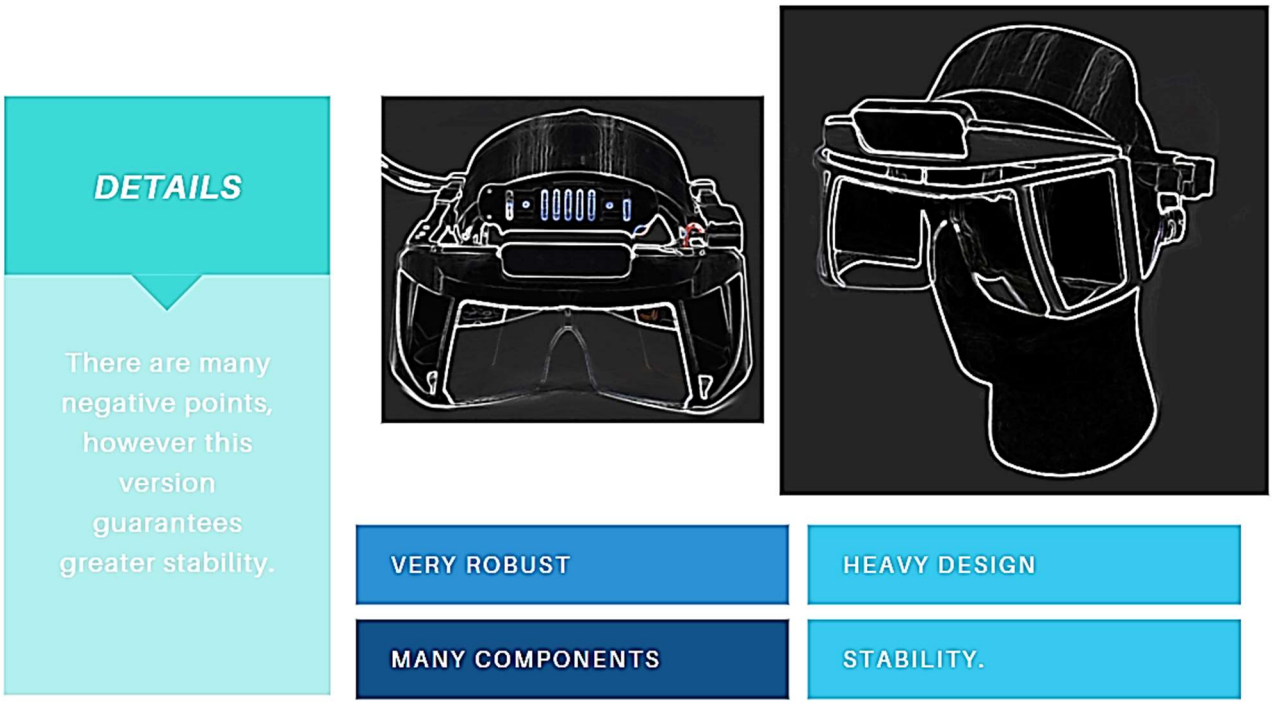



*Figure 59 – North Star Headset 2, 2018, s.p*


*Figure 60 – North Star Headset 3, 2020, s.p*

### 3.4 PROTOTYPES

To test its design and functionality, prototypes were made initially, for reasons of practicality and speed. To create a base formed from the heasdset North Star, the first option was made of wire so that it could be molded into a new shape. However, the objective was not reached, and the first prototype did not create for the construction stability and placement of the available team placement, just as it was not possible to create a good design as possible to see in the images below:

*Figure 61 - First wire prototype (Personal File)*

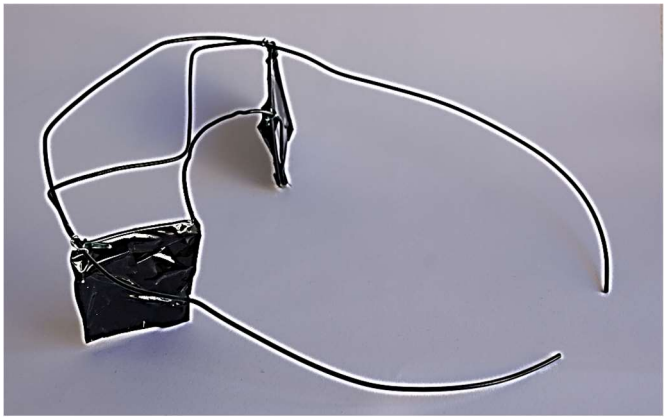


*Figure 62 – Wire prototype (Personal File)*

The second attempt, in addition to the wire, opted for the use of rubberized material, adhesive tapes and high-grassed paper plates, with three prototypes being produced where each one is concerned with the aspects covered throughout this research.

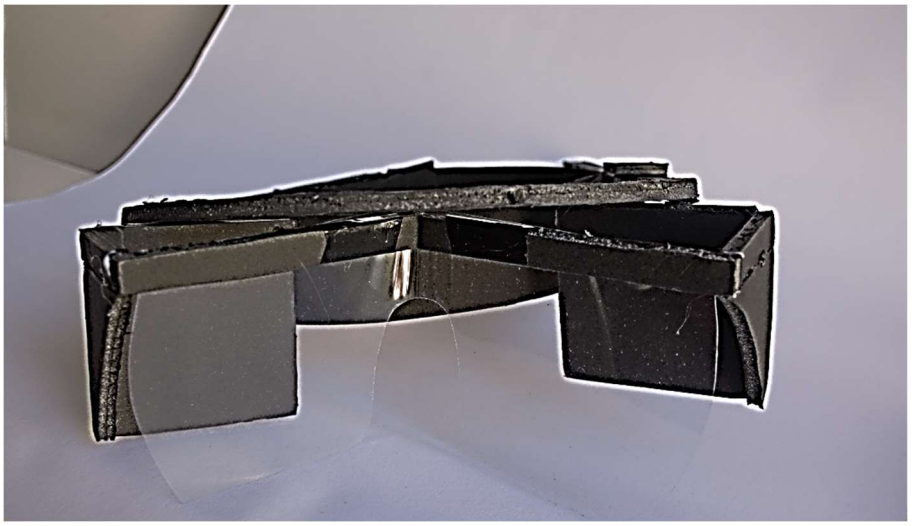


*Figure 63 – Minimalist glasses prototype (Personal File)*

In this developed model, we tried to soften it like the front part, leaving a cleaner and minimalist air that is one of the goals of this redesign, but it is still necessary to smooth and make the front shape more organic.

Another differential detail of this model is the rotation / slide upwards of the arc that supports the headset lenses as a way for the user to feel safe or free from the augmented reality device in an easy and fast way. The lateral solution for adjusting was the sliding system from the support base of the glasses generated more adequacy and comfort when positioned on the user's face.

*Figure 64 – Prototype Slide Headset (Personal File)*

*Figure 65 – Slip headset (Personal File)*

*Figure 66 – Slip headset 2 (Personal File)*

The third headset developed below was kept at the front of the lenses the same original format as the North Star headset, however this model sought to implement comfort in fitting the user's head, using a very common restraint system in bicycle helmets as previously identified in the study responsible for tightening and adjusting without pressure and discomfort in your wearability. As in the previous headset, the sliding system was maintained so that you can adapt the glasses lenses to the user's face.

*Figure 67 – Adjustment Detail (Personal File)*

Today, most helmets have a restraint system. The first step is to tighten it enough so that the helmet takes on the correct position on your head - which must be centered.

*Figure 68 – Side Adjustment (Personal File)*

*Figure 69 – glasses with original design (Personal File)*

The fourth prototype was inspired by two existing models with the front part inspired by the Canon MREAL Display MD-20 headset as in figure 42 and figure 43 in the subchapter on possible solutions as a way of separating the headset into two parts and facilitating hygiene already. that the device will be used in hospital environments and sometimes in different patients, facilitating handling.

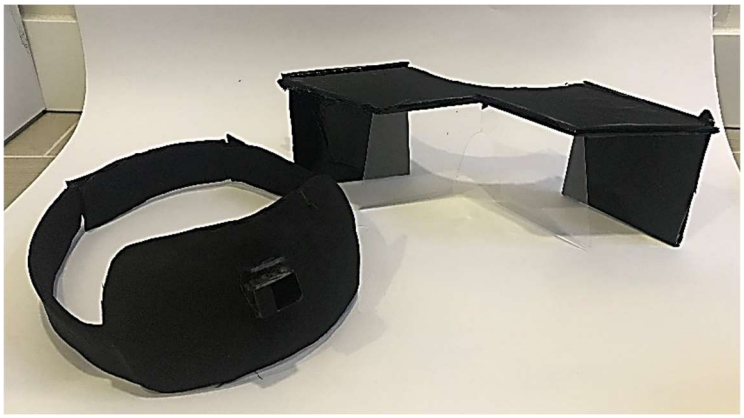


*Figure 70 – Minimalist Design Headset (Personal File)*

Another important point inspired by the Magic Leap model figure 16 and figure 17 was the head adjustment system, which would be another attempt to find a better fit, this being one of the critical points identified in the product since in this device the main point is comfort and stability in use.

*Figure 71 – Separate functions (Personal File)*

*Figure 72 – Snap Fit Detail (Personal File)*

Last interesting point in this model would be about the cleanest and minimalist design following the objective of the research and the fact that the lenses are fitted and removable facilitating hygiene.

## 3.5 EVALUATION AND TESTING OF SOLUTIONS

This is the freest phase, in which the important thing is to generate as many solutions as possible to identified and defined challenges or problems. Imagination and creativity are fundamental to be able to assess the multiple approaches that the solution to a problem can have. Divergent thinking is encouraged as it is in the original ideas that the hidden value resides, and this method encourages it. Nothing is discarded, but cataloged and analyzed later, through a process of convergence that adapts the ideas and their viability to the initial problem.

With the basic concepts, solutions and usability tests were carried out, considering the problems of Alzheimer's disease and an analysis of the proposed product. During this analysis, a decrease in the elderly's intelligible resources was observed, which can lead to not recognizing the usual caregivers and, in turn, not cooperating in their treatment, which points to the development of a product that is easy to wear and as minimal as possible. Thus, communication with the patient represents a daily challenge that needs to be facilitated, and the market is not acting in this direction.

On the contrary, the commercialized equipment focuses on the superficial and merely practical aspects of the disease, therefore, in this product, emotional and communicative needs will be considered in the development of the final prototype.

Criteria such as effectiveness, efficiency and satisfaction were applied to evaluate the product design and generate a continuous improvement cycle for the proposal.

*Figure 73 – Slip solution test (Personal File)*

In the images above, the differential and positive point is the mobility of the ate that supports the glasses and equipment, which can easily be directed upwards in case the elderly woman wants to get rid of the headset due to tiredness or bad impression during the experience with the glasses, but as the technology used in the product is augmented reality, it was found that there is no possibility and need for an “escape” from the equipment as it happens in virtual reality, where a new reality is designed for the user, which may cause some kind of stress.

This model proved to be effective and efficient but does not achieve the desired satisfaction as the minimalist aspects and does not apply to the technology used.

The following model, despite positively controlling the tension around the head in the support structure, did not prove to be innovative and consistent with the established criteria of effectiveness and efficiency, with a design that is still very robust as the original headset north star.

*Figure 74 - Front and Side view (Personal File)*

*Figure 75 – Side and rear adjustment (Personal File)*

Lateral adjustment details not as comfortable as expected, causing marks on the elderly woman's face, many readjustments are needed to consolidate this solution.

The last solution developed was the one that best suited all pre-established criteria throughout the development of this research, being the model that best responded in terms of load resistance, risk during use, storage because the treatment equipment can be divided in parts, hygiene and possibility of being used by different users.

*Figure 76 – Front and side view of solution 3 (Personal File)*

Comfort and fit are one of the main strengths of this solution as well as the minimalist design of the headset, meeting all the needs of elderly people with Alzheimer's disease, in addition to its easy wearability.

*Figure 77 – Solution details 3 (Personal File)*

## 3.6 COMMUNICATING SOLUTIONS

It is at this point that the ideas and solutions identified as potential responses to the original need and defined users are implemented, as a preliminary step towards their validation with the stereotyped people who will use them.

The goal is to develop quick and inexpensive prototypes, following a Lean Startup approach framed in an agile philosophy, which will allow you to collect further feedback, learn and update. It is a powerful communication tool that even allows you to reformulate not only the solutions, but even the challenge or problem itself.

Based on the problems and needs pointed out in the previous subchapter, a final prototype was elaborated that respected all the issues addressed throughout the development of the thesis. The final prototype below presents a minimalist profile in its functions where the main feature is the use of magnets, generating practicality in the use of the product.

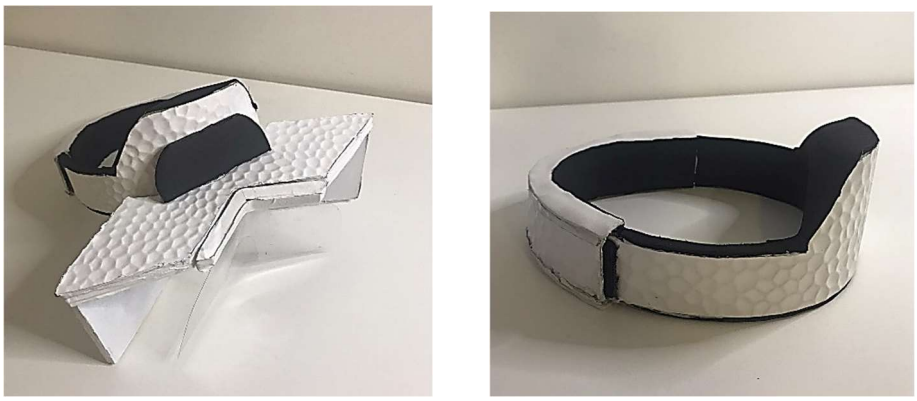


*Figure 78 – Final prototype (Personal File)*

Magnets provide benefits and facilitate a series of processes in our daily lives, being flexible fastening elements, easily removable and acting by force closing. They serve, for example, as flap closing devices to prevent accidental opening. They are used in mechanical engineering and equipment construction.

*Figura 79 – Magnet attachment detail (Personal File)*

The interior of the headset will be foam that will provide comfort and define the less dense the foam, the less rigid or soft the structure will be. As well as the use of elastics on the back that will help with fit and comfort.

*Figure 80 – Foam for interior comfort (Personal File)*

*Figure 81 – Elastic for adjustment (Personal File)*

Gathering user feedback, analyzing it, learning and interacting is the final and most important step of this method. Through the generated prototype, as hypotheses raised throughout the process, the challenge, the identified problems and the possible solutions identified are validated from the user's analysis.

Below, you can check the tests with the final prototype and the user and see how the product meets all expectations, identifying failures and errors, and the process of improving, testing, improving, testing becomes much more productive and agile.

*Figure 82 – Adjustable Headset*

*Figure 83 – Magnetic Smart Glasses*

*Figure 84 – Lenses with magnetic snap*

*Figure 85 - Final Prototype*

### 3.7 COLOR PSYCHOLOGY

According to a study by Satyendra Singh from the University of Winneepeg in Canada, about 62 to 90% of the evaluation of a product that people interact with are based on colors alone. With this, the industry increasingly uses them color as a prominent visual element for the construction and dissemination of their products. It is believed that the persuasive power that each meaning of color can generate is capable of positively influencing users and consequently consumers.

Each color can produce many, often contradictory effects, as they can generate both positive and negative sensations. Hence the importance of evaluating the context of each application to determine which sensations each color should inform.

It's undeniable that colors have functions you can use in your projects, such as organizing and conveying meaning. The latter can communicate an idea that provokes a reaction in the viewer. When talking about color, one of the most popular subjects is the symbology of colors and their psychological influence.

*Figure 86 – Color psicology (klickpages, 2021)*

In summary, color psychology studies how color is perceived by human beings. It analyzes how the brain processes the information the eyes pick up. This is an area of psychology that analyzes and defines the effects that each color generates on people, such as mood changes, the awakening of feelings and desires, among other possibilities.

Considering the aesthetics of the product developed based on minimalism and futurism as well as the target audience and the context of use, we will address the meaning of the colors that express the project concept. The minimalist aesthetic is based on a palette of neutral colors and textures that refer to natural elements that convey

tranquility and comfort to the environment and considering that these characteristics are related to the context of use for which the product was developed.

The use of white will give the product an air of boldness and personality, in addition to composing an elegant aesthetic. In many cultures, white is the color of purity, simplicity, and for an original, modern look, mix bright whites with cool neutrals of similar shades like pigeon-grey. The white color represents the clean, the sterilized, the pure. Cleaning is external, purity goes deeper. What needs to be hygienic is white. Any dirt stains are visible in the white making it easy to clean making it the perfect choice for a hospital.

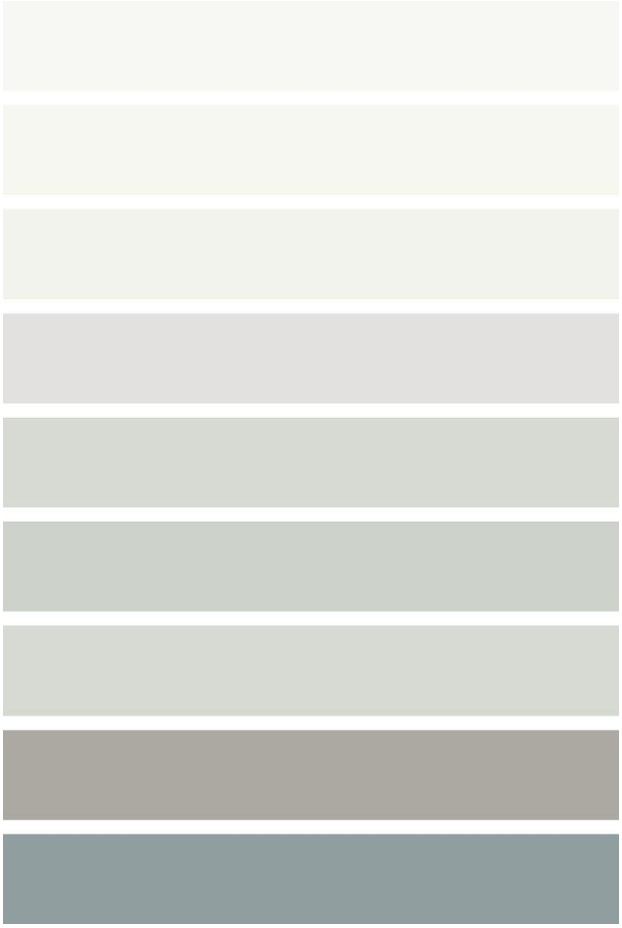


*Figure 87 - Color chart (Personal File)*

As for the futuristic aesthetics and its tones, there is nothing more inspiring than thinking about the future and adding visionary elements to your products, showing more in the design than in the color itself. So, the use of white and gray was the ideal choice for the product produced. The gray color means neutrality, elegance, sophistication and lack of emotion. As it is a neutral color, gray does not have in its characteristics the ability to stimulate or soothe. As it lacks an emotional charge, it is often characterized as a dull, motionless color. At the same time, being a neutral and emotionless color, it is also identified as a color endowed with composure, solidity and stability.

### 3.8 TEXTURE

Texture is the external appearance of a surface, that is, the “skin” of a shape, which allows it to be identified and distinguished from other shapes. When we look at or touch the surface of an object, we feel if its “skin” is smooth, wrinkled, smooth, rough or wavy. Texture is, therefore, a visual or tactile sensation.

There are several types of textures, but they are basically divided into natural - textures created by nature (bark from tree trunks, wood, rocks, skins and other animal coverings) and artificial which are textures created by man which was the case of the chosen texture in this project. Talking about textures is talking about the quality of surfaces and design is talking about one of the visual elements of form. Textures are perceived through sight and touch. In addition to the sensations that we can feel, pleasant or not, textures also serve to fulfill different functions, such as: better grip; better security; better and greater protection and resistance.

In this project, we chose to use an artificial texture that results from the intervention and use of materials and instruments properly handled with ornamental and functional characteristics that help in the adherence during the handling of the product.

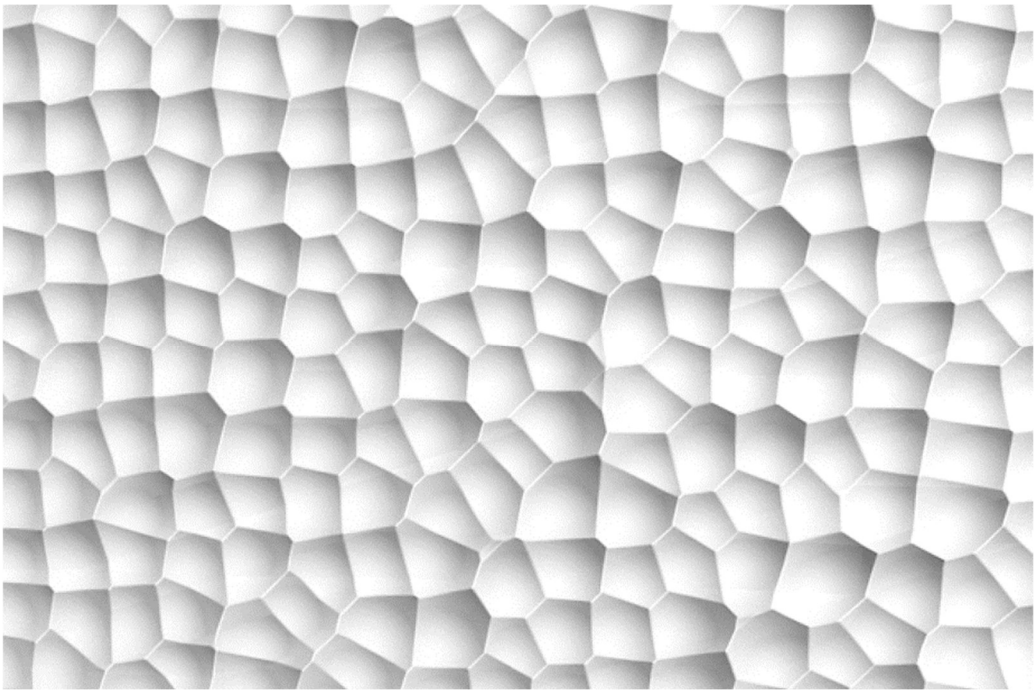


*Figure 88 - Futuristic artificial texture (Personal File)*

## 3.9 INSPIRATION

*Figure 89 – Inspiration Map*

Outstanding visual presence with solid technological knowledge the inspiration for this project was the architecture of Santiago Pevsner Calatrava Valls, a Spanish architect and engineer whose work has become quite popular in recent decades.

*Figure 90 - Inspiration Ideas*

## 3.10 REDESIGN

Redesign, redo, reapply, redesign something. Redesign is part of the strategy to make a product more adapted to your goals. Basically, the essence of this type of action is precisely the way the target audience sees it. It is of little use for the product to have great quality if it cannot reach its users or does so without paying attention to the reformulation of the identity in which it seeks to pass.

In short, redesign is the recreation of an identity that meets the user's need for aesthetics and functions. With this, color patterns and icons undergo changes, sometimes more radical, to refound the vision, objectives and goals of that product. Below are all the references previously discussed that summarize the new aesthetics and purpose of the product:

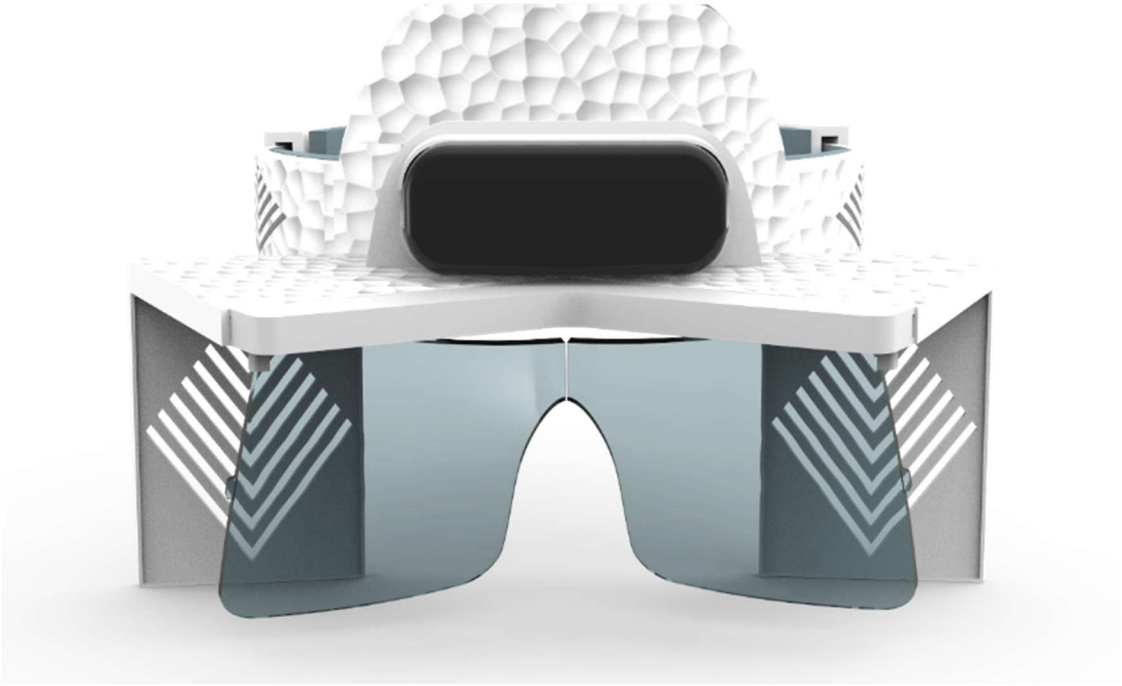


*Figure 91 – Front view redesign*

Just as technological changes have transformed the way companies sell their products and services, the way these changes are communicated through design also changes. We live in a world where visual communication is a decisive factor for a product to be consumed or not beyond its functional attributes. Therefore, updating the aesthetic identity through redesign becomes essential for new audiences to be reached, in this case a technology hitherto used among the young audience, being used integrated with a user profile that until a few decades ago had no access the technology.

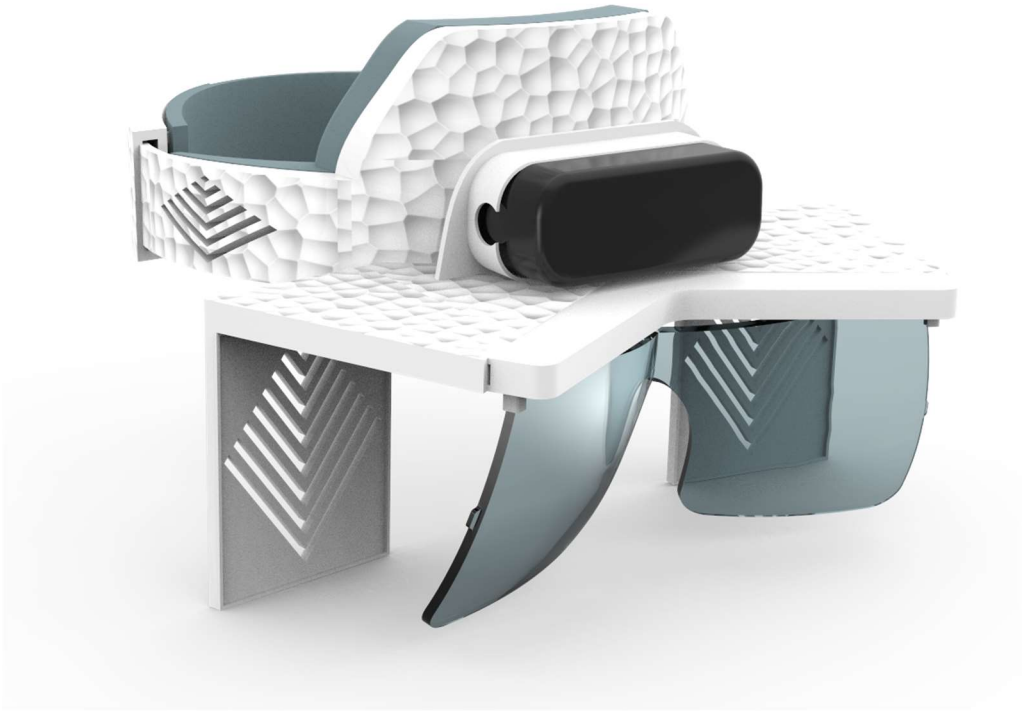


*Figure 92 – Side view redesign*

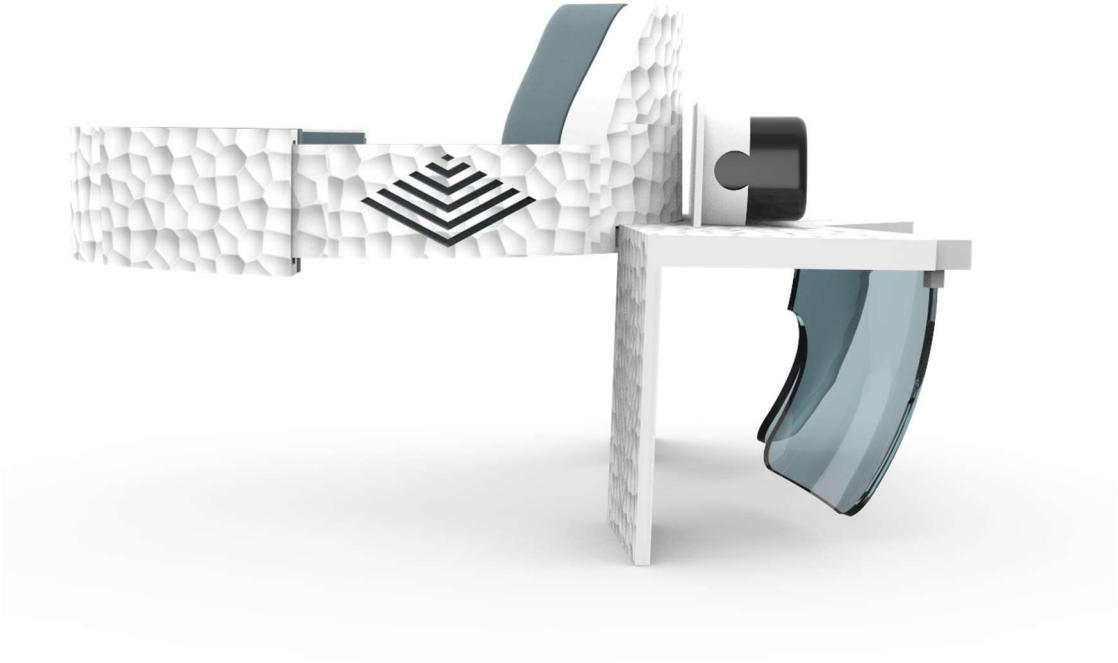


*Figure 93 - Side view redesign 2*

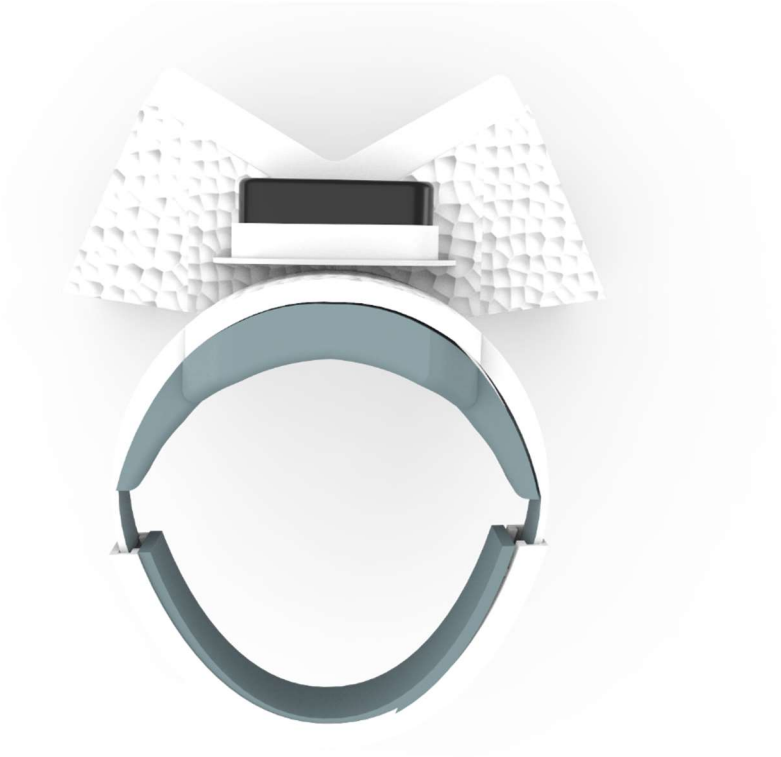


*Figure 94 – Top view redesign*

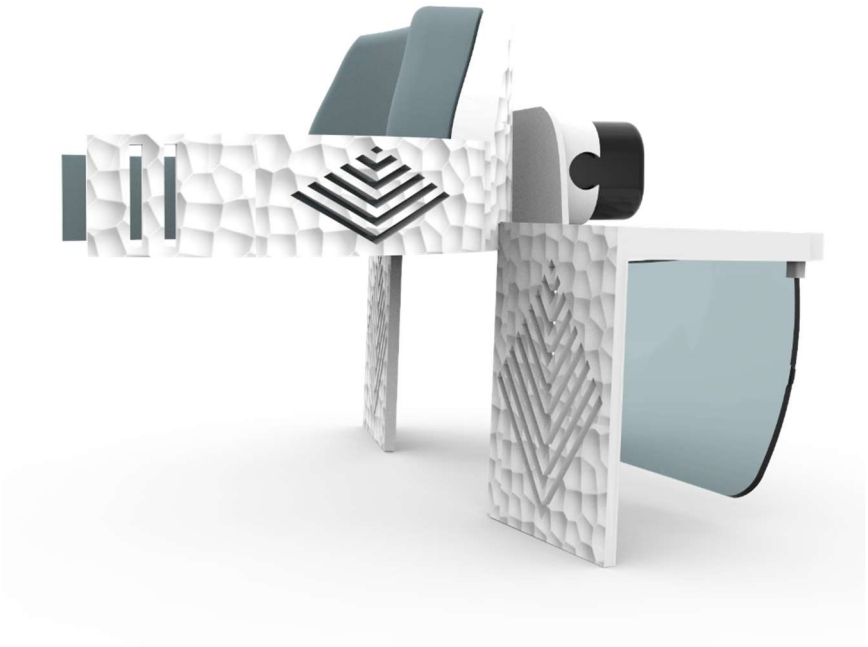


*Figure 95 – Redesign details*

*Figure 96 – Redesign from below*

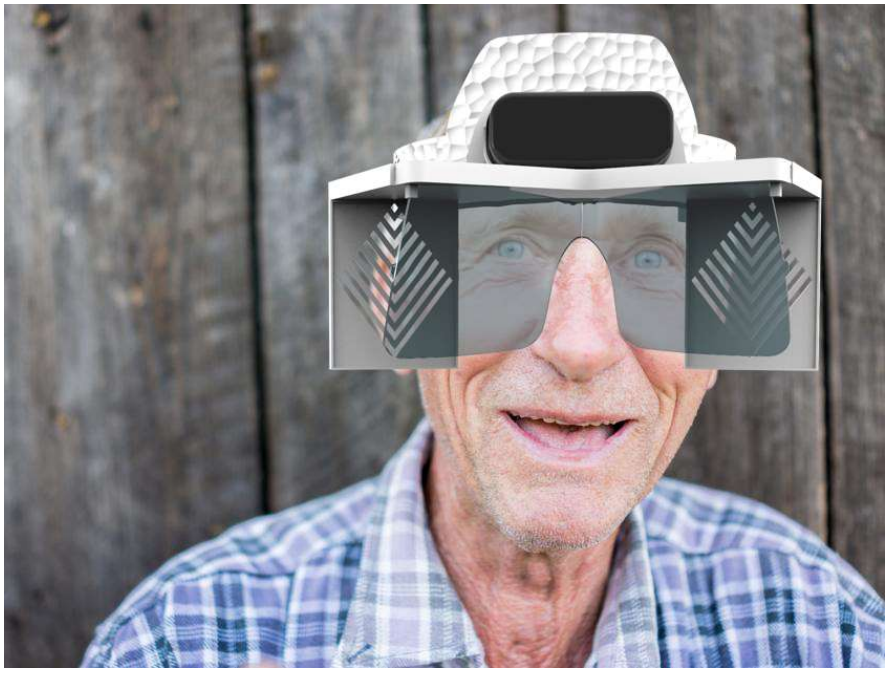
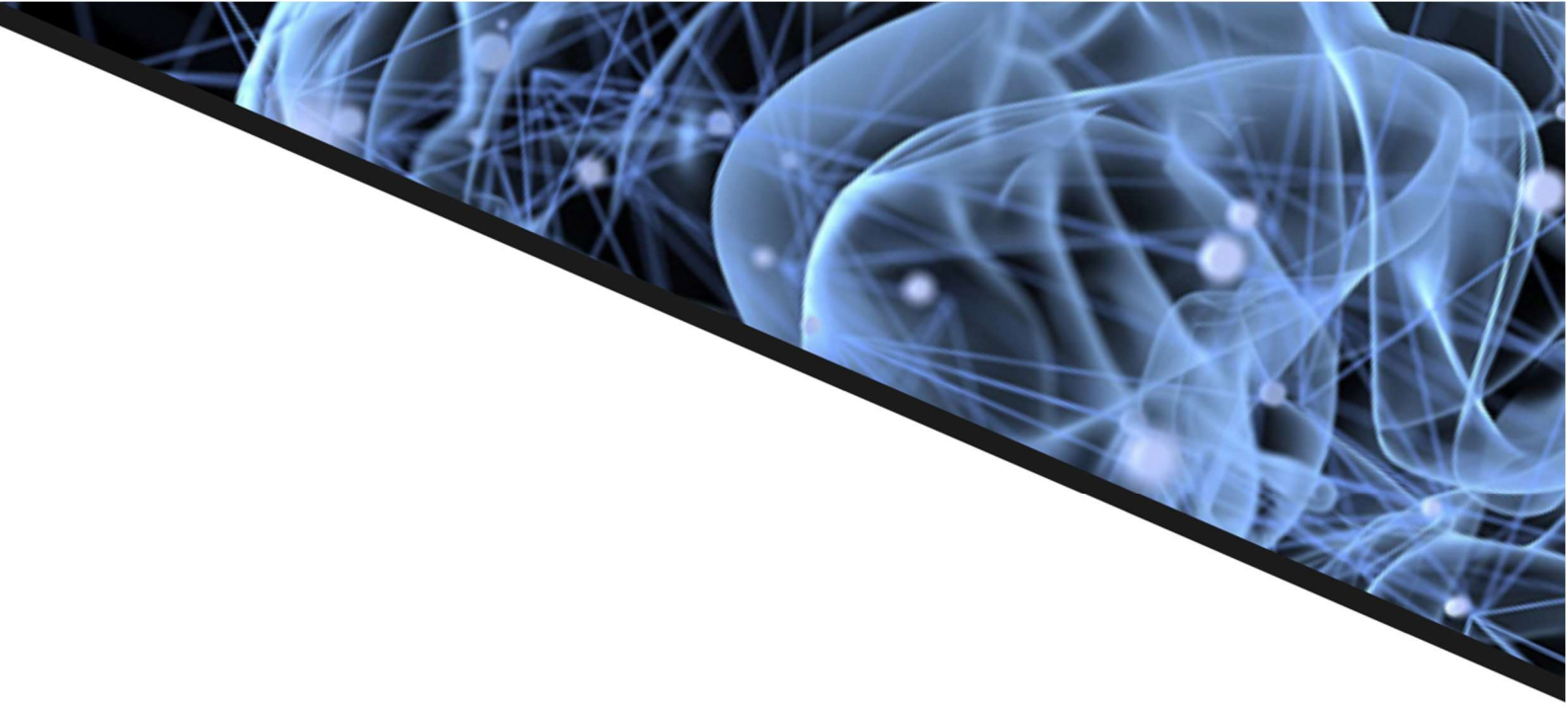


*Figure 97 - Context of use*



# CHAPTER 4
# PRODUCT PROPOSAL

## 4 PRODUCT PROPOSAL

Refer to a device that brings appropriate technology in front of a person's eyes to present data from the background information system. The screen is projected and reflected in the eyeglass lenses.

The most important thing is that the user can observe the environment without distractions when he does not need the information provided by the smart glasses. Smart glasses (headsets) are also often referred to with the term "augmented reality", which basically means augmenting (and reinforcing) the existing real world with information provided by the information system.

The device must fit / fit properly so that you do not present any inconvenience and do not pay attention to it while it is in use and part of the future product development build is done according to the needs of the business world, considering values and other issues such as sustainability as already addressed in this study.

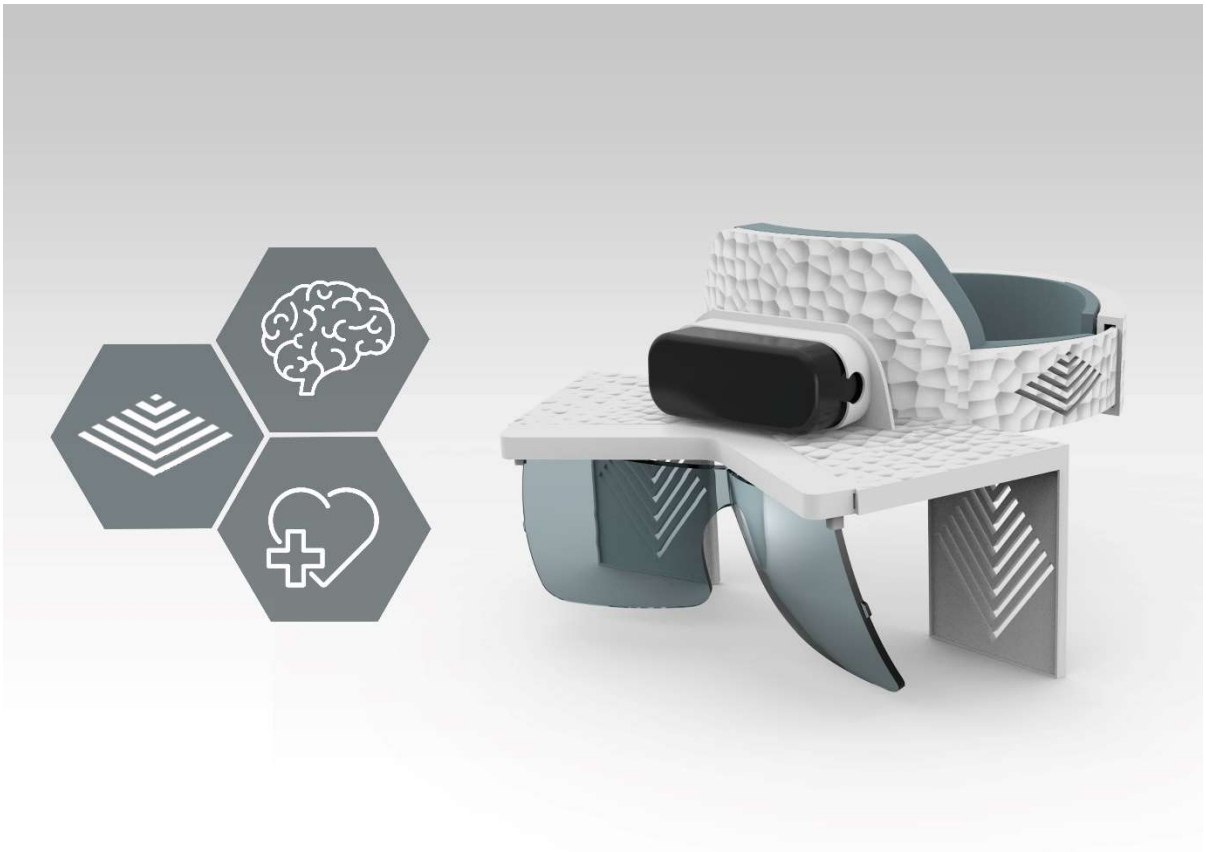


*Figure 98 – Product proposal*

## 4.1 CONCEPT

The redesign consists of an augmented reality headset for elderly people with Alzheimer's disease. It provides comfort, practicality and usability within the defined context, inspired by minimalist and futuristic architectural icons, which is the image we want to express in the developed product, making elderly people also feel part of the universe of new technologies.

It is essential in terms of technology and usability that the devices are minimalist, and the design allows them to be integrated and easily wearable. With this technology, it is easy to provide accurate and additional variable information to the user thinking about their mobility issues and symptoms.

The choice for minimalist functions is characterized by being against excesses, valuing the identification of essential elements focusing on what is important. It's all about simplifying to have fewer challenges and obstacles in use. Few decorative elements, in strategic positions that for now combine aesthetics with functionality. The choice for the white color values natural light as a way of integration with the surrounding environment, as well as easy cleaning in view of the context of use for which the headset was developed. The adaptation of minimalism in this product occurs through the basic elements of the structure to maintain comfort and avoid a superior look. It is very important that the product reflects in every aspect and detail the routine and behavioral patterns of those who will use it.

As for futuristic aesthetics, the idea is to bring design and futurism together to bring simple and innovative solutions that make the target audience have the best living conditions. Trends and behavior were analyzed to materialize concepts of the future in conceptual design solutions placing the user at the center of the project. And that's a big benefit for the user, as futurism is concerned with how things are going to be in the future, and the designer is concerned with how people are going to connect with these things in a healthy way.

## 4.2 USE CONTEXT

As previously described, the product use context will be the health area in the treatment of elderly people with Alzheimer's disease. There are more than ten thousand types of hospital equipment, and the list is very long with several factors that must be considered with the type of health facility, available workforce, area of specialists, and so on. Based on the recommendations of the World Health Organization and Anvisa, medical equipment is devices intended for medical use, diagnosis or recovery of patients benefiting everyone, helping health service providers to diagnose and treat patients, helping them to overcome diseases or illnesses, improving their quality of life.

Treatment equipment is any type of medical device or tool designed to treat a specific condition. It uses modern technology to resolve any abnormalities to restore function in the affected organs or tissues within the body.

The developed headset is considered a Durable Medical Equipment (DME) used primarily to provide therapeutic benefits for certain conditions or illnesses. Use of this equipment must be prescribed by a physician and designed to serve a medical purpose and is a long-term, reusable device that can be used in the hospital or at home for patient care. The term “durable” derives from the fact that these types of devices have been quality tested and designed to support patient safety and comfort. Some of the common characteristics of durable hospital medical equipment include for example non-slip characteristics and load resistance.

The National Health Surveillance Agency (Anvisa) has on its website a series of definitions and classifications for the most diverse types of medical equipment used in the Brazilian context, for example. Classes range from I to VI, the first being for low-risk equipment and the last for high-risk equipment. This classification serves to indicate the risks of using each equipment, both for patients, as well as for doctors and nurses. In each of these classifications, we can find framing rules for the purpose and use of the materials. (ANVISA, 2020)

The classification of each hospital medical equipment must be done immediately upon manufacture or import. Only after classification and registration, medical equipment is released for sale and consumption in the Brazilian market. The classification is made according to the risks of using each medical equipment that may be used. This classification is necessary to determine what types of documentation each piece of equipment should have, including quality tests. (MOBILOC, 2021)

The Usage Context Analysis (CoU) proved to be a useful method for capturing information about the context in which the product, service and system will be inserted. The three main points of the Usage Context Analysis should emerge from the answers to the following questions:

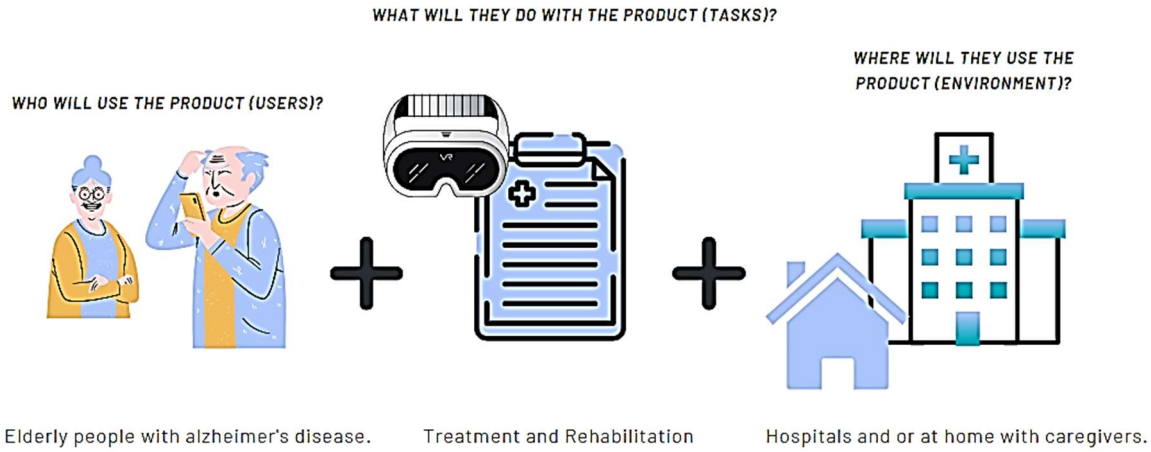



*Figure 99 – Usage context scheme 1*

CoU is applied both in the requirements definition phase and for the usability evaluation. In the first case, the method was applied right at the beginning of the project, at the time of conceptualization: identification of the target audience, definition of tasks and where the project will be applied. In the second case, which is the case of this subchapter, the Usage Context Analysis is applied in planning the application aspects that will need to be tested and under what circumstances.

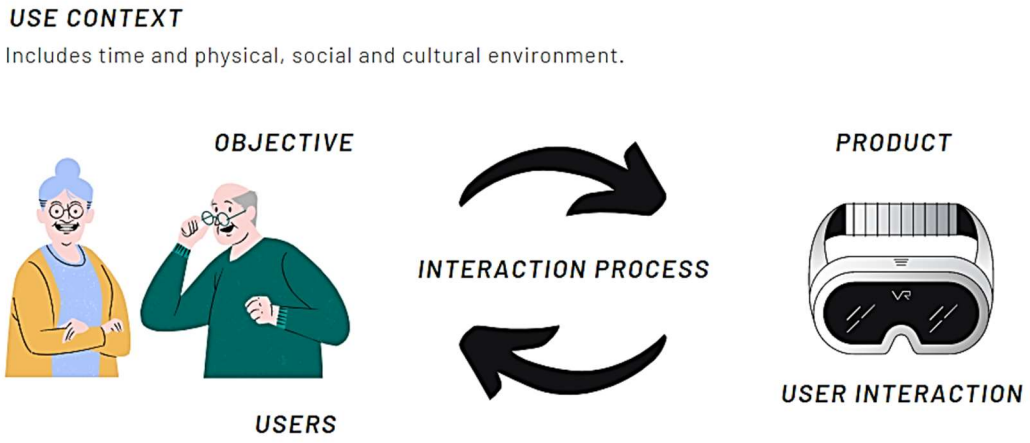



*Figure 100 - Usage context scheme 2*

The scenario helps to communicate the essence of the product/service idea within a defined likely context of use. Thinking about what the user is going to do may seem not very controllable but mapping some common scenarios can be useful to understand the limitations of the solution, after all, it is the product that must adapt to the context of use, and not the other way around. The good experience is not only in the quality of the

augmented reality technology, but also in the external factors that influence and were considered during the project. The scenario directly influenced the way of thinking about the design and the solution as explained throughout the research.

Through the different design phases of the project, the context of use was used at the beginning to map the features and concepts and during the testing and prototype phase to validate the solution in context.

*Figure 101 – Use context 2*

## 4.3 PRODUCT COMPONENTS

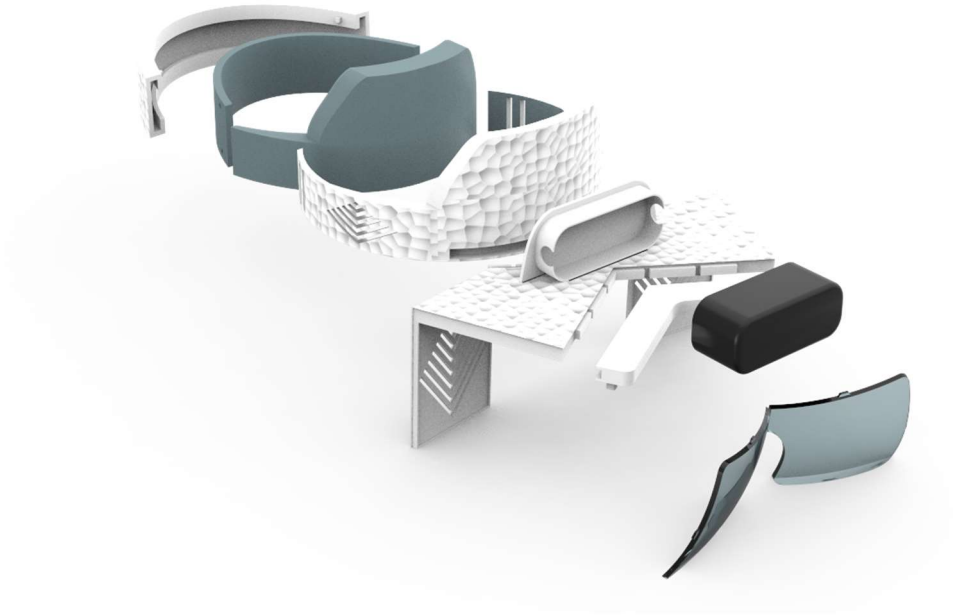


*Figure 102 – Exploded view 1*

*Figure 103 – Exploded view 2*

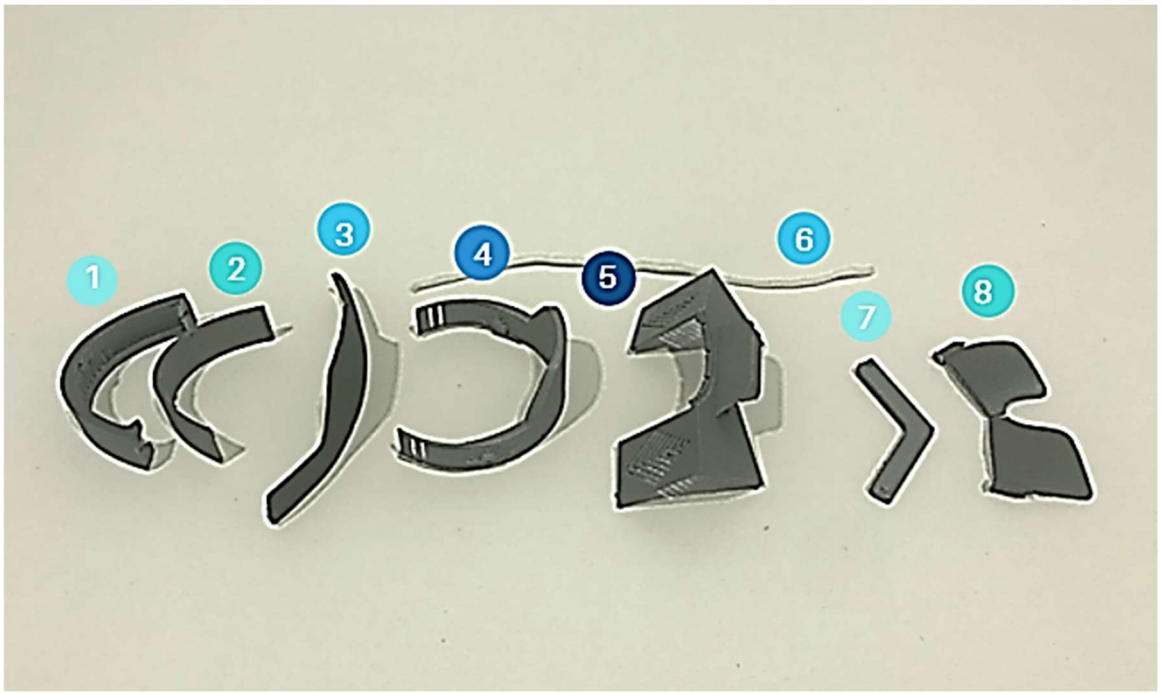
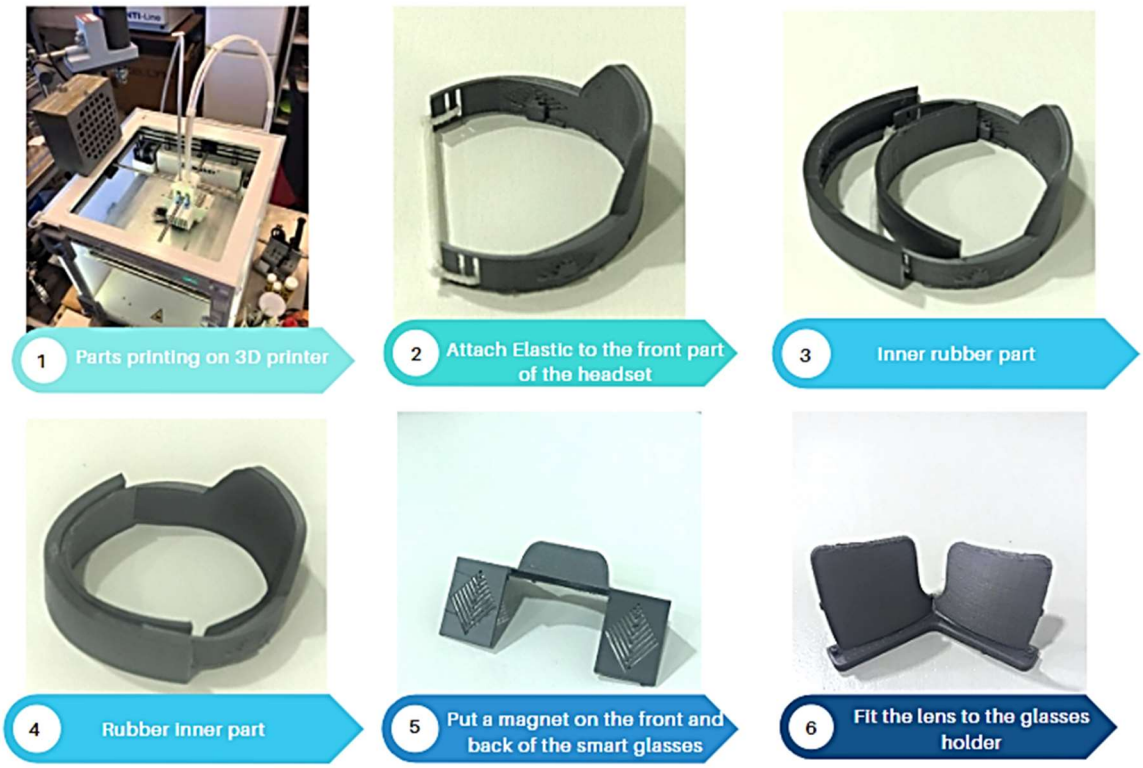



*Figure 104 - Product Components*

1. Part 1 - Rear Arch (PLA)
2. Part 1.1 - Rubber Rear Arch (TPU)
3. Part 2.1 - Comfort Fitting (TPU)
4. Part 2 - Headset (PLA)
5. Elastics
6. Part 3.1 Glasses Fitting (PLA)
7. Part 3 - Lens Support
8. Lenses

## 4.4 MANUFACTURING PROCESS

The manufacturing process involved two phases and some steps, from the production of parts in 3D printing with two different types of material to assembly. These phases are described below, in the next figures, and can be seen in some images related to the stages of the production process of the parts, with a description of each assembly step in this subchapter.



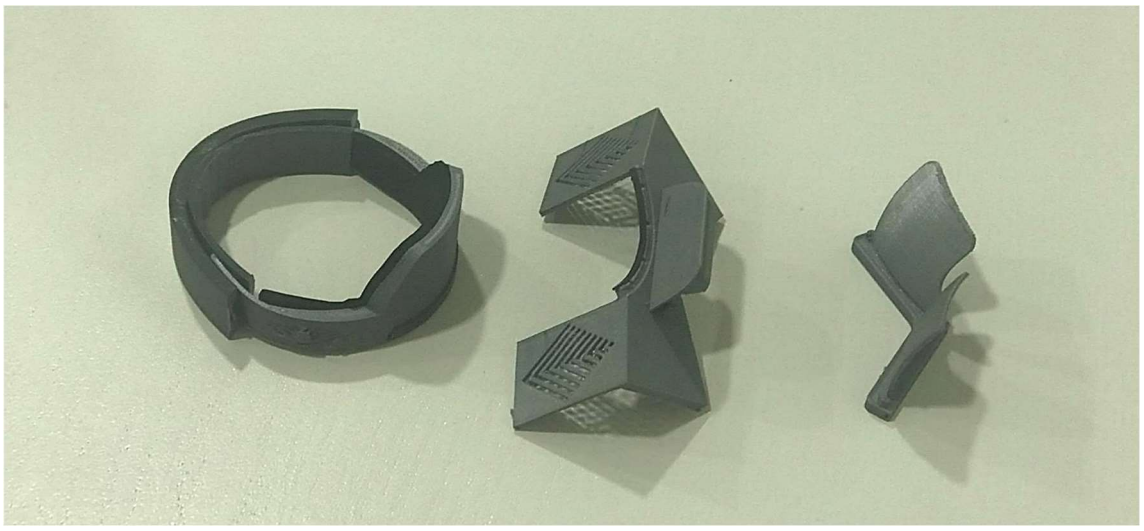



*Figure 105 - Complete Process*

## 4.5 COST ANALYSIS

In the product development process, it is crucial to ensure that the production of the concepts fits within an economically viable and market-competitive budget. First, the costs related to the production of the structure of the augmented reality device in 3D printing are presented, then the materials used to compose it and related to the comfort in using the product.

**Device Structure**

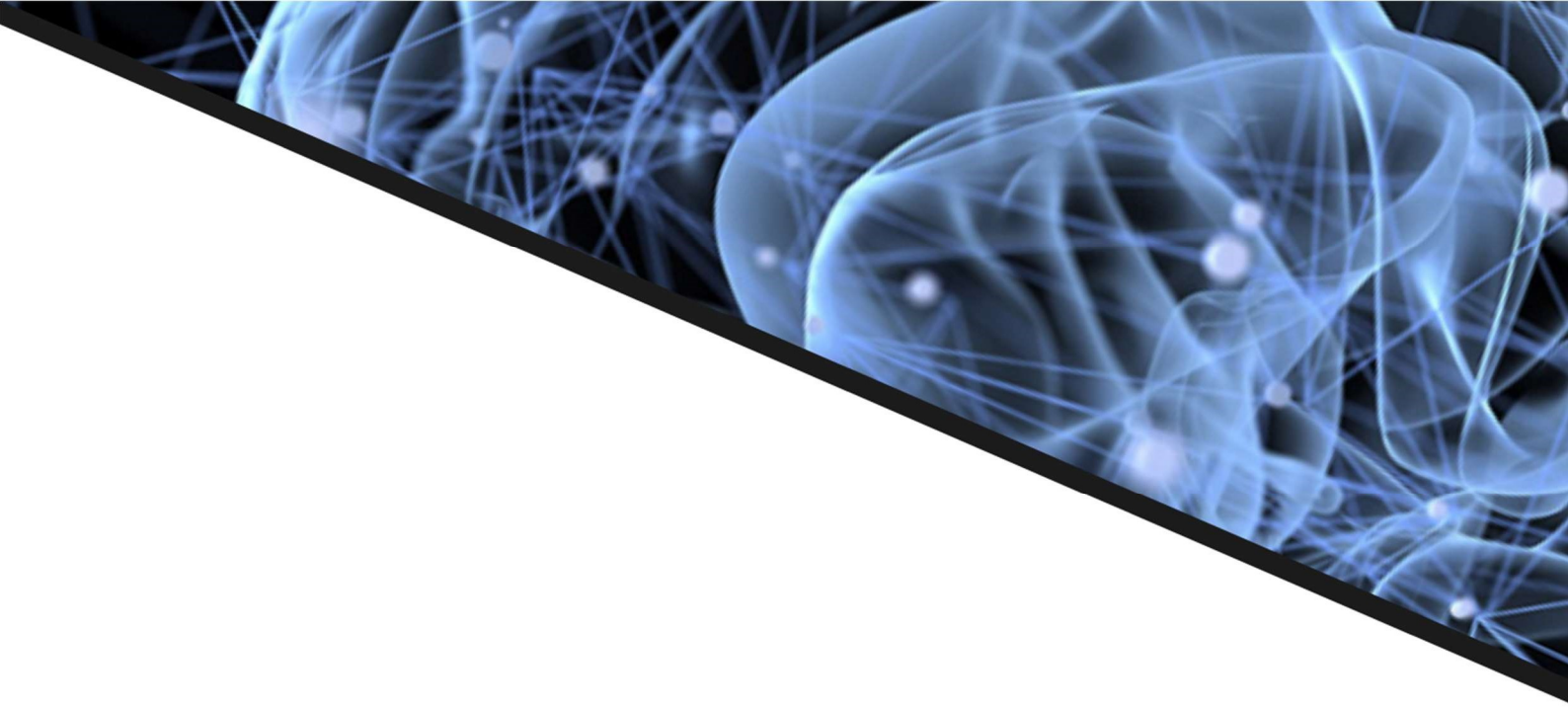
*Table 4 - Device Structure*

| PRINTED COST ESTIMATE | | |
|---|---|---|
| MATERIALS | PRICE | TIME |
| PLA | 13,51 EUROS | X |
| PRINT | 0,08 EUROS | 4,6333 HORAS |
| ENERGY KWH | 0,1445 EUROS | X |
| TPU COLORFABB FILAMENT | 24,90 EUROS | X |
| PRINTER HANDLING EMPLOYEE | 3,84 SALARY/ HOUR | 5 HORAS |
| FULL PRICE PRINT | 60,37 EUROS | |

**Materials Used / Comfort**

*Table 5 - Used Materials*

| USED MATERIALS | |
|---|---|
| MATERIALS | PRICE |
| NEODYMIUM MAGNET | 0.75 EUROS |
| ELASTIC | 1,79 EUROS |
| TOTAL PRICE OF MATERIALS | 2,54 EUROS |
| TOTAL PRODUCT PRICE | 62,90 EUROS |



# CHAPTER 5
# FINAL CONSIDERATIONS

## 5. FINAL CONSIDERATIONS

The areas involved that are part of this investigation are part of five major groups and general themes, which are: technology, product design, health and social. Within these large groups, themes such as the internet of things, social responsibility, empathic design, inclusive design, sustainability, interaction design, ergonomics and usability processes, the loss of capabilities of the elderly and market research stand out. All of these areas of knowledge are interconnected.

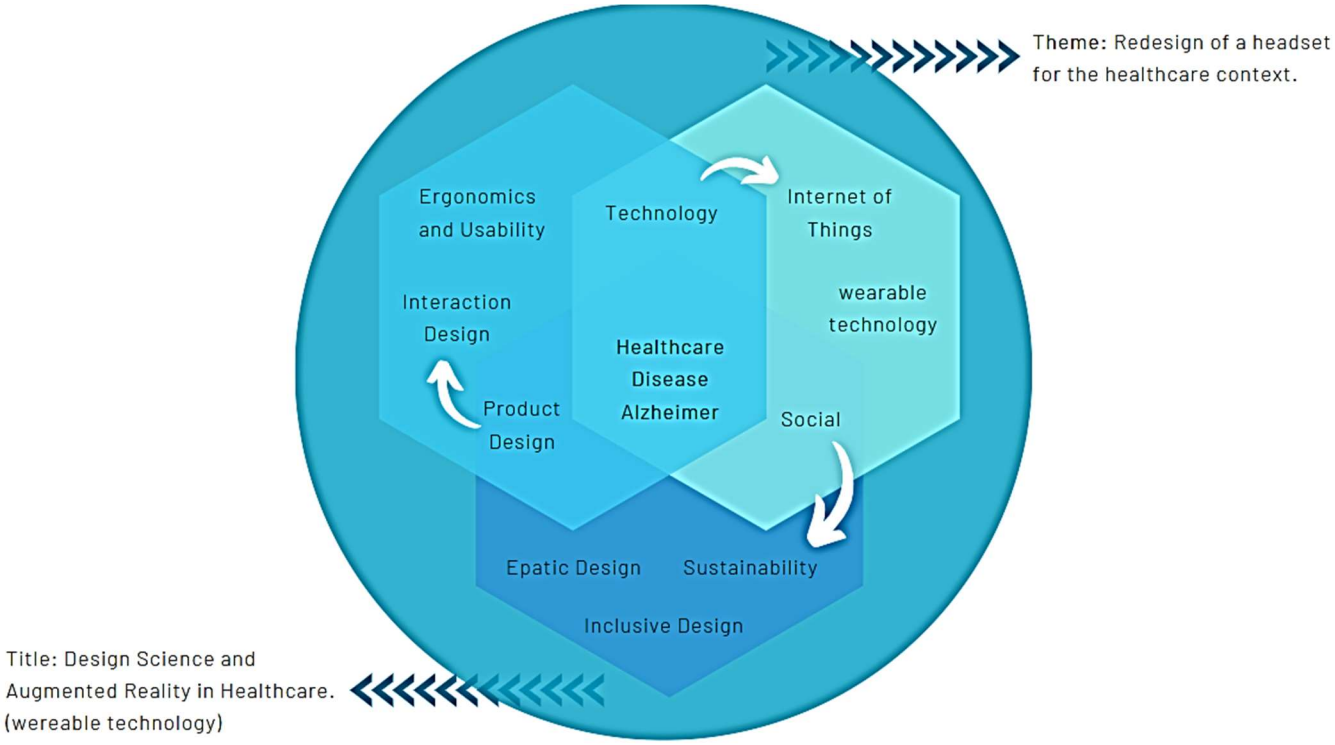



*Figure 106 – Consideration Schemes*

## 5.1 CONCLUSION

In view of the literature and the themes themselves, it is important for the project to relate them and understand how to complement each other for a design proposal. To make design respond positively to the needs of the elderly, it is not possible to dissociate it from inclusive design or from the approaches it understands.

Furthermore, the search for solutions to promote identity, the opportunity to choose and experience - where concepts such as wearable technology and usability are considered - matters for the adoption of a truly inclusive approach for those who will be the product's target audience.

The overvaluation of the functional and practical design orientation present in many products is questioned, to the detriment of the quality of the user experience and the identity of the person who improves beyond disability. After this analysis, evaluating this same overvaluation will not jeopardize the functionality itself.

This given to the functionality of the products can also be compared to that given to the active, profitable and dynamic population groups, those that are socially considered more supplied. Therefore, the most vulnerable groups are left out of the picture as to the use of new technologies, which is minimally attempted to resolve so that the product can be as intuitive as possible.

## 5.2 FUTURE PERSPECTIVES

The project is completed in an academic context, but it is not yet possible to consider it fully concluded. The main limitation of the project was the closure of spaces where they could offer a more in-depth research with the user.

However, the work process was adapted to the possible conditions, leaving a better future development open through the research. It is also essential to re-analyze the results of the superficial evaluation tests and their efficiency in terms of usability, considering comfort and safety.

It is also suggested the in-depth study of usability issues and ergonomic processes with the target audience to detect problems and information relevant to the project.

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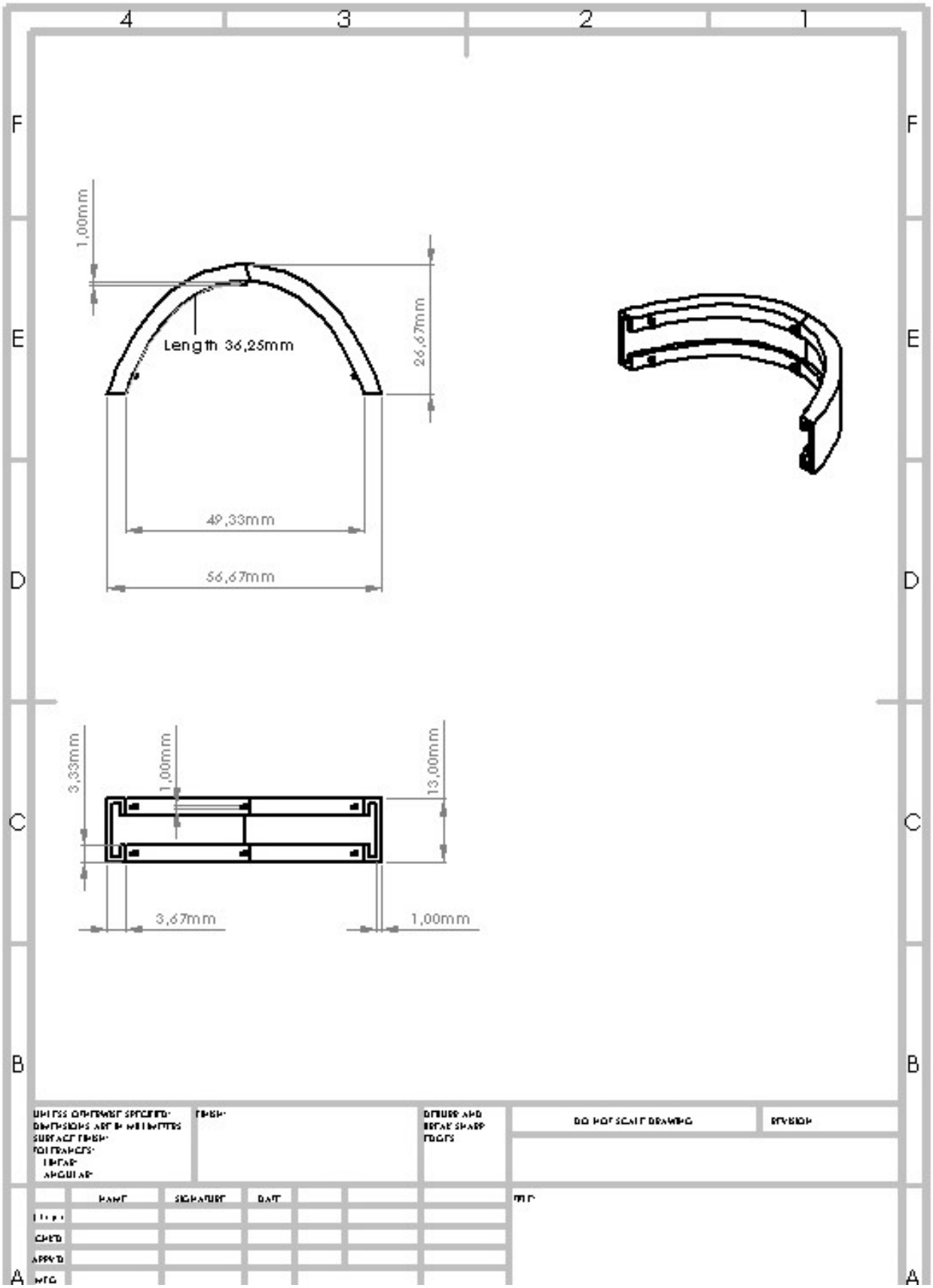
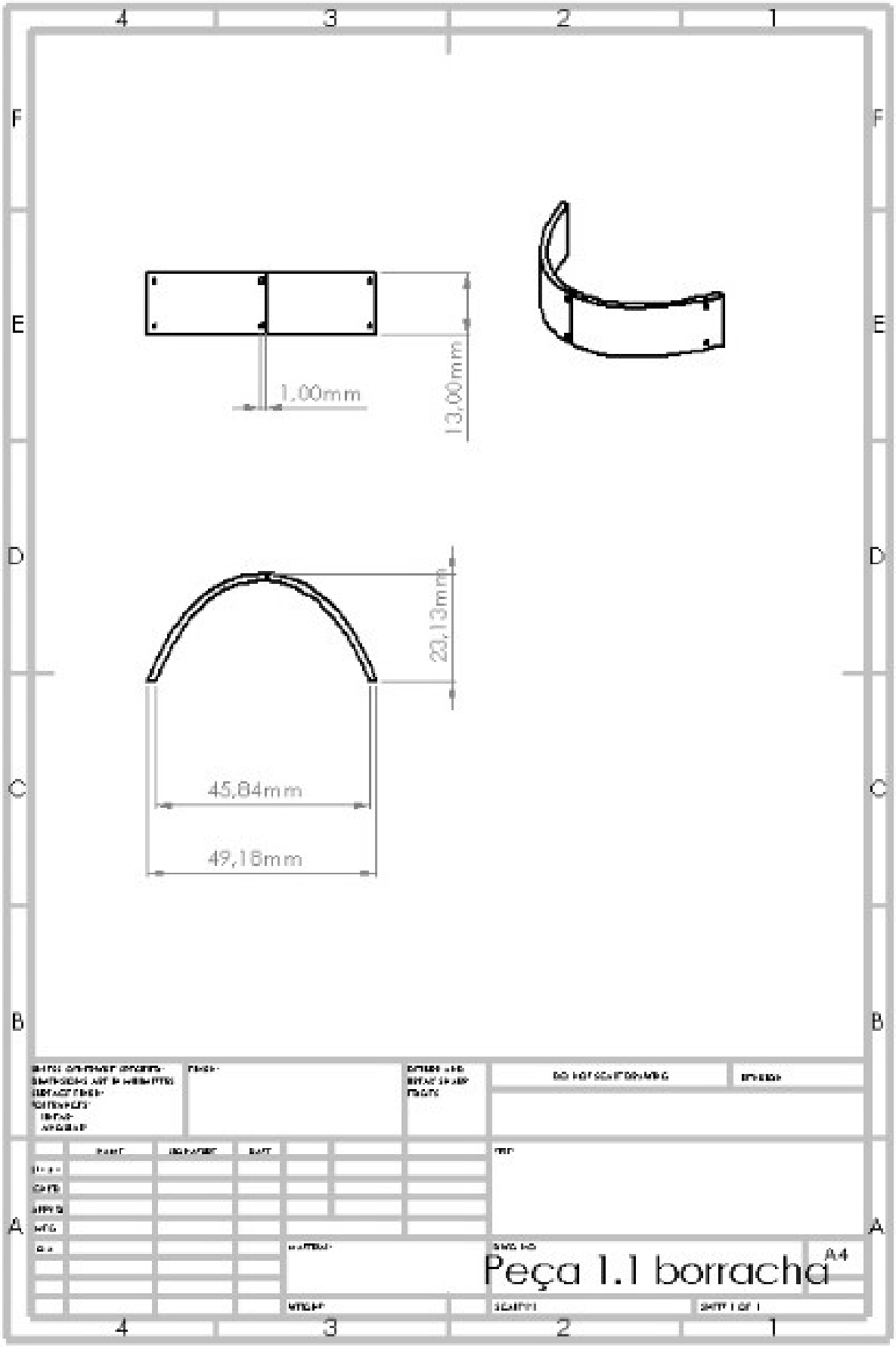
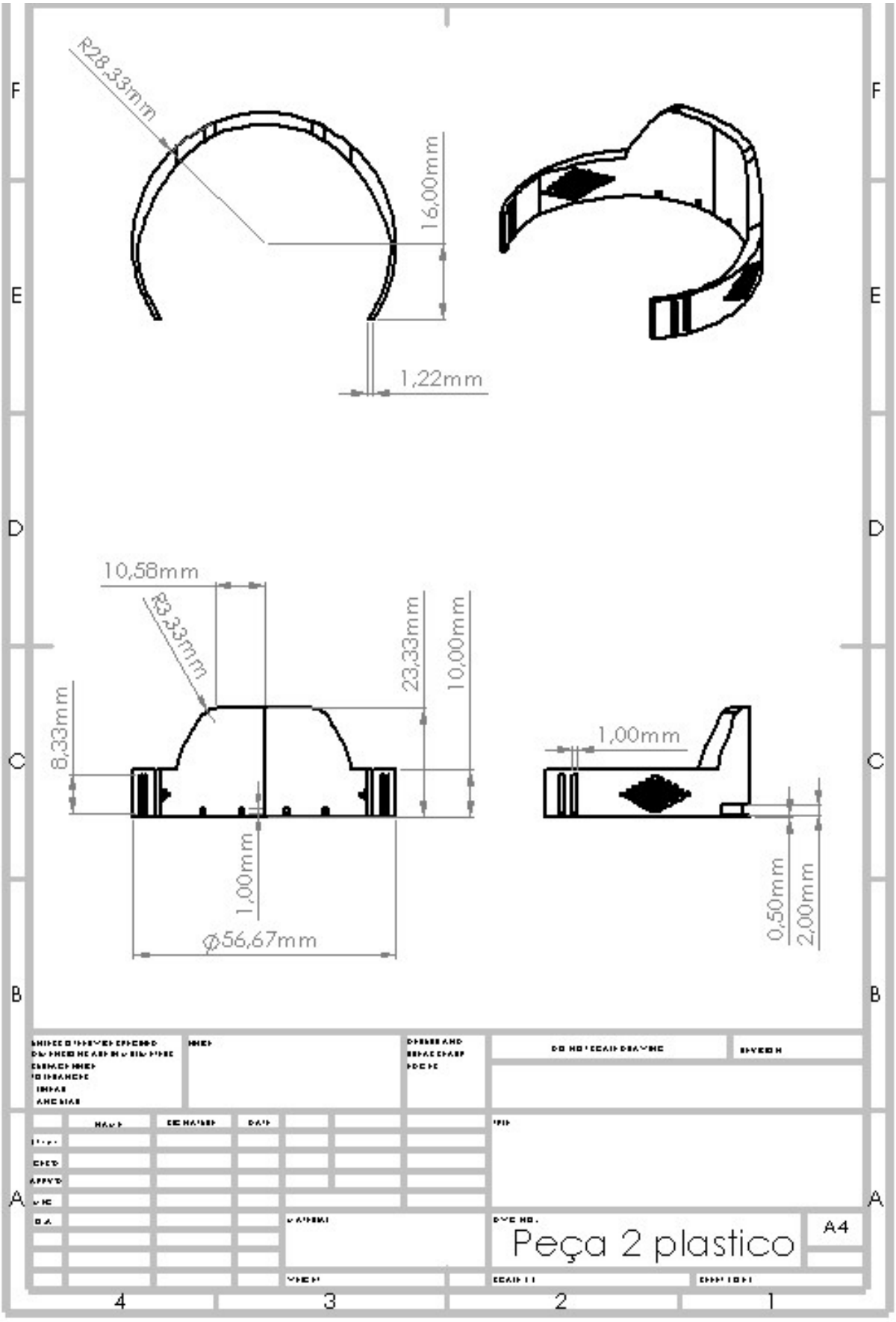
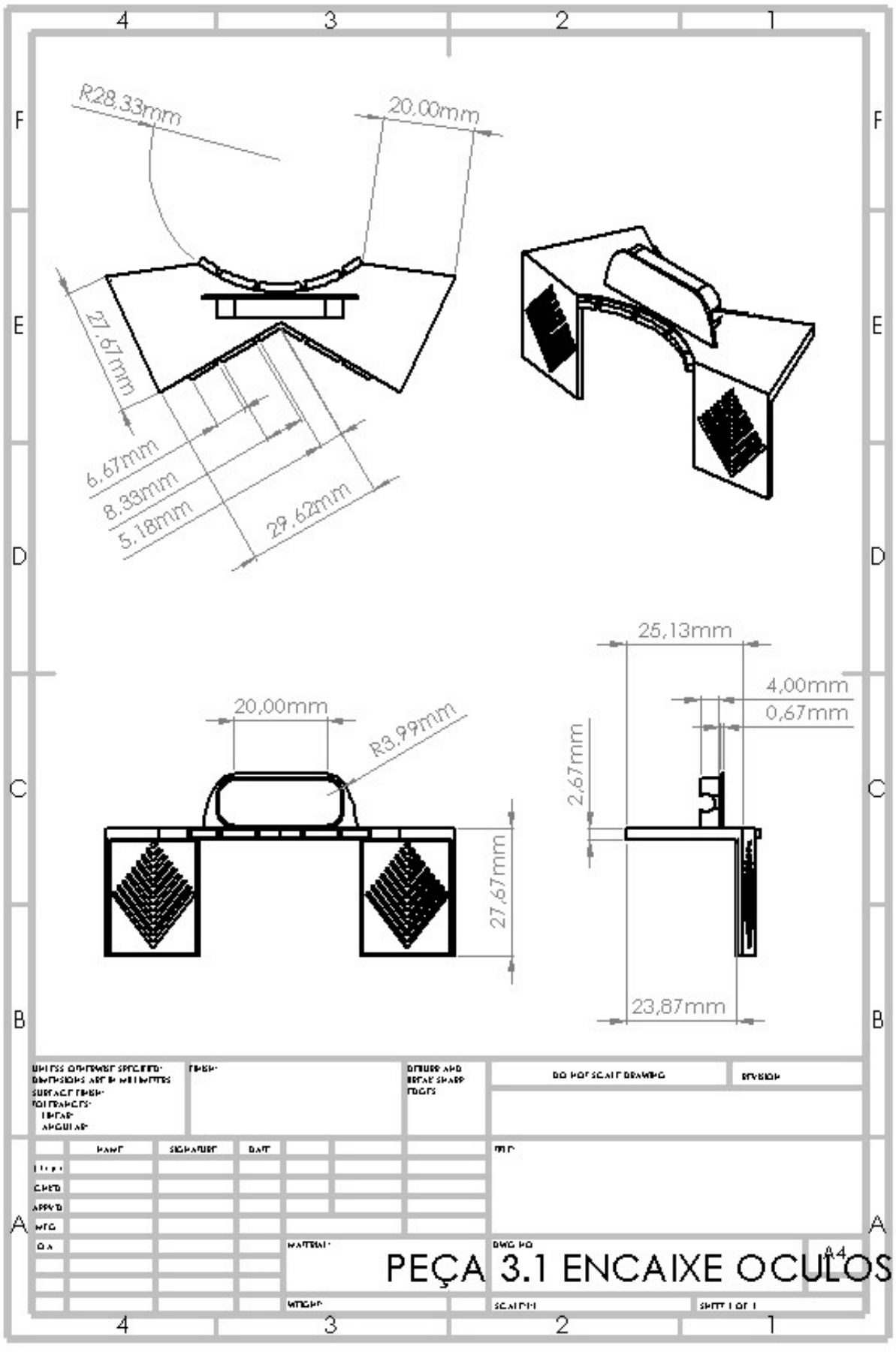
YAP, Leong; VITALLIS, Tony; LEGG; Stephen. Ergodesign: from description to transformation. In Proceedings of the 13th triennial congresso of the International Ergonomics Association. Helsink: finnish Institute of Occupational Health, 1997. V.2, p.320-322.

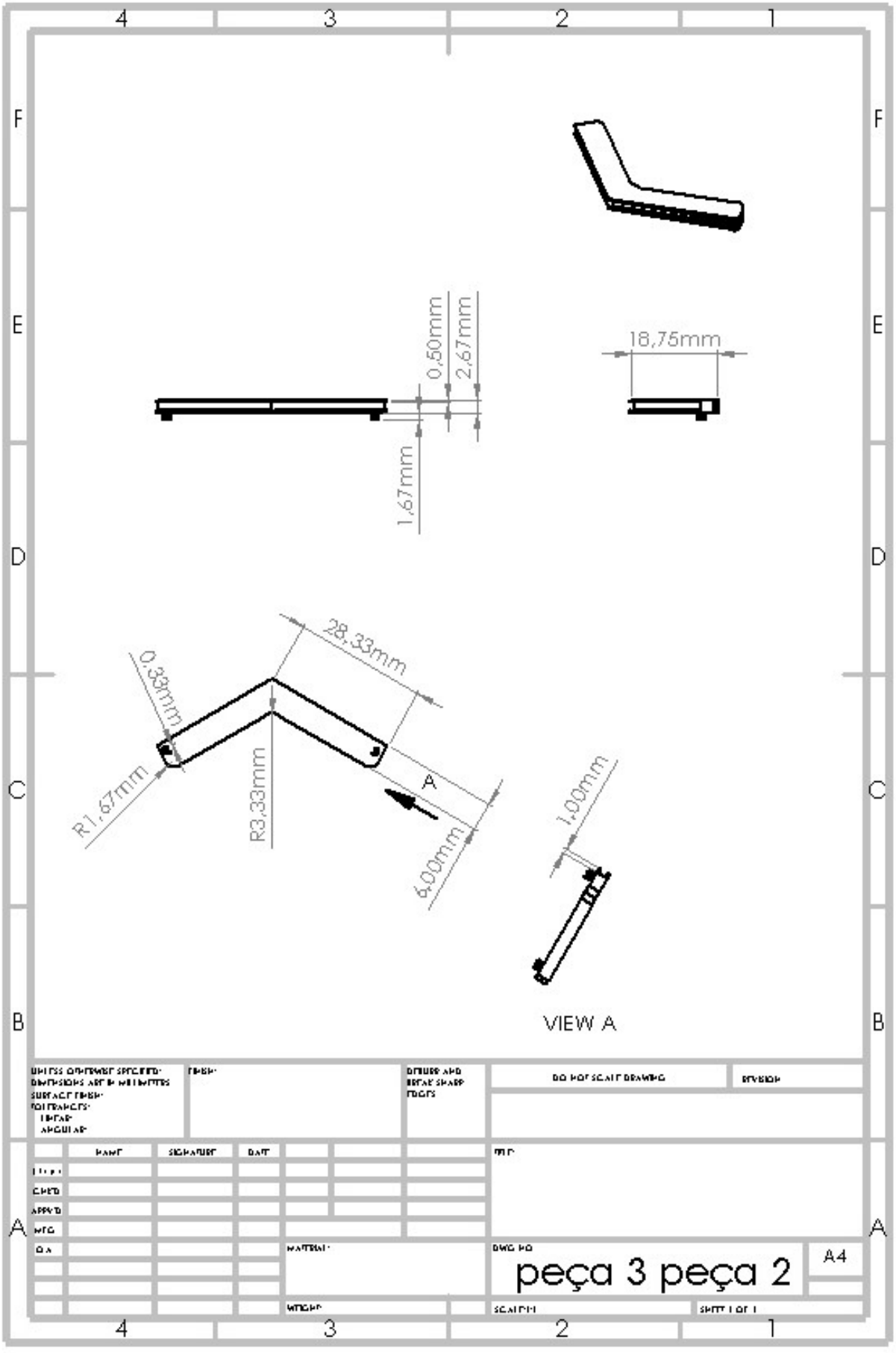
**APPENDIX**


4
3
2
1
F
E
D
C
B
A
1,00mm
Length 36,25mm
26,67mm
49,33mm
56,67mm
3,33mm
1,00mm
13,00mm
3,67mm
1,00mm
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE


4
3
2
1
F
E
D
C
B
A
1,00mm
13,00mm
23,13mm
45,84mm
49,16mm
Peça 1.1 borracha
A4


R28,33mm
16,00mm
1,22mm
10,58mm
R3,33mm
23,33mm
10,00mm
8,33mm
1,00mm
Ø56,67mm
1,00mm
0,50mm
2,00mm
Peça 2 plastico
A4


R28,33mm
20,00mm
27,67mm
6,67mm
8,33mm
5,18mm
29,62mm
20,00mm
R3,99mm
27,67mm
25,13mm
4,00mm
0,67mm
2,67mm
23,87mm
PEÇA 3.1 ENCAIXE OCULOS 1


4
3
2
1
F
E
D
C
B
A
0,50mm
2,67mm
1,67mm
18,75mm
28,33mm
0,33mm
R1,67mm
R3,33mm
A
4,00mm
1,00mm
VIEW A
DO NOT SCALE DRAWING
peça 3 peça 2
A4