Cyprus University of Technology

Faculty of Fine and Applied Arts

Doctoral Dissertation

A SYSTEMATIC APPROACH FOR DESIGNING AN ELDERLY-FRIENDLY VIRTUAL REALITY STORYTELLING APPLICATION

Zoe Anastasiadou

Limassol, May 2024

CYPRUS UNIVERSITY OF TECHNOLOGY

FACULTY OF FINE AND APPLIED ARTS

DEPARTMENT OF MULTIMEDIA AND GRAPHIC ARTS

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Approval Form

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ABSTRACT

Virtual reality (VR) can be useful in efforts aimed at improving the well-being of older members of society. The work presented aims to provide elderly people with a user-friendly and enjoyable VR application incorporating memory recall and storytelling activities that can promote mental awareness so that negative side effects associated with brain inactivity could be prevented. To fulfill the aim of the thesis, a multi-phase methodological framework was adopted. The first phase of the approach involves a thorough literature review aiming at understanding the physical and mental limitations of the elderly population that often prevent them from using state-of-the-art technologies like VR. Furthermore, existing VR applications that target the elderly population were reviewed. During the second phase of the approach, the reactions of elders towards existing applications were investigated, enabling the derivation of conclusions related to the factors that should guide the design of elderly-friendly contemporary applications. Based on the conclusions derived from the first two phases, a prototype VR application was developed. The application allows users to enter a storytelling experience where they have the chance to describe the contents of photographs showing places from their childhood. The primary application was evaluated so that main areas requiring improvement were defined. During the fourth phase, a number of design factors were further explored allowing the improvement of the proposed application. A key factor that emerged from this process was the need to introduce a virtual audience that listens to the stories presented by elderly users and interacts with the user, maximizing in that way the storytelling experience for elder users. The last two phases of the methodology concerned the development and evaluation of the final application. The evaluation aimed to determine whether older people are willing to use the proposed VR application and whether they believe it can help to improve their well-being and reduce the effects of loneliness and social isolation. The results show that elderly users are positive about using such an application in daily life, as a means of improving their overall well-being. Furthermore, as part of the work, a number of design guidelines for VR applications for elderly users were derived. The overall work carried out, can contribute to the efforts of modern societies to support the elderly population.

Keywords: Virtual Reality, Elderly, Memory Recalling, Storytelling Application Design;

ΠΕΡΙΛΗΨΗ

Η εικονική πραγματικότητα (ΕΠ) μπορεί να είναι χρήσιμη σε προσπάθειες που στοχεύουν στη βελτίωση της ευημερίας των ηλικιωμένων μελών της κοινωνίας. Η εργασία που παρουσιάζεται στοχεύει να παρέχει στους ηλικιωμένους μια φιλική προς το χρήστη και ευχάριστη εφαρμογή ΕΠ που ενσωματώνει δραστηριότητες ανάκλησης μνήμης και αφήγησης που μπορούν να προάγουν τη νοητική επίγνωση, ώστε να μπορεί να συμβάλει στην αποτροπή αρνητικών παρενεργειών που σχετίζονται με νοητική αδράνεια. Για την εκπλήρωση του στόχου της διατριβής υιοθετήθηκε ένα πολυφασικό μεθοδολογικό πλαίσιο. Η πρώτη φάση της προσέγγισης περιλαμβάνει μια διεξοδική βιβλιογραφική ανασκόπηση με στόχο την κατανόηση των σωματικών και πνευματικών περιορισμών των ηλικιωμένων που συχνά εμποδίζει τη χρήση τεχνολογιών αιχμής όπως είναι η ΕΠ. Επιπλέον, μελετήθηκαν υπάρχουσες εφαρμογές ΕΠ που στοχεύουν στους ηλικιωμένους. Κατά τη δεύτερη φάση της προσέγγισης, διερευνήθηκαν οι αντιδράσεις των ηλικιωμένων απέναντι σε υπάρχουσες εφαρμογές, επιτρέποντας την εξαγωγή συμπερασμάτων σχετικά με τους παράγοντες που θα πρέπει να καθοδηγούν τον σχεδιασμό σύγχρονων εφαρμογών φιλικών προς τους ηλικιωμένους. Με βάση τα συμπεράσματα που προέκυψαν από τις δύο πρώτες φάσεις, αναπτύχθηκε μια πρωτότυπη εφαρμογή ΕΠ. Η εφαρμογή επιτρέπει στους χρήστες να εισέλθουν σε μια εμπειρία αφήγησης όπου έχουν την ευκαιρία να περιγράψουν το περιεχόμενο φωτογραφιών που δείχνουν μέρη από την παιδική τους ηλικία. Η κύρια εφαρμογή αξιολογήθηκε έτσι ώστε να καθοριστούν οι κύριοι τομείς που χρήζουν βελτίωσης. Κατά την τέταρτη φάση, διερευνήθηκαν περαιτέρω σχεδιαστικοί παράγοντες που επέτρεψαν τη βελτίωση της προτεινόμενης εφαρμογής. Ένας βασικός παράγοντας που προέκυψε από αυτή τη διαδικασία ήταν η ανάγκη εισαγωγής εικονικού κοινού που ακούει τις ιστορίες που αφηγούνται οι ηλικιωμένοι χρήστες και αλληλεπιδρά με τον χρήστη, μεγιστοποιώντας με αυτόν τον τρόπο την εμπειρία αφήγησης για τους χρήστες. Οι δύο τελευταίες φάσεις της μεθοδολογίας αφορούσαν την ανάπτυξη και αξιολόγηση της τελικής εφαρμογής. Η αξιολόγηση είχε στόχο να καθορίσει εάν οι ηλικιωμένοι είναι πρόθυμοι να χρησιμοποιήσουν την προτεινόμενη εφαρμογή ΕΠ και αν πιστεύουν ότι μπορεί να βοηθήσει στη βελτίωση της ευημερίας τους και στη μείωση των επιπτώσεων της μοναξιάς και της κοινωνικής απομόνωσης. Τα αποτελέσματα δείχνουν ότι οι ηλικιωμένοι χρήστες είναι θετικοί στη χρήση μιας τέτοιας εφαρμογής στην καθημερινή ζωή, ως μέσο βελτίωσης της συνολικής ευημερίας τους. Επιπλέον, ως μέρος της εργασίας, προέκυψαν κατευθυντήριες γραμμές σχεδιασμού για εφαρμογές VR για ηλικιωμένους χρήστες. Το συνολικό έργο που επιτελέστηκε, συμβάλει στις προσπάθειες των σύγχρονων κοινωνιών για τη στήριξη του ηλικιωμένου πληθυσμού.

Λέξεις Κλειδιά: Εικονική Πραγματικότητα, Ηλικιωμένοι, Ανάκληση Μνήμης, Σχεδιασμός Εφαρμογής Αφήγησης.

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Chapter 1: Introduction

This chapter introduces the context, objectives, extent, and contribution of the dissertation. It reviews the prior research that influenced the development of the specific research questions and describes the methodology and activities carried out to address these questions. The chapter ends with a description of the structure of the dissertation and a summary of the next chapters.

1.1 Aim of the Work

Elderly are exposed to a variety of technologies, aimed at improving their quality of life. Among those technologies, Virtual Reality (VR) can offer elderly users the opportunity to become immersed in virtual worlds where they can interact with their environment, giving them a realistic experience that allows them to actively participate in creative experiences. The use of emerging technologies by the elder people is becoming increasingly important, especially in periods of social isolation caused either by external factors (i.e., a pandemic) or by internal factors associated with reduced mobility in the elderly. Through the use of emerging technologies, the elderly could be offered a way to reduce the side-effects caused by social distancing (Tomaka et al., 2006). Technology has the potential to enhance the lives of older adults by improving their safety, security, and self-confidence in everyday life (Rogers et al., 2005). Recently, the design and evaluation of emerging technologies in the form of Virtual Reality (VR) applications for the elderly are becoming more important as there is a growing need for older people to use such technologies (Lee et al., 2019).

A key characteristic of most elderly people is a keen interest to treasure their memories of the past (Belkacem et al., 2020). By sharing past experiences elder people gain a sense of self-existence, and at the same time they perform an important activity that could be helpful for their mental agility (Huang, 2023). Older people often experience a gradual loss of memory about recent events, but they are more likely to remember important events from the past (Levine and Bluck, 1997), which they are keen to share with younger people. Therefore, memory recalling storytelling activities offer a way for the elderly to cope with social isolation issues by engaging in a rewarding experience, while providing a mental awareness exercise that can help to prevent the effects of brain inactivity. Historically, storytelling has served as a medium for communication, entertainment, and education. Various forms such as textbooks, religious texts, and films are employed to preserve historical events, experiences, and knowledge, ensuring that information is shared and disseminated effectively (Freeman et al., 2020). A number of studies identified that engagement in storytelling activities has positive effects on older people (Mager, 2019; Scott and DeBrew, 2009), hence it is important to get the elderly to engage in such activities.

Although, older adults are being exposed to technologies and improving their expertise (Lee and Kim, 2019) the use of VR applications by older users is not widespread yet (Cherniack, 2011), in comparison with other mainstream technologies. The main reasons that prevent older users from adopting VR in their daily life are equipment cost (Ghobadi and Sepasgozar, 2020), difficult set up and not appropriate design (Pang and Cheng, 2023), not interesting scenarios for elder users, physical limitations like eye sight related diseases (Mascret et al., 2020) and limited interactivity (Lee and Kim, 2019). VR offers users the ability to get immersed into a virtual world where they can react and interact with the environment enabling them to have realistic experiences. Given that many elder people have mobility limitations, Virtual Reality could offer an ideal medium for supporting memory sharing of past experiences. The mix of interactivity and the ability to provide high-fidelity 3D visualizations of places and objects provides viewers with a one-of-a-kind experience that is impossible to replicate with traditional media.

The aim of the research presented in this thesis is to produce a Virtual Reality application that will allow elderly users to deal with the problems of social isolation, while providing at the same time a way to keep them alert, in a way that could prevent the effects of diseases associated with brain inactivity. By considering the potential of utilizing VR for the benefit of elders, along with the desire of elder people to describe experiences from the past, we focus on developing a VR-based user initiated storytelling application that allows elder people to visualize photographs from their past, and describe the contents of the photographs. A key feature of the proposed application is the existence of a virtual audience that aims to interact through pre-animated movements with the users and motivate them to engage in a storytelling memory recalling experience. The work described in this thesis falls under the general topic of making emerging technologies accessible to elder users, a topic that gains continuously increasing significance.

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1.2 Elderly Users and Technology

When compared to 2021, by 2050, the worldwide population of individuals aged 65 and above is projected to be doubled reaching 1.5 billion (see Figure 1.1). The number of people aged 80 years or older is growing even faster (Wilmoth et al., 2023). Contemporary seniors have experienced the monumental shift from analog and electronic to digital technologies throughout the last century. They've actively engaged in and influenced the remarkable evolution of daily routines from predominantly manual to predominantly digital.

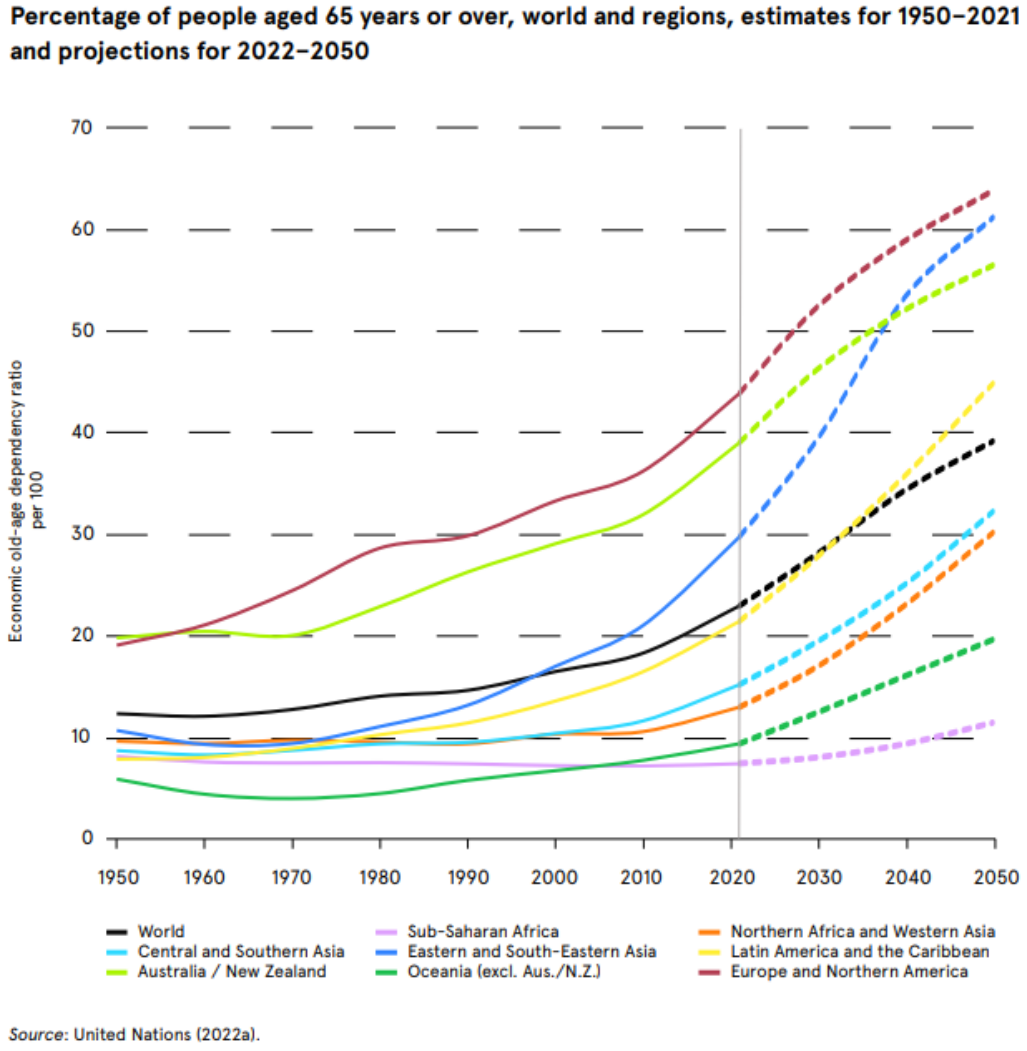

Figure 1.1: Percentage of people aged 65 years or over, world and regions, estimates for 1950–2021 and projections for 2022–2050, Image source: United Nations (2022a).

However, despite their contributions, older age is frequently portrayed as a challenge in media, policy, and research discussions, often seen as a hindrance to utilizing modern information and communication technologies in daily life (Köttl et al., 2021). The elderly are part of the society in which we live and with the pace at which technology advances in our daily lives, they also need to join the general group so that they do not feel isolated but also can solve daily problems that arise due to the lack of knowledge that have towards technology. The combination of rapid population aging and increased technology accessibility opens up avenues for older individuals to join digital communities, facilitating their participation in diverse social interactions online (Ebardo and Suarez, 2021). However, as part of this effort it is essential to deal with usability and accessibility issues that will enable the elderly population to adopt emerging technologies.

The future sustainability of the world and especially the European welfare relies significantly on addressing the provision of care for the elderly. In political and public discussions, the elderly are often portrayed as individuals with specific needs and desires, necessitating guaranteed and organized care. This portrayal reflects a cultural framework that idealizes certain characteristics of elderly individuals. By examining how society constructs the identities, needs, and roles of the elderly, we gain insight into the prevailing care systems and cultural values, which can prompt critical analysis and potential reform of existing care arrangements (Weicht, 2013). Contemporary digital advancements offer individuals the chance to work from anywhere and enjoy various forms of entertainment. The internet facilitates activities such as reading news, creating and viewing blogs, arranging vacations, and finding and exchanging health-related information. For older adults, technology serves as a means to stay connected with loved ones, participate in leisure activities, and pursue interests, yet the absence of support systems can impede their adoption of technology (Pirhonen et al., 2020).

The aging population, longer life expectancy, and desire for independent living are well-known societal shifts placing significant strain on healthcare systems. In this context, integrating and engaging elders in the digital realm is imperative. Assistive technology, with its remarkable advancements, is seen as a potential solution bridging the gap between the desires and needs of older adults. Despite the prevalence of technology in seniors' lives, interacting with it directly can often be frustrating and stigmatizing,

largely due to usability issues. There's a misconception that technology design is inherently user-friendly (Iancu and Iancu, 2020). Digital tools like online healthcare platforms empower the elderly to extend their period of independent living at home. Independence entails the freedom for older individuals to shape their lives according to their own priorities. With the widespread integration of digital multimedia devices into society, including among older adults, there arises a pressing need for tailored training for this demographic. Despite not being inherently incapable due to age or frailty, older adults frequently encounter challenges in using digital devices like smartphones, often lacking fundamental digital literacy necessary for operating multimedia devices with touchscreen interfaces. This deficiency stands as a primary factor contributing to the significant digital gap experienced by older generations in the twenty-first century (Blažič and Blažič, 2020).

Immersive headsets offering virtual reality (VR) present a promising avenue for delivering interventions aimed at enhancing physical, mental, and psychosocial well-being. Research on VR applications for older adults has predominantly centered on rehabilitation and physical capabilities, addressing areas such as gait, balance, fall prevention, pain management, and cognitive function (Dermody et al., 2020). Huygelier et al., (2019) mention that contribution of VR health applications in elderly users will neither be hindered by negative attitudes nor by cyber sickness, indicating the potential of elderly users to adopt VR technologies. The prospect of using VR technology for enhancing the wellbeing of the elderly population has prompted the research described in this thesis.

1.3 Workflow

In order to design and implement an engaging Virtual Reality application that will allow elderly users to deal with the problems of social isolation, a dedicated design methodology was adopted. The methodology follows a multi-phased co-design approach with the active participation of groups of people related to the elderly, such as caregivers, medical personnel, and elderly users. Furthermore, professionals with expertise in the development of Virtual Reality applications were also involved in the design process. The main phases of the design are shown in the flow diagram in Figure 1.2. The main phases of the workflow include the literature review in relation to user

requirements and previous approaches in designing VR applications for the elderly, a study related to the expectations of the target user group towards new technologies, the design and evaluation of a pilot test application, the refinement of design elements of the application, the development of the final application, and the evaluation of the application with the target population of elderly users.

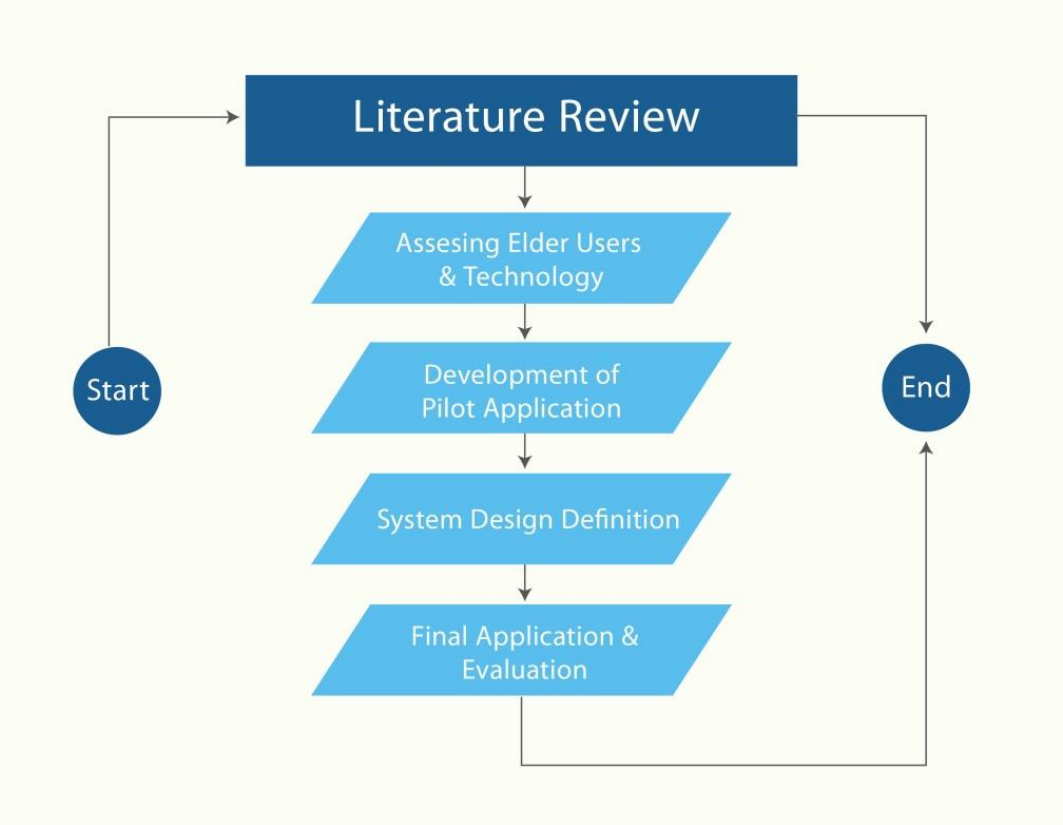

Figure 1.2: Flow Diagram of the main phases of the design process of thesis.

1.4 Contribution of the study

This study aims to contribute both at a theoretical and applied level to the area of designing VR applications for the elderly population. Studying about VR and the connections between the elderly requires a theoretical background from different scientific fields that include fields related to the limitations faced by elderly, VR, the connection between the elderly and technology, and factors influencing older people to make use of technology. Immersive VR has found applications across various domains, spanning from critical areas like healthcare support and training to educational contexts and entertaining computer gaming. Although the concept of VR in relation to the elderly

has attracted a lot of attention, the literature on the application of VR, especially in conjunction with the factors we study such as addressing the social isolation of the elderly, is still relatively small. Few studies have investigated the benefits of using VR in relation to the elderly (Appel et al., 2020; Garcia-Betances et al., 2015) and whether the elderly are willing to engage with these technologies (Charness and Boot, 2009). The purpose of this research study is to determine whether older adults are willing to engage and use virtual reality applications that can improve their overall wellbeing, through a user-friendly application. In addition, the importance of the research is enhanced by the multi-phased co-design approach that ensures that the VR application developed fulfills the expectations of the target user group. As part of this effort, a systematic approach for determining the optimum design elements that make VR applications desirable for the elderly population is presented, providing in that way insights that can inform the development of effective VR applications that target the elderly. Furthermore, the multiple evaluation experiments carried out as part of the action research methodology, supported the derivation of conclusions that guided the design process.

Previous studies have noted a shortage of clear directives for ensuring the safe integration of older adults into immersive VR environments and facilitating their seamless transition between virtual and real worlds. Some evidence points to the effectiveness of involving diverse stakeholders through participatory design methods. While existing literature primarily focuses on assessing overall user experience, it often overlooks longitudinal evaluations. Consequently, the study underscores the importance of establishing guidelines to inform the design process and selection of user experience evaluation techniques specific to immersive VR experiences for older adults (Ijaz et al., 2022). For this purpose we aim to study and design an application based on the needs of the users through the design factors, to provide convenience and ease of use to the user, while enhancing the user experience.

It should be noted that apart from the literature review and the evaluation experiments, a significant part of the effort in this work was devoted to the actual implementation of the applications used as part of the experiments described in this thesis. In conclusion, the three important points which this research contributes are the following:

- The multi-phase co-design methodology adopted for the design of the elderly-friendly VR application.
- The design factors considered for making user-friendly VR apps, which are not clearly documented in the literature so far.
- The actual end application that offers a simple and effective way to get elder people to use the application.

Apart from the scientific contribution of this thesis, the work described, and the end application provides a service to the elderly population, and the overall society, as it can be used as part of the efforts for improving the wellbeing of elder users.

1.5 Research Questions and Methodology

The main research questions that constitute the fundamental core of this thesis research project are the following:

RQ1: *Are elderly users willing to use Virtual Reality applications?*

RQ2: *Do elderly people believe that Virtual Reality can help to increase their well-being?*

In addition to the above basic research questions, in each chapter that follows, additional research questions related to specific aspects of the work were raised and analyzed as shown in the following chapters.

In order to answer the above research questions, the action research methodology was followed. Action research methodology is characterized by its participatory, iterative, and context-sensitive approach, aiming to generate practical insights and drive positive change in real-world settings (Reason and Bradbury, 2008; McNiff and Whitehead, 2006). More specific, action research is iterative and cyclical, consisting of repeated cycles of planning, action, observation, and reflection. Researchers continuously refine their strategies based on feedback and outcomes, leading to ongoing improvements and iterations. In addition, it emphasizes collaboration between researchers and participants, often involving them as active partners in the research process. This collaborative approach fosters shared decision-making and fosters mutual learning and empowerment. At the same time, it aims to address real-world problems and bring about tangible changes in practice or policy. It focuses on generating practical insights and solutions

that can lead to substantial improvements in the context under study (Stringer, 2007). Ethical issues are paramount in action research, with researchers prioritizing the welfare and rights of participants. This includes obtaining informed consent, maintaining confidentiality and ensuring that research activities do not cause harm or exploitation. Finally, action research is characterized by a flexible and adaptive methodological approach. Researchers can use a range of qualitative, quantitative or mixed methods, choosing methods that best suit the research questions and objectives (Brydon-Miller et al., 2003).

1.6 Thesis Structure

The thesis is structured as follows:

Chapter 2: *Literature Review*. This chapter presents the most common characteristics of the physical and mental condition of elders, allowing the readers to understand the main difficulties faced by elder users of Virtual and Augmented Reality. Definitions of Virtual and Augmented Reality applications are presented below. Furthermore, a review of Virtual and Augmented Reality technologies that target the elder population is presented, with emphasis on applications that target users suffering with dementia, and applications that aim to compact social isolation, especially in relation to the recent COVID-19 pandemic. Overall, this chapter explores the present understanding within the discipline, highlighting essential elements and offering a concise description of the subject being examined.

Chapter 3: *Assessing the willingness of elder users in using virtual and augmented reality technologies.* In this chapter, we present an experimental investigation that aims to assess the willingness of elder users to use virtual and augmented reality technologies and derive conclusions related to the main issues that attract or deter elder users from using such technologies. Three preliminary experiments related to the use of virtual and augmented reality by elderly have been completed (Anastasiadou and Lanitis, 2021). The design of the experiment is based on a 3-stage hierarchical structure where in each step the participants are exposed to more technologically intensive interaction styles starting with the use of a common smartphone application and gradually moving on to immersive applications.

Chapter 4: *Development and Evaluation of a Prototype VR Application for the Elderly*. This chapter presents the design and development of a prototype Virtual Reality tool that allows elderly users to deal with the problems of social isolation, while providing an entertaining brain-triggering activity. An initial user evaluation provided information related to the strengths and limitations of the prototype application that guided the process of optimizing the application for elderly users.

Chapter 5: *Refining Design Elements of the VR Application - Determining Optimum Audience for Storytelling VR Applications for the Elderly*. As part of our work to provide to elderly a user-friendly, and enjoyable Virtual Reality (VR) application, a prototype VR application that allows elderly to enter a storytelling activity was developed. An important aspect of the application is the virtual audience who listens to the stories presented by elderly users and the type of photographs that are presented in the application. In an attempt to maximize the impact of the VR application, a dedicated study aims for establishing the main characteristics of the virtual audience and the type of photographs to use. The results of this study are important for creating a more engaging experience for elderly users.

Chapter 6: *Final Application, Evaluation and Discussion.* Given the results of the evaluations of the pilot application, and the results of the online questioner regarding design elements of the application, the final application was designed and developed (Anastasiadou et al., 2024). Specifically in this chapter, we are focusing on the redesign of the application and the evaluation. The results of this study are important in order to answer the main research questions posed.

Chapter 7: *Conclusions and Future Work*. This chapter presents the conclusions derived from the finding of this dissertation. Moreover, this chapter presents the contribution of the research and the limitations that were encountered during the process. Furthermore, it presents the future direction of this work and new research ideas and techniques that could be used in future applications.

Chapter 2: Literature Review

This chapter presents a literature review describing the most common characteristics of the physical and mental condition of elders, allowing the readers to understand the main difficulties faced by elder users of Virtual and Augmented Reality. Furthermore, a review of Virtual and Augmented Reality technologies that target the elder population is presented, with emphasis on applications that target users suffering with dementia, and applications that aim to compact social isolation, especially in relation to the recent COVID-19 pandemic. Overall, this chapter explores the present understanding within the discipline, highlighting essential elements and offering a concise description of the subject being examined.

2.1 Characteristics of Elderly

There is no agreement on when a person becomes old. Chronological boundaries, such as chronological and biological age, initially identify life-cycle changes and the principle of old age, but in essence, the principle of old age is marked by a combination of chronological, functional and social parameters. The UN accepts the age of 60+ as an adult enters old age (Bickenbach, 2011). The age of 65, which coincides with the retirement age in most developed countries, is considered to be the beginning of old age (Anastasiadou, 2015). Seniors define successful aging as an active method that includes events and exercises that focus on promoting or keeping physical, functional, psychological, and social health (Phelan et al., 2004). According to world epidemiological data (Anastasiadou, 2015) soon older people will be more than children for the first time in the history of humanity (see Figure 2.1).

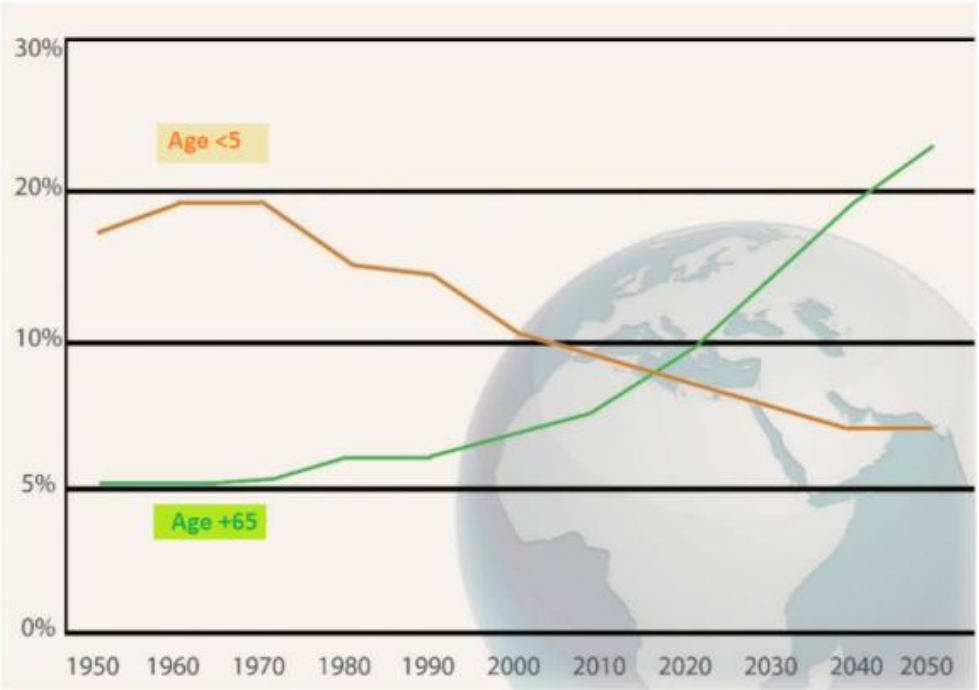

Figure 2.1: Percentage of children and the elderly in the world population, Image Source: Anastasiadou, 2015.

In general three subgroups of elderly are distinguished: The first consists of so-called young adults, aged 60+ or 65+ up to 74 years old (young old). These people are usually fit, active, and take care of themselves. They present quantitatively the least medical and social problems. The second subgroup relates to people aged 75+ to 84 years old (mid

old). After the age of 75 the condition of the elderly is becoming more fragile and is characterized by severe physical and mental impairment. Finally, the third subgroup consists of older people over 85 years (the oldest old group) of age who are usually very fragile, have severe physical and mental impairments, are highly dependent on other people, and due to mobility problems are usually confined to home.

Technology has the potential to enhance the lives of older adults by improving their safety, security, and self-confidence in everyday life. However, too often older adults' abilities and limitations are not reflected in the design of current and future technologies. Although older adults experience specific limitations as they age, the word old does not necessarily identify people who are disabled or sick. Many people over the age of 65 are reportedly in good health (Rogers et al., 2005). The involvement in end-of-life education promotes successful aging, as the activity of learning in old age can positively influence the quality of life and overall well-being (Boulton-Lewis et al., 2006).

Physical activity is seen to present an important role in promoting the functional status, psychological status, and well-being, and has social advantages (Syed-Abdul et al., 2019). The overall physical abilities and appearance of people deteriorates as they grow older (Lanitis et al., 2013). In terms of vision, these include changes in visual acuity, color perception, and susceptibility to glare. In the auditory domain, older adults face higher difficulty perceiving high-pitched sounds and greater interference from background noise (Fook and Morgan, 2000). In a very literal sense, older adults may perceive technology differently than younger adults do (Charness and Boot, 2009).

2.1.1 The effect of aging on the abilities of elders

Over time, physical and functional changes occur in humans that are not necessarily based on chronological age. These changes push people to appreciate their abilities and ways of dealing with those who interact with others and the natural environment (Farage et al., 2012). In this section age related-changes are categorized in sensory, physical and cognitive changes, and a relevant discussion for each category is presented. It is important to note that good design for the elderly is often a good design for everyone so designers should take into account sensory, physical and cognitive factors to ensure the adoption of design for all principles.

2.1.1.1 Sensory

One of the first signs of aging is the weakening of the near focus or presbyopia, where it is repaired with reading glasses or binocular lenses. Most people first notice this weakening in their early 40s. The focus on the nearest point is 10 cm at the age of 20, contrasted to 100 cm at the age of 70. People over the age of 70 are more likely to have some degree of vision and hearing loss. Another feature of vision that changes over time is the field of view where there is a reduction due to factors such as the decline characterized by the eyelash tilt (Payne and Isaacs, 2017). In late adulthood, the deterioration of visual acuity affects the eyes of the elderly where it is particularly evident in many diseases such as cataracts, macular degeneration, glaucoma, and diabetic retinopathy (Zavlanou and Lanitis, 2016).

The understanding of touch, pressure, and vibration decreases with age, especially in the hands and feet (Farage et al., 2012). The sense of touch is the creation of two subsystems. Sensation of the skin records information about vibrations, pressure, heat, cold and tissue damage (pain). The proprioception, the sense of the machine system, is able to determine the position and movement of the limbs and the collision of external forces (Wichert and Klausing, 2013). Lower pressure sensitivity makes it harder to feel when the body is in full touch with a surface or when a small surface is pressed, such as an elevator button or keypad (Farage et al., 2012).

2.1.1.2 Physical

Elderly people show several physical changes including muscle weakness, vertebral compression fractures, and/or back muscle weakness are known to be related to kyphotic curvature of the thoracic and/or lumbar spine in elderly patients (Kasukawa, et al., 2010). The kyphotic curvature of the spine negatively affects the quality of life, thus affecting the experience of using AR in the elderly. A study revealed that declines in physical and mental health, the loss of functional capabilities, and a weakening of social ties represent obstacles to active aging among institutionalized older adults (Syed-Abdul, et. al., 2019). In the elderly population the range of body motion is limited, muscle strength is reduced, the body is less flexible and reflexes are more moderate. The height of the trunk and the length of the arm are reduced, making it more difficult

to access items. Furthermore, diseases, such as arthritis, cause joint hurt and stiffness, making it tough to grip and hold different surfaces (Farage et al., 2012).

Diseases that occur frequently in elders, such as Parkinson's, stroke or mechanical damage to the facial nerve, can lead to dysfunction of facial muscle movements. One consequence of this is that the structure of daily life has to adapt to the health issues. For example even simple tasks like food intake require longer time due to difficulties in eating and swallowing (Wichert and Klausing, 2013).

2.1.1.3 Cognitive

Age-related changes in cognitive function vary considerably between individuals and cognitive domains, with some cognitive functions appearing more sensitive than others to the effects of aging. Much of the basic research on cognitive aging has focused on attention and memory, since deficiencies in these fundamental processes may explain much of the variation observed in higher-level cognitive processes (Glisky, 2007). Dementia is a term used to describe a decline in mental abilities, including memory, language, and logical thinking, that is severe enough to affect daily living (Borelli et al., 2020). An important element of the research is that older adults usually appear to activate different brain structures than younger adults when performing cognitive tasks (Glisky, 2007).

2.2 Difficulties faced by the elderly in VR and AR applications

Virtual Reality is defined as the use of computer technology to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence (Bryson, 2013). Extended Reality (XR) is a broad term that includes augmented reality (AR), virtual reality (VR), and mixed reality (MR). AR blends virtual elements with the real world in real-time, while VR enables users to interact with and explore a simulated environment, whether it’s a replica of the real world or an entirely fictional one. These technologies are frequently combined to create more engaging and immersive experiences (Chuah, 2018).VR utilizes interactive computer-generated 3D environments (Gorini and Riva, 2008), primarily incorporating auditory and visual feedback, and occasionally haptic feedback. VR can be categorized into non-immersive,

semi-immersive, and fully immersive systems (Mujber et al., 2004). Non-immersive setups are desktop-based with limited interaction (e.g., keyboard, joypad) and immersion (e.g., PC, tablet). Semi-immersive systems typically feature a large monitor/projector with moderate interaction and immersion (e.g., Kinect, data gloves). Immersive systems utilize tools like head-mounted displays (HMDs) or the cave automatic virtual environment (CAVE) for high interaction (e.g., trackers) and deep immersion in the virtual environment (VE). Moreover, VR can be viewed as a spectrum between reality and virtually, where aspects of the VE blend with the real world (augmented reality) or vice versa (augmented virtually) (Milgram et al., 1995).

Virtual reality holds great promise as a tool that could improve the treatment of cognitive and emotional disorders in the elderly. While VR applications have been successfully used in clinical environments with adolescents and children, there has been comparatively less research conducted on its application in the geriatric population (Skurla, 2022). Some virtual reality applications are designed to combine virtual representations with the perception of the physical world. Stereo sound may contribute to the immersion, as well (Gachet et al., 2012). Many virtual reality applications are about combining real-world virtual representations providing the user with information about the natural world that they would not be able to obtain otherwise. This type of application is referred to as augmented reality. With this technology, the user perceives the real world by receiving information invoked by virtual elements so instead of experiencing the physical reality, one is placed in another reality that includes the physical along with the virtual (Sherman and Craig, 2002). AR and VR are typically associated with younger populations, as they are sophisticated technologies considered to be the most suitable for gaming platforms and have features such as complexity for creating and using them. Augmented Reality (AR) and Virtual Reality (VR) technology have quickly been used in a number of cases, including games, navigation, medicine, education and design (Lee et al., 2019).

The use of VR and AR technologies by the elderly is affected by several difficulties faced by elders. However, VR and AR can play an important role for maintaining for the wellbeing of older people, hence it is necessary to recognize the challenges and difficulties faced by older people when using VR and AR technologies, and study the reasons that make elder people reluctant to utilize those technologies. In a community

where our elderly population is increasing significantly, we have to find ways to support aged people.

As we mentioned above virtual reality technology offers the user immersion into a virtual world where they can react and interact with the environment enabling them to have realistic experiences. Augmented reality enhances this situation by providing a realistic environment with additional virtual information. Currently, older adults are being exposed to technologies and improving their expertise as concerns using interactive technologies with the support of younger people (Lee and Kim, 2019). For technology-based learning activities, a typical person needs perceptual, motoric, and cognitive skills. However, as people age, their cognitive, physical, and sensory skills tend to decline as mentioned in section 2.1.1. Furthermore, the high cost for private use of such technologies hinders the accessibility of technological tools to elder people. Additionally, older adults may refrain from using the latest technologies because they believe that modern technologies are difficult to control or impossible to use.

Technologies such as AR and VR have been identified as a solution used to assist elders who face various difficulties later in life. The principal purpose of these emerging technologies is to promote their care and control their health. Social and emotional well-being has also recently been recognized as an important factor in improving the quality of life of elder people. Though, there is a deficiency of AR and VR technologies to support their social and emotional well-being. New technologies that have been designed without understanding the characteristics of older adults are limiting their experiences with these technologies or even harming helpless users. To answer the question of whether older people can use technologies by incorporating them into their daily lives, (Lee et al., 2019) proposed an evaluation framework, focusing on three categories: physical, social, and psychological well-being. More details about each of these categories are presented below:

2.2.1 Physical well-being

Physical well-being consists of the ability to execute physical activities and perform social roles that are not prevented by physical limitations and experiences of bodily pain, and biological health index (Capio et al., 2014). About the challenges and planning for the physical well-being, older adults worry about how other people

perceive them. For this purpose, they will be careful when using or wearing devices, if the external appearance of a VR device relates to a support tool for health because they do not want other people to view them as weak. In addition, if during the use of the application dizziness occurs in the user then it can develop into a secondary disease. Designers should consider how to overcome older adults' physical and cognitive barriers and how to support a stable, comfortable experience for them while they use VR and AR systems. To ensure they do not miss the attention and to support their engagement with the system, it is necessary to design the system for controllability, such that they have control and feel as though they are in control. Often, VR requires a level of technical interference to either set up the application or use it. Therefore, caregivers or family members should be able to use any application to help elders in their use or adoption (Lee et al., 2019). However, since the ability to use VR applications without assistance is an important issue, elderly-friendly VR applications should be easy to install and execute, without requiring additional equipment (i.e. motion trackers or dedicated controllers) that may be difficult to set up.

2.2.2 Social well-being

Social well-being can be defined as the ability of people to coexist peacefully in communities with opportunities for advancement (Cole et al., 2009). About the design issues for social wellbeing, a person's quality of life is increasingly affected by relationships with other people. For this purpose, several technologies (Lin et al., 2018) and robotics (Shishehgar et al., 2018) have been developed to improve the connection between elders and their families, relatives, friends, nurses, and doctors and to support social interaction. Elderly people feel unfamiliar with the use of virtual reality and thus find it difficult to integrate it into their daily lives and social interactions. In this case, because the technology is designed to promote social interaction with older adults, they can experience a sense of isolation instead. It is required to try to provide technology-based activities similar to those in a physical environment by comparing emotions experienced by elders while interacting with characters in a virtual environment with emotions experienced in real relationships. Older adults will engage and become more active when they feel engaged in a particular activity or human relationship while using the system.

2.2.3 Psychological well-being

Psychological well-being refers to levels of positive functioning that include one's relatedness with others and self-referent attitudes that include one's sense of mastery and personal growth and is based on eudemonia building on thoughts, feelings, and behaviors (Biracyaza and Habimana, 2020). Concerning the design issues for psychological wellbeing, AR and VR are designed to promote an autonomous adult lifestyle, but due to ancillary issues such as configuration problems and software updates, elder people face difficulties in utilizing such technologies to improve psychological wellbeing. An elderly person is significantly affected when cerebral cognitive impairment occurs (see section 2.2.1), making it difficult to complete a scenario of a virtual reality application and as a result elder people may prefer not to use at all complicated VR/AR applications. Furthermore, it is important to recognize how the installation process can be clarified so that the elderly can install VR/AR applications without the need of assistance. As mentioned above, an elderly person with cognitive impairment cannot accept much information as he will most likely forget it in a very short time, hence explicit instructions related to the use and installation of new applications must be readily available.

VR and AR can independently meet the needs of older adults by recognizing and understanding their behavioral patterns and can make choices for users when needed. When this design principle is applied, it is possible to defeat the anxiety, worry, and stress that elder people feel while using the technology. Many studies on AR have centered on old adults with a disability. Most studies of interactions between older adults and AR use have defined the age of the user as a criterion for the successful use of the application. Age is not a predictor for use of interactive technology. It is a fact that physical capacity limits as one becomes old.

Older adults have different levels of skills and abilities and different tastes and needs and it is necessary to recognize this fact. VR and AR technologies can be designed and adapted to the individual's cognitive level and movement issues. When this design principle is applied, it is possible to reduce the fear, difficulty, and stress they feel while using the new technology (Lee et al., 2019).

Hayhurst (2018) mentions an issue that arises for the design part of virtual reality applications for people with dementia. Also focuses on the settings they need at the beginning of the application for the user, which requires technical assistance from caregivers or family members who should be able to use any application for support of people with dementia so they can use it later. There is a risk that designers will use the "One Size Fits All" method. Any interruption of assistive technology should be designed to reflect the necessities of the disease and should be considered the idea that their needs may vary over time depending on how the situation of their health affecting them at the specific moment.

2.3 VR and AR technologies and the elderly

There is a generally supported view of the interest of keeping older adults in sync with the latest technological developments. As well as joining with family and friends, technology can support older adults in improving social support, increasing access to medical knowledge, enabling them to engage as citizens in decision-making processes, and allow them to keep fit using dedicated fitness apps (Peleg-Adler et al., 2018). In this section typical AR/VR applications that target the elderly population are described.

In today's aging society, falls represent a significant public health issue for the elderly population. While virtual reality technology shows promise in mitigating fall risk (Conner et al., 2022), the lack of user body representation in VR environments diminishes spatial presence. Augmented reality, offering greater presence and embodiment, presents an alternative. To address this, Chen et al., (2020) created an AR-based exergame system tailored for the elderly to reduce fall risk. Data analysis revealed positive user evaluation, with pragmatic quality rated as good and hedonic quality as excellent.

Lera et al., (2014) describe a human-robot interaction architecture called MYRA, used to build a system for elderly support and medical dose control that includes augmented reality to improve the interaction with the robot. Through their prototype, it is possible to follow simple medical guidelines to take the everyday pill dose, thanks to the help given by the augmented reality, with just displaying the pillbox to the robot or to a camera. As demonstrated in Figure 2.2 the elderly has the interaction with the robot and the pillbox and with the use of AR, the task could be complete. To the other side, an

operator controls the robot to offer real-time assistance to the elderly, using the camera speakers and phone mounted onboard. The research concluded that the use of AR had indeed positive impacts on the users.

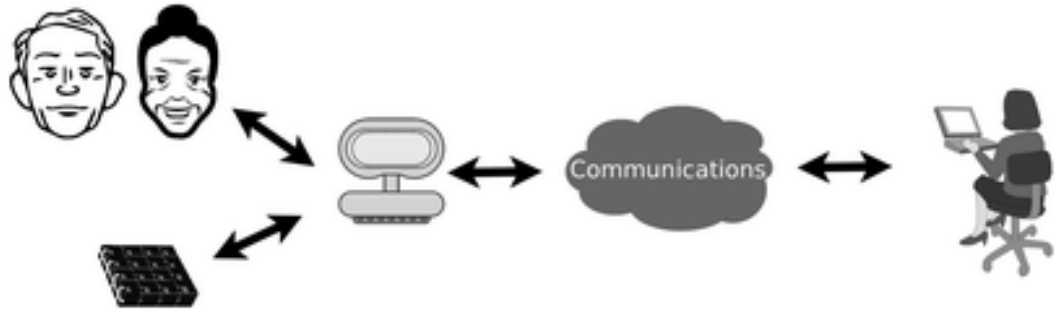

Figure 2.2: Shows the general concept of the project MYRA, Image Source: Lera et al., 2014.

Stammler et al., (2023) describe an AR-based application named Negami for spatial neglect treatment, integrating visual exploration training with active, eye, head, and trunk rotation. The app overlays a virtual origami bird into the patient's real environment (see figure 2.3), which they explore using a tablet camera. Subjective feedback from healthy elderly participants (n=10) and stroke patients with spatial neglect who used the Negami app was analyzed. Usability, side effects, and gaming experience were assessed through various questionnaires. Healthy elderly participants found training at the highest difficulty level to be challenging but not frustrating. The app received high ratings for usability, minimal side effects, and high levels of motivation and enjoyment. Stroke patients with spatial neglect consistently rated the app positively in terms of motivation, satisfaction, and enjoyment.

Levy et al., (2016) investigates how virtual reality related to serious games can be used to handle the pathological phobia of falling. Specifically, the fear of falling is the continuing fear of falling that cannot be explained by physical examination. Sixteen participants were randomly selected from either a treatment group or a waiting list, and the duration of the virtual reality therapy with serious games consisted of 12 weekly sessions. The mean age for the treatment group was 72 years and for the control group was 69 years. Participants' ratings of fear of falling were improved after treatment, leading to a significant difference between the two groups. As they mention, serious games-based virtual reality exposure therapy can be used to treat the fear of falling, though further studies are needed to confirm its effectiveness and determine its underlying mechanism.

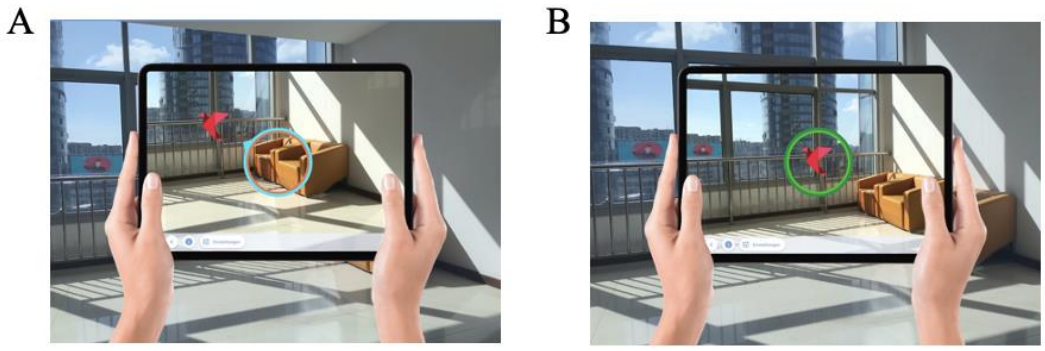

Figure 2.3: The patient has the task to follow the flying origami bird and to keep the bird within the orange/blue circle (A). If the task is successfully solved the circle turns green (B). Image Source: Stammler et al., 2023.

Baños et al., (2012) explore ways in which seniors can increase the number of positive experiences in their daily lives through exposure to two virtual environments (VEs) used as mood induction procedures. According to several studies (Kok et al., 2013; Vázquez, et al., 2009), positive emotions significantly affect mental and physical health, contributing to the well-being of the elderly. In the work of Baños et al., (2012), VEs contain activities to create positive autobiographical thoughts, consciousness, and slow breathing rhythms. During an experimental investigation, a sample of 18 participants over 55 years of age used the VE's in two cases. Twelve of them used the environment of joy, while 16 used the environment of relaxation. Moods were assessed using Optical Analogue Scales (Pointer, 2004) before and after each session. After using both VEs, the results showed significant increases in joy and relaxation and significant reductions in sadness and stress. Participants also recorded low levels of difficulty in use and high levels of satisfaction and sense of proximity. Therefore, VEs prove their usefulness in promoting positive effects and enhancing the well-being of the elderly.

VR has been employed in various areas for rehabilitation purposes, especially in stroke recovery. Consequently, recent guidelines have advocated for the integration of VR into both motor and cognitive rehabilitation programs for stroke survivors (Tuena et al., 2020). Optale et al., (2010) tested the efficacy of a program of VR memory training in improving the cognitive functioning of elderly adults with memory impairment. For the experiment, they assigned 36 elderly residents of a rest care facility with middle age the 80 years old. The experimental group experienced six months of VR memory training

that involved auditory stimulation and VR activities in path finding. The initial training phase lasted three months, and there was a booster training phase during the following three months. The control group experienced equivalent face-to-face training sessions using music therapy. Both groups participated in social and creative plus assisted-mobility activities. They found that the participants who received the VR memory training presented an improvement of general cognitive functioning and oral memory after the initial training period. The most important results were observed in long-term memory, in keeping with the cognitive abilities stimulated by the auditory session of the VR memory training. The improvements in executive function capabilities, in contrast, were small and did not perform corrections for the reduced depression scores of the experimental group participants. Furthermore, despite the spatial nature of the VR sessions, no effect was observed on the visuospatial abilities.

Peleg-Adler et al., (2018) studied the practicality of AR technology for older adults by observing their interactions and performance in a path-planning task compared to younger adults. They assessed task completion time, error rate, device movements, and subjective impressions using both AR and non-AR interfaces. Forty-four participants from two age groups were selected: community-dwelling, healthy adults over 65, and younger individuals aged 25–40, mostly university students. Older adults were slower in both interfaces, consistent with age-related declines in perceptual and cognitive skills. However, the impact of AR on performance was similar across age groups. Despite being unfamiliar with AR, older adults showed similar performance changes as younger adults when using AR compared to non-AR applications. Interestingly, older adults preferred the AR interface and reported a better user experience compared to younger participants. They found the AR application user-friendly, practical, easy to learn, and intuitive. These findings suggest that older adults are willing and capable of embracing new technologies, especially when they perceive benefits in their daily lives.

More recently, Kosti et al., (2024) indicate that seniors showed a strong interest in VR and modern technologies, with a desire to generate their own content. This content was integrated into the virtual village's outdoor features. Participants were motivated by the interactive and social aspects of the VR environment, feeling both creative and exploratory. Image sentiment analysis confirmed their positive reception, indicating high levels of acceptance.

Lin (2017) sought to study and understand how virtual reality will affect the emotional and social well-being of the elderly through the Rendever VR platform. The study was conducted with sixty-three residents from four assisted communities and lasted two weeks where residents interacted with one of two intervention conditions - VR (ie. experimental mode) or television (i.e. control status). The results showed that VR provided more positive results than the control group that used a TV with the same content. He concludes that VR has the potential to improve the well-being of the elderly. In contrast to the existing application Rendever where they offer video of personal moments of the elderly, we will offer the possibility of interaction through a virtual audience and a tour of the virtual space.

According to Rojo et al., (2023) ensuring adherence to physical exercise training is crucial for older adults and individuals with neurological disorders. Immersive technologies, increasingly incorporated into neurorehabilitation therapies, offer potent motivational and stimulating elements. This study aims to assess the acceptance and potential safety, utility, and motivation of a developed virtual reality (VR) system for pedaling exercise among these populations. A feasibility study was conducted with patients from Lescer Clinic and elderly individuals from the residential group Albertia. Participants engaged in a pedaling exercise session using the virtual reality platform, PedaleoVR (see figure 2.4). The findings indicate that PedaleoVR is considered a credible, user-friendly, and motivating tool for adults with neuromotor disorders to perform cycling exercises, potentially enhancing adherence to lower limb training activities. Furthermore, PedaleoVR does not induce negative effects associated with cyber sickness, while the sense of presence and overall satisfaction among the geriatric population were positively evaluated.

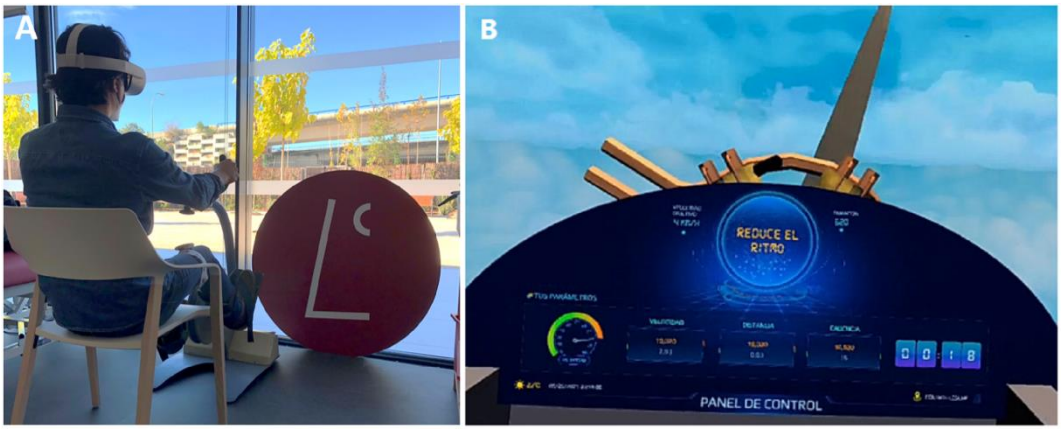

Figure 2.4: (A) Participant using the virtual cycling platform. (B) Capture of the first-person view of the virtual scenario 'High Flight', Image source: Rojo et al., 2023.

With the right combination of technologies it can be very useful about the elderly, as for example artificial intelligence-based robots used for social care promote social exchange and emotional relaxation, and the use of exciting content can enhance life satisfaction and family ties (Lee and Park, 2020). Tammy Lin and Wu (2021) study showed that the Proteus effect, which involves adjusting avatar age in virtual reality, works well for older people when they exercise. The findings demonstrated that, for older individuals who did not participate in strenuous exercise, the virtual reality embodiment of younger avatars causes a larger perceived exertion of exercise. The Table 2.1 presents the applications that have been mentioned in this section categorized by the type of application and a brief description.

2.4 VR and Dementia

Elderly people often treasure their memories of the past, and by sharing them, they can gain a sense of self-existence; however, due to the gradual decline of memory, all that remains are deep memories of the past; as a result, they tend to vividly repeat the same matter, but frequently forget more recent things and people (Wu et al., 2018).

VR applications could help persons with dementia (Wijma et al., 2018). The mix of interactivity and the ability to give high-fidelity 3D visualizations of places and objects provides viewers with a one-of-a-kind experience that is impossible to replicate with traditional media. For example, virtual worlds could be used as memory aids, allowing users to engage with artifacts that are difficult or expensive to obtain in the real world,

or to provide an experience of a location that is no longer accessible, such as a famous street from the past (Siriaraya and Ang, 2014). The interactivity of virtual worlds may enable older individuals to participate actively in a more playful and creative recollection experience, rather than just being passive observers of things and settings.

Table 3.1: Summary of applications described in this section

Researchers	Type	Description
Chen et al., (2020)	AR type	AR-based exergame system for the elderly to reduce fall risk.
Lera et al., (2014)	AR type	Human-robot interaction architecture system. Through their prototype, it is possible to follow simple medical guidelines to take the everyday pill dose.
Stammler et al., (2023)	AR type	Application named Negami for spatial neglect treatment, integrating visual exploration training with active, eye, head, and trunk rotation.
Levy et al., (2016)	VR type	Investigates how virtual reality related to serious games can be used to handle the pathological phobia of falling.
Baños et al., (2012)	VR type	Virtual environments (VEs) used as mood induction, contain activities to create positive autobiographical thoughts, consciousness, and slow breathing rhythms.
Optale et al., (2010)	VR type	Tested the efficacy of a program of VR memory training in improving the cognitive functioning of elderly adults with memory impairment.
Peleg-Adler et al., (2018)	AR type	Studied the practicality of AR technology for older adults by observing their interactions and performance in a path-planning task compared to younger adults.
Kosti et al., (2024)	VR type	Participants were motivated by the interactive and social aspects of the VR environment, feeling both creative and exploratory.
Lin (2017)	VR type	Study and understand how virtual reality will affect the emotional and social well-being of the elderly through the Rendever VR platform.
Rojo et al., (2023)	VR type	This study aims to assess the acceptance and potential safety, utility, and motivation of a developed virtual reality (VR) system for pedaling exercise.
Tammy Lin and Wu (2021)	VR type	Study showed that the Proteus effect, which involves adjusting avatar age in virtual reality, works well for older people when they exercise.

Narrative gerontology is known for enhancing the well-being of elders through intergenerational sharing, promoting "well-aging." Digital storytelling, utilizing sound, images, and music, can convey a biography in minutes, sharing it with a small circle or a global audience. By merging narrative gerontology with digital storytelling into "digital narrative gerontology," we aim to introduce a new concept that will positively impact elders' well-being and aging process, while also sharing these beneficial values with the broader community (Pecorini and Duplaa, 2017).

Wu et al., (2018) describe an experiment with 12 patients with mild dementia. The experiment included observations of behavior for three weeks during memory therapy activities. In the preliminary stage of this study, the existing digital narration application software is first analyzed through the most popular applications such as Storybirds (https://www.storybird.com/), Photo Story (https://shorturl.at/mNP09), Puppet Pals (https://shorturl.at/bgU37) and Toontastic Jr. Pirates (https://shorturl.at/buvP6). A questionnaire survey was then conducted in Old Taiwan which is an old country as the elderly remember it, that corresponded to the treatment of memory images, for the image database of the application mentioned below. There were a total of 185 questionnaires were conducted in categories, including Taiwanese characteristics, childhood, food, costume, architecture, vehicle and education, etc. As part of this effort, the "ReStor" app was created, which allows them to maintain a tale intact while presenting it through the app and sharing it with others without fear of forgetting or repeating it. The "ReStor" design mixes recordings and graphics to communicate narrative information, making the story production process more intuitive and decreasing interface operation difficulties, which can effectively assist the elderly with dementia in tale creation. Memory will be enhanced by the re-narration of earlier stories, which will help to halt the progression of dementia. It is envisaged that the "ReStor" technique will help the elderly retrieve their memory and cognitive abilities by reopening earlier stories.

Unlike the work reported by Wu et al., (2018) the proposed work utilizes an immersive display rather than just displaying images on a screen. Furthermore, a virtual audience and elderly-friendly VR design techniques are adopted in the proposed approach.

Siriaraya and Ang (2014) aimed to explore the use of 3D virtual world technology to engage individuals with dementia in long-term care. They developed three versions of

virtual world prototypes (reminiscence chamber, virtual tour, gardening) using gesture-based interaction, focusing on older dementia patients and their caregivers. The prototypes utilized gesture and touch-based interfaces with Microsoft Kinect sensor and ZDK middleware in Unity3D, displayed via projector. Initially designed for whole body interaction, later versions simplified to arm movements due to resident fatigue. Prototypes included a virtual room with historical artifacts and music, virtual tours, and a virtual garden. Data collected through observations highlighted the potential of virtual worlds to stimulate memories and improve self-awareness. The study emphasized the importance of considering design issues and the complementary role of virtual and physical activities in dementia care, suggesting virtual environments can enhance confidence and relationships in long-term care settings.

When compared to the work described by Siriaraya and Ang (2014), in our work we allow the user to tell stories from his/her past through his/her personal photos and feel the feeling of security and relaxation through a VR headset. Also compared to the above research in our work we aimed to minimize the need for dedicated equipment, such as motion detectors, in order to maximize the accessibility of the proposed tool to people from their own homes, where they don’t necessarily have access to dedicated equipment.

Rose et al., (2021) described a study where people with dementia were invited to use a HMD-VR in a hospital room with a familiar caregiver in the evaluation. The use of a VR Headset (Samsung Gear VR with a Samsung Galaxy S6 mobile phone (HMD-VR)), allows the user to be fully immersed by controlling the viewing direction by turning their head as they would in the physical world. Users were presented with a ‘menu' of five different VEs from which to choose that include a forest, countryside, sandy beach, rocky beach, and a cathedral. Dementia patients were given a maximum of 15 minutes of HMD-VR exposure, with the VE (s) being viewed through the headset. Data was collected over a two-month period using a mixed techniques methodology that included observations and semi-structured interviews. People with dementia were excited to use HMD-VR and participated effectively in the sessions, according to caregivers. They also stated that HMD-VR had a beneficial impact on people's post-session well-being and encouraged them to do outdoor activities. The careers said that they learned new skills and interests about the person with dementia as a result of attending the session,

and that the success of the session made them reassess their involvement in other activities. The sample size was small, and the study was limited to a particular hospital setting, which limited the generalizability of the findings. Despite this, significant data has emerged from this study in relation to the practicality of using HMD-VR technology with a potentially difficult patient group. This research differs from ours in that the experience was not individualized for each user but rather predetermined for all users, whereas in our approach the content is personalized for each user.

Matsangidou et al., (2020) explored challenges in designing and implementing a virtual reality (VR) system for physical training in moderate to severe dementia patients. Their study, conducted in a mental health facility, involved a participatory design process with input from patients and health specialists. Two types of interactions and three exercise types were tested in VR. Study 1 involved a workshop to select appropriate VR content, choosing a forest backdrop and three exercises: climbing a rope, climbing a wall, and seated cable row. Study 2 assessed usability of VR interactions for a boxing exercise. Study 3 allowed patients to use the VR system in a familiar hospital room with their physiotherapist and psychologist present, focusing on task performance, reaction time, and patient independence. Findings suggest the potential of VR physical training for dementia patients and offer guidelines: providing regular feedback, ensuring stable and visible visual targets, tailoring virtual worlds to patient interests, and effectively transitioning patients back to reality to minimize anxiety and confusion. It is thought that encouraging people with generalized anxiety disorder to perform aerobic exercise as a stress-reduction strategy can be accomplished through virtual exercise therapy (Wang, 2020).

The above research is clearly aimed at people with dementia where the evaluation of the three phases was done. In our case the research relates to elderly people who do not suffer from dementia, and aims to investigate whether the use of virtual reality can get users engaged in an attempt to act as a way of preventing dementia.

2.5 VR for elderly and COVID-19 pandemic

The December 2019 novel coronavirus (COVID-19) outbreak in China has affected more than 9.97 million people and appeared in over 480,000 deaths worldwide, which has led to global quarantine as supported by local governments and the World Health

Organization. Indeed, quarantine can help relieve people's exposure to COVID-19 and, therefore, decrease the risk of getting the virus. However, the quarantine orders have created many social challenges that have had intense results on financial, physical, psychological, and emotional health among people of all ages (Gao et al., 2020). Ma et al., (2023) study indicates that employing virtual reality (VR) for mindfulness training is a successful and inventive approach for enhancing mental health conditions among adults.

The surge in the elderly population is aligning with the escalating complexities of a digitally-driven society across various socio-cultural settings. The preliminary investigation of Humboldt et al. (2020) seeks to examine how older adults perceive the impact of smart technology on their sense of purpose during the Covid-19 pandemic. The findings suggest that smart technology played a significant role in enhancing the meaning of life for older individuals during this crisis, primarily by fostering meaningful connections, engaging activities, and spiritual fulfillment. Future initiatives targeting older adults during pandemics should acknowledge the array of factors contributing to their well-being, taking into account cultural diversity.

Gao et al., (2020) mention that virtual reality technology is a tool that can provide effective treatment for the elderly by applying non-immersive virtual reality to the hallway or immersing a patient in a realistic environment, such as a city or park with a head-mounted display or inside a CAVE. In this way physical and occupational therapy sessions can be improved, thereby increasing the chance of successful adaptation to the real world. An example of an experiment was when participants found that exercising on a stationary bike with VR that immersed them in nature was much more enjoyable than traditional cycling without VR. Since VR was an interesting activity for older adults, this could lead to better compliance with a rehabilitation program, which in turn can lead to better outcomes for patients' health. Using rehabilitation techniques at home would lead to more effective rehabilitation, as older adults can receive real-time feedback from home using VR during periods when they are not in the clinic. This can be especially important during the COVID-19 pandemic, as older adults may want to be quarantined in their homes due to the increased risk of contracting the virus. Virtual reality home remedies can also help relieve stress from healthcare providers. This reduction in over-scheduling for physical and occupational therapists can allow them to

provide better care during their sessions. In addition, during personal appointments, VR exercise can be supplemented to increase the patient's motivation and enjoyment.

The use of virtual reality to improve the environment of the elderly is the content of many works but two were the most prevalent during the pandemic: the Rendever (https://www.rendever.com/) and MyndVR (https://www.myndimmersive.com/). Rendever was established with the aim of combating social isolation by fostering shared experiences, a mission that holds heightened significance today. Through the use of virtual reality headsets, users are transported to entirely different environments or scenarios instantly. Over the last four years, Rendever has implemented its virtual reality platform in close to 200 senior communities across the United States and Canada. Rendever aim to offer a remedy by providing an application that supports immediate immersion in exciting experiences. This is particularly beneficial for seniors with cognitive impairment, vision issues, or mobility constraints. (Welcome to Rendever, 2021).

Their primary offering consists of personalized VR hardware and content designed not just for senior living residents but also for private consumers. Through 360-degree videos uploaded directly to Rendever's client accounts, seniors can partake in family gatherings, weddings, and various events alongside their loved ones. The success of startup Rendever serves as evidence to the project's authors that applying virtual reality to seniors holds commercial promise (Lhotska et al., 2019).

The MyndVR app was used to study the impact of virtual reality on older adults living in a variety of healthcare settings. MyndVR stands at the forefront in delivering Virtual Reality solutions tailored for senior living communities, veteran homes, home health agencies, and individuals aging in place. With an extensive collection of VR content and the establishment of MyndVR Studios, the company crafts unique therapeutic experiences aimed at enhancing the well-being of individuals across various healthcare settings (MyndVR, 2021). Kruse et al., (2021) using a human-centered design approach, they built and evaluated a motor-cognitive exergame in which older persons can virtually visit well-known locations in their city of residence using immersive virtual reality technologies. The player's goal is to use a monitored wearable that mimics an actual camera to take images of famous sites. A senior living institution was used to enroll 10 people with mild dementia. The participants were on average 82.8 years old.

The study lasted nine weeks, including six weeks of playing the game twice a week and three weeks of questioning sessions. Each gaming session lasted 15 to 25 minutes and was followed by three questions. All of the players said they enjoyed the game and found it enjoyable to play, which corroborated earlier research on the use of exergames. The game's significance was highlighted, as it provided participants with a relevant task, a distraction from their daily lives, and a sense of accomplishment. Caregivers and family members benefited from the game as well, as it provided meaningful activities at a time when other exercise groups were no longer possible.

According to the above studies, it has been found that researchers are interested in involving the elderly in the studies concerning Virtual and Augmented Reality. In conclusion, we found that the gap that emerges from the above researches we will try to cover in terms of our effort to empower users to interact with the application in order to exercise their minds through an application designed appropriately for the target audience.

Following an extensive review of the literature, it was determined that our research diverges in specific aspects, prompting a desire for further exploration in those particular areas. Initially the involvement of the virtual audience to interact with the user through physical presence in the virtual space and through audio instructions. Furthermore, the proposed application focuses on simplicity and execution on low cost VR devices, allowing in that way elder users to use the application without requiring extra assistance or dedicated equipment. Finally, it should be noted that the proposed application is not aimed at medical treatment but it aims to improving the overall wellbeing of elder uses aiming at the prevention, rather than the treatment, of mental disabilities.

Chapter 3: Assessing the willingness of elder users in using virtual and augmented reality technologies

In this chapter, we present an experimental investigation that aims to assess the willingness of elder users to use virtual and augmented reality technologies and derive conclusions related to the main issues that attract or deter elder users from using such technologies. Three preliminary experiments related to the use of virtual and augmented reality by elderly have been completed (Anastasiadou and Lanitis, 2021). The design of the experiment is based on a 3-stage hierarchical structure where in each step the participants are exposed to more technologically intensive interaction styles starting with the use of a common smartphone application and gradually moving on to immersive applications.

3.1 Introduction

Following the knowledge derived from the literature review in the previous chapter (see Figure 3.1), in this chapter, we aim to assess the willingness of elder users to use virtual and augmented reality technologies and derive conclusions related to the main issues that attract or deter elder users from using such technologies. This step is essential before engaging in the process of designing a VR application for the elders, as it aims to define important factors that guide the development of an appealing VR elder-friendly VR application. In particular we aim to derive information related to the expectations and requirements of elder users in relation to contemporary applications. Three preliminary experiments related to the use of virtual and augmented reality by elderly have been completed (Anastasiadou and Lanitis, 2021). The experiments were performed with groups of seniors to get results on the relationship they have with virtual and augmented reality technologies through evaluation of questionnaires completed after users were exposed to such technologies.

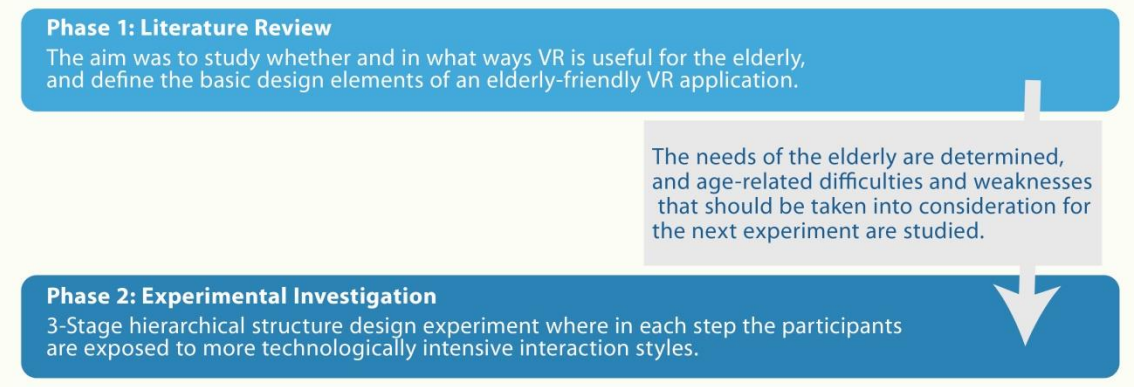

Figure 3.1: The main conclusions from the literature review that guided the work in Phase 2.

The objective of the initial study is to investigate the following research questions:

RQ1: *To what extend older people use emerging technologies (VR and AR, Teleconferencing, Smartphones) during social isolation and for what purpose?*

RQ2: *Are elder people willing to use emerging technologies as part of their daily activities?*

RQ3: *What are the main factors that prevent elderly to use emerging technologies?*

The design of the experiment is based on a 3-stage hierarchical structure where in each step the participants are exposed to more technologically intensive interaction styles starting with the use of a common smartphone application and gradually moving on to immersive applications (see figure 3.2). More details about each stage are presented below.

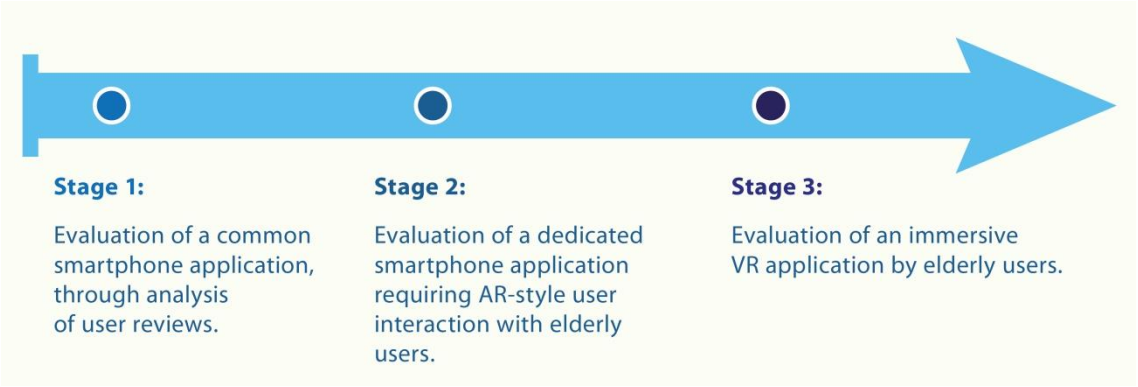

Figure 3.2: Diagram of the 3-stage hierarchical structure adopted in the experimental investigation.

Stage 1: Initially the main attitudes related to the use of the basic technology with the use of a common medicine management smartphone application are explored. The target groups considered in this experiment are people who are receiving medicines, and they need to use a medicine management application. This experiment is mainly aimed at confirming the findings of other studies (D'Addario et al., 2020; Lukoff et al., 2018; Kim et al., 2013), i.e. to define the most important features that motivate users to use smartphone applications. Although this experiment was not carried out with elderly people, the analysis of a subset of reviews depicting people with medical issues implies that the majority of the users considered are within the age ranges associated with older ages. Hence, the analysis of the response from users with medical problems allows the deduction of useful information in relation of the most important requirements of smart-phone users who are in need to use a particular application, such as elderly users.

Stage 2: The aim of the experiment carried out during stage 2 was to investigate the reactions of older people to more specialized applications that go beyond the standard use of a smart device through the need to engage in a more technologically demanding interaction, thus more effort is required to use such applications. More specifically,

Stage 2 involves the engagement of a group of elderly users in evaluating an application that incorporates basic functionality commonly encountered in AR-style applications.

Stage 3: Stage 3 of the experiments, involves the exposure of volunteers from the target group to using an immersive Virtual Reality application with a dedicated VR headset. In addition to physical factors that prevent elderly users to use efficiently state of the art technologies (Chen et al., 2023, Mitzner et al., 2010), elder users are often reluctant to utilize new technologies (Kuerbis et al., 2017). This experiment exposes the volunteers to new ways of interacting with 3D environments, enabling the derivation of conclusions related to the reactions / concerns of the target group towards using emerging technologies in the form of Virtual Reality.

A more detailed description of the experiments carried out during each stage, and the results obtained is given below:

3.2 Stage 1: Evaluation of a common smartphone application, through analysis of user reviews.

3.2.1 Overview

For the experiment, the free commercial application Pill Reminder and Medication Tracker by Medisafe (https://shorturl.at/abGJL) has been selected for evaluation. This application has over five million installations and has been rated with 4.6 out of 5 stars by 237,000 users. The main reason for choosing this particular application was its popularity and top-rating. Secondly, it was chosen due to the fact that the users of the application are people who receive medical treatments, implying that a large percentage of the users are likely to be elderly. The aim of this study is to determine the most importance design-related factors of the application that motivated users to use this type of applications. To achieve the goal of this study, we analyzed a large number of user reviews in an effort to deduct conclusions related to the most important issues that attract users towards using this particular application, and at the same time determine possible concerns of the users towards the application.

Previous research efforts that aimed to analyze the usage of apps by elderly /ill users mainly focused on registering the number of apps that target certain disease categories

(Xu and Liu, 2015), whereas other researchers concentrated on the potential harm to users stemming from breaches in information security and privacy violations (Dehling et al., 2015). Many apps and studies focus on diabetes and depression, yet there's a notable shortage of apps for conditions like anemia, hearing loss, and low vision, highlighting a gap that needs to be addressed. In contrast, in the work described in this section, the focus is on design issues in relation to people who in a real need to use the specific of medical dose management application.

3.2.2 Application Description

The application helps users to receive their medicines correctly so that they don't miss doses or receive double dosing by accident. In the category of pharmacist application is currently the most popular application among 461 applications. It has a simple design so that it does not make it difficult for the user to navigate the application (see Figure 3.3). Specifically, when the user logs in, he/she can enter in the application the medicines he/she takes and the corresponding dosages. Then the medicines appear in the application in a calendar so that the user has direct access to a daily schedule concerning the administration of medicines. At the same time, the application reminds the user of the time the user has set as the recommended time to take their dose. In general, the application aims at few and simple commands, but if the user wishes, there is also some more advanced features like the ability to arrange appointments with doctors, finding information about doctors, noting when there is need to buy new medicines and display of the user's general medical history.

3.2.3 Set-up

Given the extended number of users of the "Pill Reminder and Medication Tracker", the analysis was done by analyzing existing user reviews. During the process 1000 user reviews were collected using the software Appbot (https://appbot.co/) that allows the collection of user reviews for an application and automatically categorizes customer feedback by theme with topics and tags. Among the reviews collected, 166 reviews were not used in the analysis because they did not contain any information related to the parameters under investigation. All reviews were divided into the negative reviews (104 reviews rated with 1-2 stars indicating dissatisfied users) and positive reviews (654

reviews rated with 4-5 stars indicating satisfied users). In addition, user reviews were divided into the ones where users declared that they have a medical condition (116 users) and the ones where users do not state that they have a medical condition. Although we did not have any data related to the age of the users, it is reasonable to assume that a significant proportion of users who indicated a medical condition should be elderly people who are receiving medication due to some medical condition.

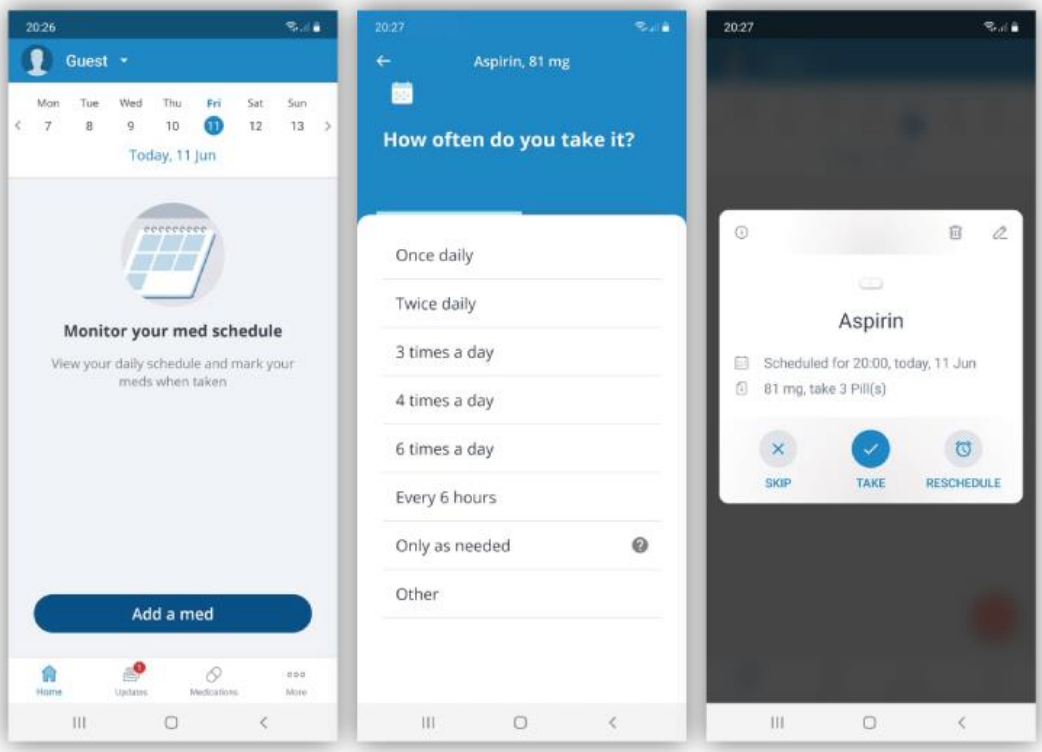

Figure 3.3: Interface designs of Pill Reminder and Medication Tracker by Medisafe.

3.2.4 Results and Discussion

User review analysis was carried out by initially filtering the reviews based on keyword analysis followed by content-based analysis in order to classify the reviews into the ones referring to functionality, usability, interface design, cost, number of existing users and user reviews. It has been noticed that among all subgroups considered the functionality of an applications is considered as the top factor (see Figure 3.4). However, usability and interface design were also found to be highly important. Dissatisfied users (with star rating 1-2) posted most review ratings with the theme of functionality when compared to the other groups under consideration and especially

satisfied users (see Figure 3.5), indicating that most dissatisfied customer's complaint about the functionality. In contrast satisfied users seem to comment more on usability and interface design indicating a connection of satisfied users with issues related to usability and interface design.

An important observation is the high increase in review scores related to usability, functionality and interface design, for users who declared a medical condition, when compared to the corresponding scores among all reviews considered. This indicates that especially for people who need to use the application because of a medical condition, usability, functionality and interface design are crucial factors when compared to other factors. Overall functionality, usability and interface design are determined as the most important factors for users, whereas issues like cost, number of existing users and user reviews do not seem to be top priority issues in user reviews among all groups considered. The results indicate that to attract users to use an application the most important factors are the actual usefulness of the application (functionality), the usability and the interface design.

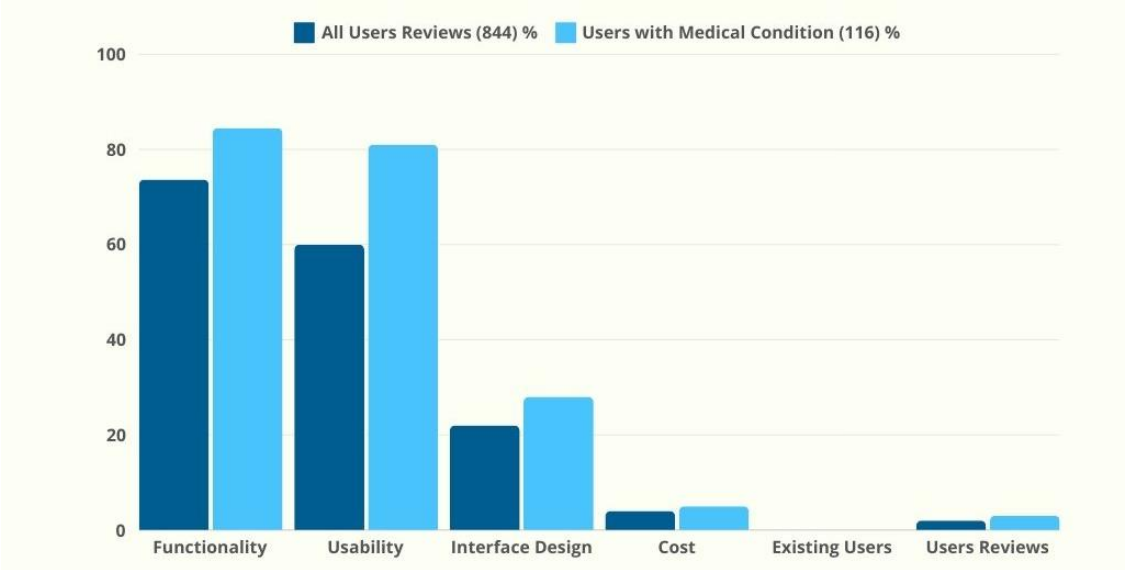

Figure 3.4: Keywords analysis results for a) All users reviews and B) The users with a medical condition.

Figure 3.5: Keywords analysis results for a) Dissatisfied users who rated the application with 1 or 2 stars and B)Satisfied users who rated the application with 4 or 5 stars.

3.3 Stage 2: Evaluation of a dedicated smartphone application requiring AR-style user interaction.

3.3.1 Aim

The experiment in Stage 1 reconfirmed the need to provide functionality and usability to attract the target population to using an application. In Stage 2 we explore whether elderly people are willing to use applications with a more technologically enhanced interaction style. More specifically the aim of this experiment is to investigate the reaction of the target group in relation to a new technology and whether they are willing to use such technologies. More specifically the application under evaluation offers more advanced capabilities than a simple smartphone application since it incorporates the use of the camera in conjunction with audio-visual feedback.

3.3.2 Application Description

This experiment is based on the Easypharm application (Anastasiadou, 2016), as a means of providing an easy to use and universally acceptable application for managing medicine administration. For the needs of the experiment, the prototype application presented by Anastasiadou (2016) was further developed to suit the needs of the current

investigation. The Easypharm application aims to help the user, who may be visually impaired, by instantly locating, by scanning a QR code, the necessary information available on drug packages. The QR code used by the application should be a dedicated code that incorporates both medicine related and patient related information. Although the Easypharm app is not a typical AR application, it bears similarities to AR-style applications in that through the use of the camera, a QR code on a medical package is scanned to present the user with specific drug information.

Through the application, the user initially has direct access to important information related to medicines that is not always readily accessible on packages especially for users who face physical limitations. For example, elder users, who often suffer from visual impairments often, find it difficult to read information on medical packages. The information presented by the Easypharm application not only refers to general information of the medicine package such as expiration date, recommended dose, risks/side effects, and other recommendations, but also refers to patient specific information, for example the actual dosage recommendation provided by the doctor and the time of administration of the dose. Once the dedicated patient-specific QR code is scanned, the user can see the information on the mobile screen, and or he/she can even read the corresponding information brochure in electronic format. This feature offers the user the convenience of zooming in on the leaflet with the instructions to be able to read better, since in the printed leaflet the letters are usually too small to be able to fit all the information of the medicine on one form.

At the top of the home screen there is the menu button that leads to the log in screen that allows users to login in order to access their personal data or locate on-call pharmacies and emergency telephones. If the user logs in, their personal information is displayed at the top of the screen along with a chronologically sorted list of medications they have scanned. In the category with personal information, the user can add any allergies or health problems, so that in the case that the user scans the QR code of a medicine he/she gets a notification on the home screen of the application if the specific medicine contains dangerous substances for the user, as determined from his/her medical history.

Finally there is the settings screen where it allows the user to change the language, font size and background color depending on what the user prefers to better read the information in the application. This feature ensures the accessibility of the information

to most users, including elderly users. Figures 3.7 – 3.11 show typical screenshots of the Easypharm application.

3.3.3 Evaluation Procedure

The scenario followed by the users during the evaluation was the following:

a) A package of the drug Moxiclav was given to the users (see Figure 3.5)
b) The user is instructed to scan the dedicated QR code on the package.
c) Then, when the user recognizes the target, he/she is transferred to the next screen where the information about the drug is displayed (see Figure 3.6).
d) The user is able to choose the name of the drug and read the description, having the possibility to see photos of the packaging (see Figure 3.7).
e) In the next step, the user is instructed to choose a category to display more information among the options: expiration date, dosage, recommendation and risks (see Figure 3.6).
f) Then the user has the choice to listen or read the information. It should be noted that in the evaluation we concentrated on reading information rather than receiving audio feedback. However, due to the appearance of dedicated icons on the interface, it was understood by the users that the possibility of audio feedback was available (see Figure 3.8).
g) At the bottom of the screen there is the option for "More Information" where the instructions enclosed in the package appear in digital format (see Figure 3.8).
h) For the last step, the user was instructed to log in (see Figure 3.9) so they could check their drug history (see Figure 3.10).

Figure 3.6: Moxiclav drug packaging photo.

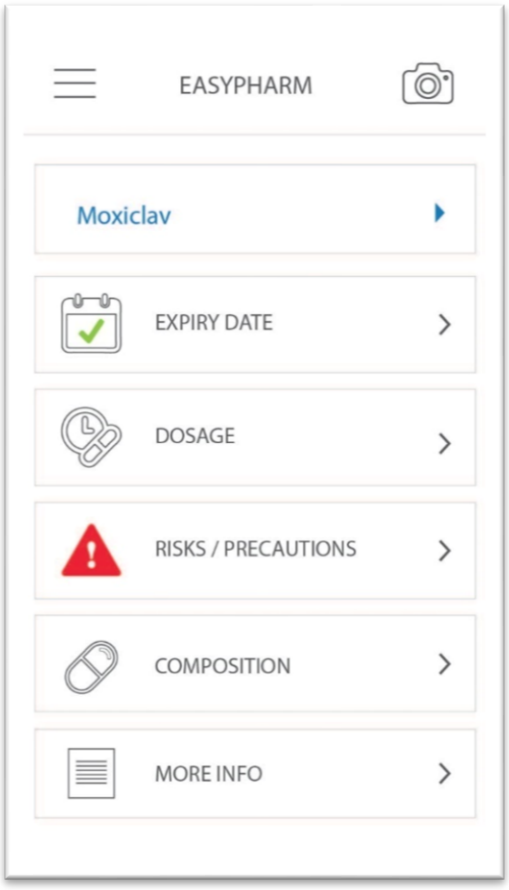

Figure 3.7: Interface of Easypharm showing the information about the scanning drug.

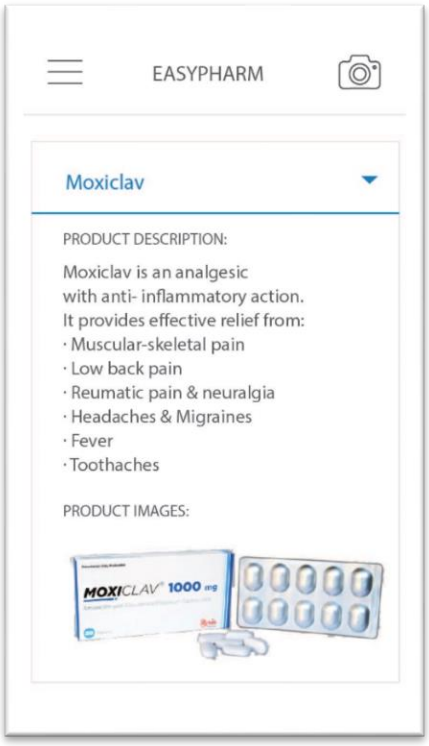

Figure 3.8: Interface of Easypharm showing the information about the scanning drug.

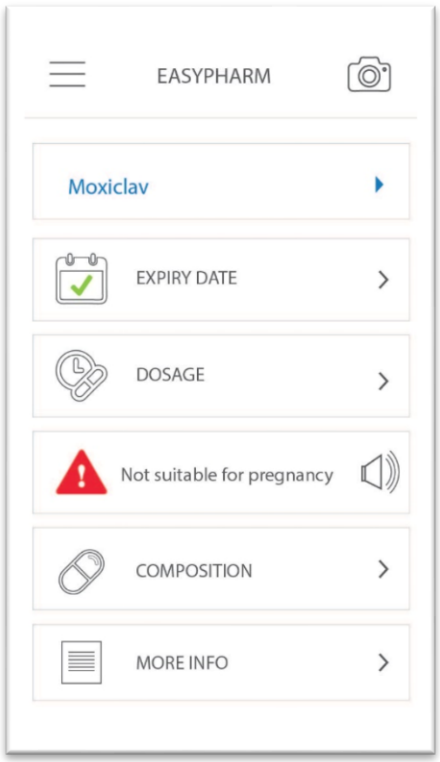

Figure 3.9: Interface of Easypharm showing sound volume function.

Figure 3.10: Interface of Easypharm showing log in page.

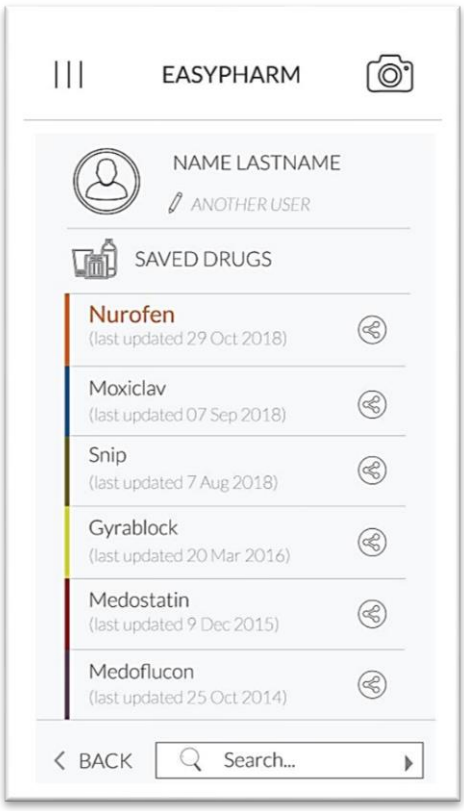

Figure 3.11: Interface of Easypharm showing drugs history of the user.

3.3.4 Experimental Set Up

Fifteen adults (6 male, 9 female) aged 50-70 years (mean 57 years) participated in the experiment. The selection of the target group was done based on the typical target group expected to use pharmaceutical applications. Furthermore, users from the selected group are already classified as old users, or they are approaching the ages of the target user group. Each participant who participated in the experiments had to be a smartphone user and had to have basic knowledge regarding the consumption of medicines. Both aforementioned factors are important to safeguard that participants could evaluate objectively the pharmaceutical management application. All volunteers were asked to complete a series of actions described in section 3.3.3 in relation to specific tasks through the marvel app (https://marvelapp.com). Through the process, results were obtained through observation of the actions of the participants while they were completing the preset tasks. At the end of the process, the participants completed a questionnaire and attended an interview where they were asked to answer questions related to their experience.

3.3.5 Results and Discussion

The questions used were based on the "Computer System Usability Questionnaire" (Lewis, 1995) modified appropriately to match the application evaluation. To collect results in the questionnaire the Likert scale method was used where users had to respond with 1 (Strongly Disagree) to 5 (Strongly Agree) to the questions. The most important questions from the questionnaire are shown in Table 3.1.The actual questionnaire is shown in Appendix I.

To achieve the internal consistency of the questionnaire, which reflects the reliability, the questionnaire was evaluated through the Cronbach’s Alpha method with a result value of 0,891. A Cronbach’s Alpha coefficient higher than 0.7 indicates the validity of the questionnaire. Based on the results of the questions related to reading text in the application (see Table 3.1, Q2 and Q4) it was observed that 87% disagreed with the question about whether it was difficult to read characters on the screen, while 33% agreed that the text in the application was legible and 53% was neutral. When asked whether users would like to use the application in their daily lives where it concerns our primary research questions, a percentage of 33% were positive and would like to use a

similar application in their daily lives while only 14% disagreed. Respectively in relation to the usefulness of the application (see Table 3.1, Q7) only 7% of users disagreed with the question stating that the application is designed to meet the needs of users. With the above data we conclude that the target group that was evaluated is willing and would be interested to learn more and use on daily basis more advanced applications. Based on the results of Q11 (see Figure 3.12) it is derived that the most important factors that make users use the application is the functionality, usability, and interface design of the application. In contrast, volunteers did not consider the cost of an application or the user's reviews as an important factor in selecting the application.

As part of the analysis of the results, the 15 volunteers were divided into 2 groups where the first group (with 6 volunteers) contains the ones who had a medical problem and had to use a pharmaceutical management application whereas the second group contains the volunteers with no medical problems. A comparison of the responses for question 11 of volunteers between the two groups indicates that no significant differences between the responses from each group were detected, with the value of p-value be smaller than 0.05.

Through the monitoring during the evaluation, it was observed that most users were able to complete the test scenarios. Only a small section of users was unable to locate some buttons on the screen. It was obvious that people over the age of 65 are less familiar with new applications and need more time to adapt to new interfaces. When assessing the application, participants tried to adapt directly to the application environment to quickly identify the commands they were asked, although it was not easy for everyone. Most participants have been struggling to execute the first request, possibly because they did not have enough time to adapt to enable them to locate easily the buttons on the screen. Eleven volunteers stated that they were fully satisfied with the existing features that the application offers such as the choice of audio commands and the simple grid-based layout of the interface. Few volunteers expressed the opinion that the symbols, such as the menu button, it is more readable the way it was designed. Regarding the functionality, few users suggested to include notifications in cases where a drug is approaching the expiration date and can be dangerous for consumption.

Table 3.1: Indicative questions used during the evaluation of "Easypharm".

1. The overall response to the application was satisfactory.
2. It was difficult to read the characters on the screen.
3. The application information organization was clear.
4. The text in the application was readable.
5. It was easy to remember the information displayed on the screen.
6. Implementing actions in the application was complex.
7. The application was designed to compete with the needs of users.
8. I was able to quickly complete the tasks and scripts using the application.
9. The information contained in the application is clear.
10. I would like to use the application in my everyday life.
11. Which parameters will make you use this type of app: functionality, usability, design, cost, existing users, and reviews.

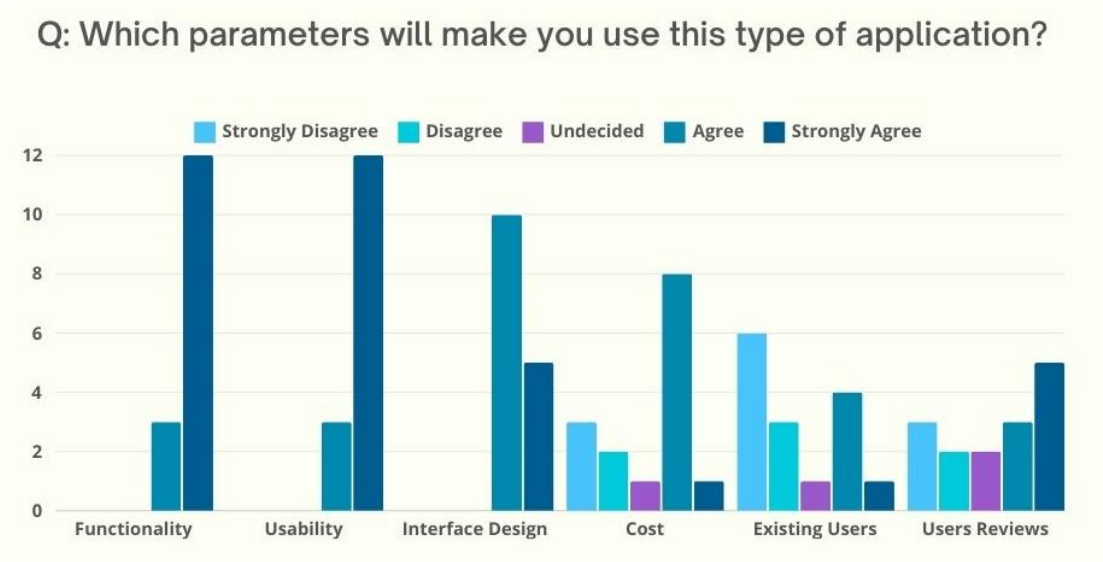

Figure 3.12: Results for question “Which parameters will make you use this type of application?”.

Furthermore, since the importance of the initial induction period was highlighted, it is necessary to improve the usability of such applications by making available suitable training material for the operation of the application. In conclusion, it was observed that users are willing to use a more technologically intensive application as long as the factors of functionality, usability and interface design are covered.

3.4 Stage 3: Evaluation of an immersive VR application by elderly users.

3.4.1 Aim

The results of the experiments in Stage 1 and 2 show that if a target population is presented with an application with useful functionality and friendly interface, they are willing to use the application, even if the application demands more dedicated interaction styles. The experiment in Stage 3 aims to investigate whether these observations are still valid for a completely new type of applications, in the form of immersive Virtual Reality. More specifically, the aim of the experiment was to test whether elderly living in Cyprus know what virtual reality is and if they would be interested in incorporating it into their daily lives to facilitate wellbeing issues.

3.4.2 Application Description

Unlike the experiment described in Section 3.3 where the application tested was developed by the author, for the needs of the current experiment the commercial VR application “First Aid Training” (see Figure 3.13), executed on the Oculus Go (https://rb.gy/de7zox) headset was used. The purpose of the application is to help the users to learn the basic steps of providing first aid. The focus is on the rescue chain and reanimation with assessment (initial situation), cardiac massage, and ventilation. Each is divided into instruction and training to learn how to perform the steps safely. For the purposes of the experiment, the Oculus Go VR headset was used. For the user interaction, the device's joystick was used. In order to conduct the experiment, a scenario was chosen to follow the steps to provide the first aid in order to put the patient in a resuscitation position. The user had to carry out the instructions given on the screen where they were displayed via a flashing symbol. To complete each stage the user had to select the flashing symbol that appeared on the screen through the joystick. When the first aid procedure was completed by the user, then the completion of the questionnaire of the second phase and the interview took place.

Figure 3.13: Samples of Interfaces of First Training Aid Application, Image source: First Aid Training, 2023.

3.4.3 Set Up

Ten participants aged between 50 to 70 years participated in the experiment which was completed using Oculus Go equipment and using the application "First Aid Training". For the purposes of the experiment, users were asked to complete a series of operations to obtain results according to their relationship with virtual reality technologies (see Section 3.4.2). More specifically, initially they were given a questionnaire (see Appendix I) where in the part A had questions about virtual reality (VR). To get acquainted with the virtual space, volunteers used for a few minutes a game available on the device, so that they got acquainted to the interaction style this enable the users to have better control over the 3d mouse operation, allowing more practice movements in the 3d environment. Then the volunteers used the "First Aid Training" application according to the voice instructions given to them by the researcher, and finally they were asked to answer part B of the questionnaire. Initially the instructions were given so that for any reason the user felt unwell, they could to stop the process immediately. Furthermore, in order to prevent possible accidents, the evaluation was done with the users sitting (Figure 3.14).

Figure 3.14: Picture captured during the interaction with the virtual reality environment and the use of Oculus Go.

3.4.4 Results

Participants were 50% women and 50% men with a mean age of 62 years. 50% of the participants were suffering from some disease while 30% had used virtual reality applications again. Based on the results we got before the use of virtual reality (see Figure 3.15), 90% of the participants believe that the main purpose of the virtual reality applications is entertainment, while 30% believe that its use can improve their daily life to some extent. On the contrary, 80% were negative to include VR in their daily routine while only 20% believe that VR is useful for older people. Finally, 60% would like to use the VR to practice and gain knowledge related to health issues.

The results obtained after the use of virtual reality (see Figure 3.16) indicate that 60% of users found their navigation in the VR area easy while 90% describe the experience as enjoyable. An important fact that we received through the questionnaire was that 60% of users believe that they have learned about the resuscitation position and can apply it in their life while 70% indicated that they would like to use VR to practice for health-related issues. Also, although 90% managed to complete the process according to the

voice instructions given by the researcher, 40% state that their experience caused dizziness while 60% found it difficult to understand what to do in the application. Finally, for the question related to the usefulness of VR for older people, 50% of the participants indicated that they think that VR is useful. When compared to the responses to the same question before the intervention, an increase of 30% was recorded.

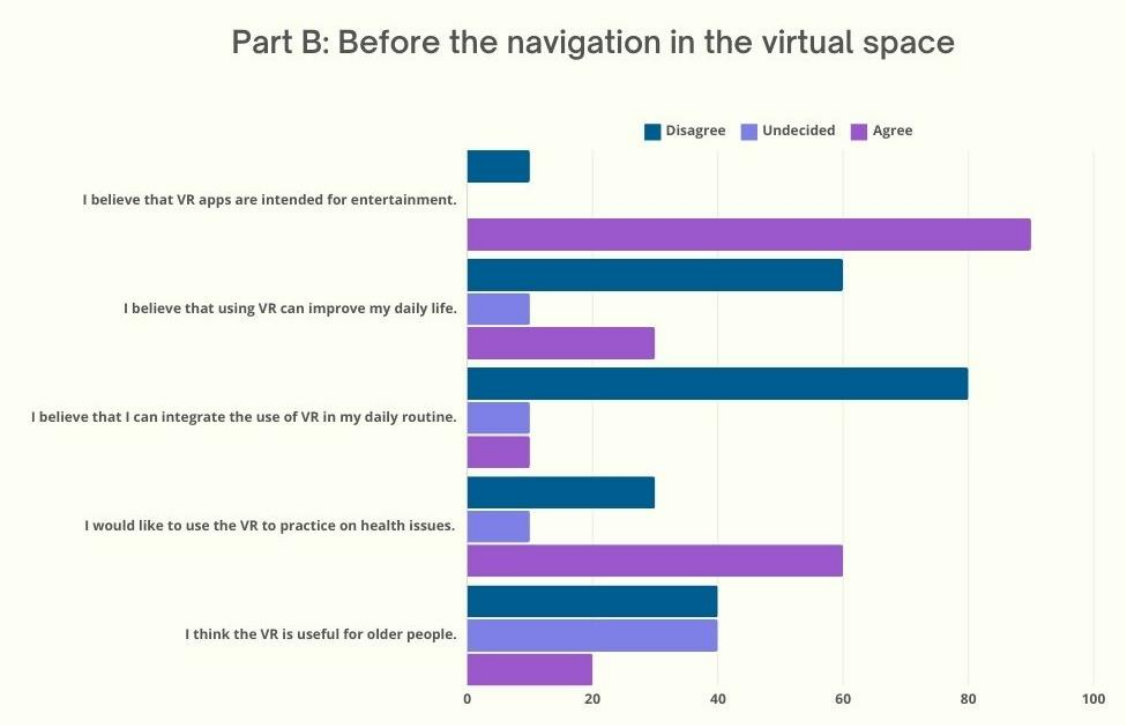

Figure 3.15: Results from Part B before the navigation in the virtual space.

Following the questionnaire, users were asked to answer which categories of applications they would be interested in using daily with the highest percentage 70% going to entertainment, while the category of health, information and education got 60%, leaving in the last place the category of sport with a percentage of 50%. Finally, when asked what elements they would like to improve in order to use VR technology, the highest percentage indicated the cost of equipment with a percentage of 50% while they sated that the design (20%), the interaction (30%) and the quality (30%) do not seem to need any major improvement as users felt satisfied. It should be noted that although the issue of the ‘cost’ was not important for the first two experiments, in this case it emerged as a key issue. This is due to the fact that the users realized that unlike the previous cases, dedicated equipment is needed for running VR applications.

As mentioned above, this experiment was performed to get an idea of what prevails in this target group in relation to the use of a more advanced technology. It was found that a large percentage of older people used virtual reality for the first time and yet would like to practice using it to learn about health issues. Based on the user responses it is evident that after the intervention participants have changed their view on whether virtual reality is useful for seniors since initially only 20% considered VR useful, (see Figure 3.15- Q8) and after the intervention this figure increased to 50% (see Figure 3.156- Q8). Respectively in question Q7 a percentage of 30% (see Figure 3.15- Q7) disagreed on whether they want to use virtual reality to practice on health issues, while after use it dropped to 10% (see Figure 3.16- Q7). These results show that users out of ignorance are negative towards such technologies since when properly informed they are willing to use them not only for entertainment but also for obtaining information. It was also noticed that the cost for this virtual reality equipment is an issue that concerns them so that they can make daily use of the application, while they seem to be quite satisfied with the interface design as 70% would not like to change (see Figure 3.17).

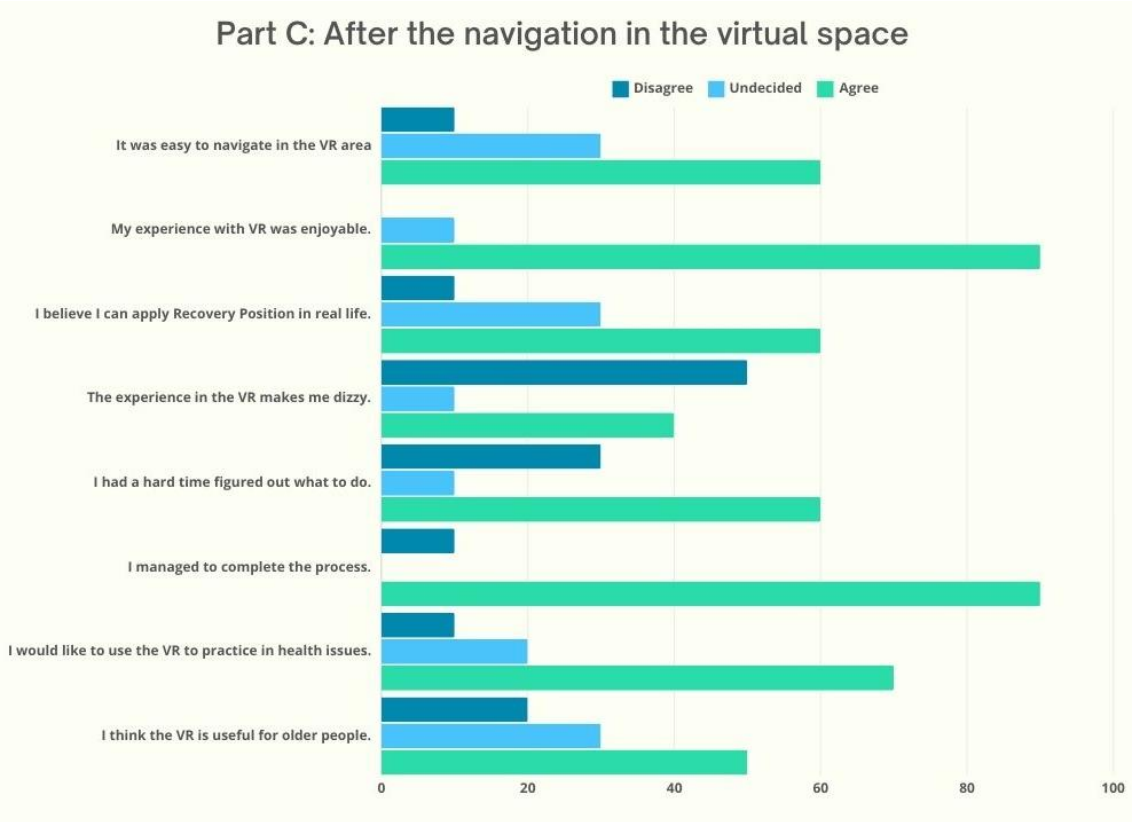

Figure 3.16: Results from Part C after the navigation in the virtual space.

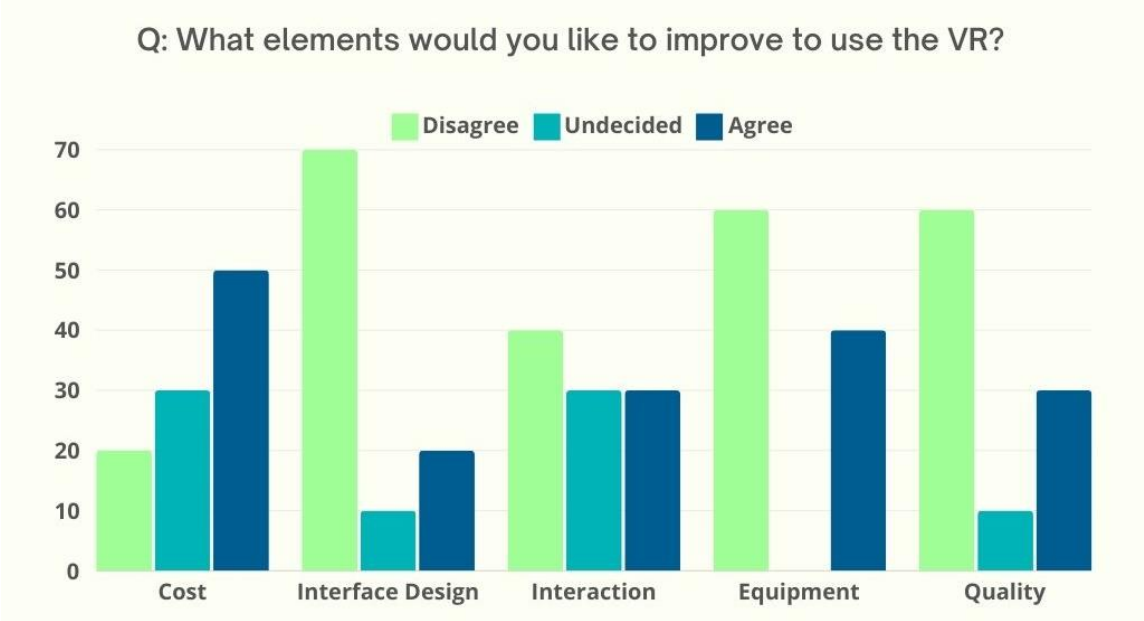

Figure 3.17: Results for question "What elements would you like to improve to use the VR?".

3.4.5 Conclusions

The purpose of the experiment was to gather information in order to identify the needs that arise in the specific target group in relation to VR. Based on the results from the experiment we concluded that before getting exposed to the VR application, the target group believed due to ignorance that VR was mainly for fun. After using the application, they thought it was useful for their own needs and they realized the potential of adopting VR in everyday life. Also it was observed that participants are willing to use such technologies, and did not find particular difficulties in using the application with the interface. A new parameter that was included in Experiment 3 and did not exist in the other experiments, was the cost as it now requires the purchase of equipment to use of virtual reality and this was the main concern they expressed. Finally, it was observed that functionality is a main factor that makes users wants to use the application.

3.5 Concluding Comments

Through a series of experiments we followed we reached the following conclusions which helped us to develop our research in the following stages:

Stage 1: The key points that play an important role in the use of a common application of health are functionality, usability and design. Covering these needs of the user, then they are motivated to use an application on a daily basis with satisfaction.

Stage 2: Also in this case, functionality and usability are the key points that the user needs to meet his needs. In addition, with a specific audience, the desire to use such technologies and learn more information on how to integrate them into their daily lives has been observed. The more advanced interaction mode did not deter users, provided that the other requirements are met.

Stage 3: Through the exposure of older people to a new technological environment in the form of a VR application, a positive response and the urge to learn more about these technologies was observed. However, apart from usability and functionality, the issue of the cost involved also emerged as an important factor that could deter users from using VR applications.

Based on the findings, we conclude that older people are not put off by the prospect of using more technologically advanced technologies as long as the requirements of functionality, usability and design are met. On top of that, in the case of the need of using dedicated equipment, the issue of the cost is also introduced as an important factor. Furthermore, in the case of new technologies, it is important to provide training, as this will allow elder people to realize the full; potential offered by emerging technologies.

Based on the results and the relevant analysis the answers to research questions posed in this chapter are:

RQ1: *To what extend older people use emerging technologies (VR and AR, Teleconferencing, Smartphones) during social isolation and for what purpose?*

Older people have increasingly adopted emerging technologies such as virtual reality (VR) and augmented reality (AR), teleconferencing, and smartphones, especially during periods of social isolation. According to the results of our research, it appears that the elderly use smartphones to call, send messages, access social media, browse the Internet and use health-related applications. Teleconferencing technologies like Zoom and Skype have seen increased use among older adults, especially during the COVID-19 pandemic (Ray et al., 2022). The adoption of VR and AR is lower compared to smartphones and teleconferencing. However, there is growing interest and use in specific contexts. Those technologies are used for virtual travel experiences, physical rehabilitation, mental health therapy, and engaging in immersive educational content. Physical limitations, such as poor eyesight or dexterity issues, can make using smartphones and VR/AR devices difficult for some older adults. In summary, older adults are using emerging technologies to varying extents, primarily for maintaining social connections, accessing health and wellness resources, engaging in mental and cognitive activities, learning, and entertainment. Their adoption of these technologies has grown, especially during periods of social isolation, highlighting the importance of support and training to overcome barriers and maximize the benefits.

RQ2: *Are elder people willing to use emerging technologies as part of their daily activities?*

Based on our research older adults are increasingly willing to adopt emerging technologies as part of their daily activities, particularly when they perceive clear benefits such as enhanced communication, health management, and entertainment. Their willingness is significantly influenced by factors like ease of use, availability of support and training, affordability, and social influence from family and peers. Technologies such as smartphones, teleconferencing tools, and health monitoring devices see higher adoption rates, while VR and AR are gaining interest for specific applications like therapy and cognitive engagement. Despite challenges such as technological literacy, physical limitations, and privacy concerns, the trend towards greater acceptance is growing as these technologies become more accessible and user-friendly.

RQ3: *What are the main factors that prevent elderly to use emerging technologies?*

Several key factors prevent older adults from using emerging technologies like VR, AR, teleconferencing, and smartphones. These include technological literacy issues, where older adults may feel intimidated or find technology too complex, and physical limitations such as poor eyesight, hearing loss, and reduced dexterity. Cognitive barriers like memory decline, psychological factors including fear and perceived irrelevance, and financial constraints due to the high cost of devices and internet services also play a role. Additionally, concerns about privacy and security, a lack of support and training, and negative societal attitudes towards older adults using technology further hinder adoption. Addressing these barriers requires accessible and user-friendly designs, affordable options, targeted training and support, and promoting positive attitudes towards technology use among older adults.

Based on the findings of the studies presented in this chapter, during the next phase of the design process a pilot VR application that targets the elderly population is described. More specifically, the design of the pilot application is guided by the need to produce an easy to use application, with an attractive theme and functionality.

Chapter 4: Development and Evaluation of a Prototype VR Application for the Elderly

The elderly need to communicate with their loved ones but also they need to get engaged in activities that require mental awareness as a means of preventing negative side-effects related to brain inactivity. This topic is becoming increasingly important during periods of social isolation caused either by external factors, such as a pandemic, or by factors associated with reduced mobility in the elderly. In this chapter, a prototype Virtual Reality tool that will allow elderly users to deal with the problems of social isolation, while providing an entertaining brain-triggering activity, is presented. The results of an initial user evaluation provides insights related to the strengths and limitations of the prototype application, allowing the derivations of conclusions that can guide further development of the final application.

4.1 Introduction

The aim of the work presented in this chapter is to provide an innovative VR-based approach that will allow elder users to overcome problems related to social isolation. This goal meets a real need that arises in modern societies, and it's been escalated in the midst of the COVID-19 pandemic (Ciotti et al., 2020). Based on the findings of the experimental investigation described in Chapter 3 (see Figure 4.1) older users are willing to use modern technologies provided that the applications have useful functionality, are easy to use, and costs are kept to a minimum. Therefore, special emphasis was devoted to developing a scenario that is highly interesting for elderly users, while minimizing the complexity of the application.

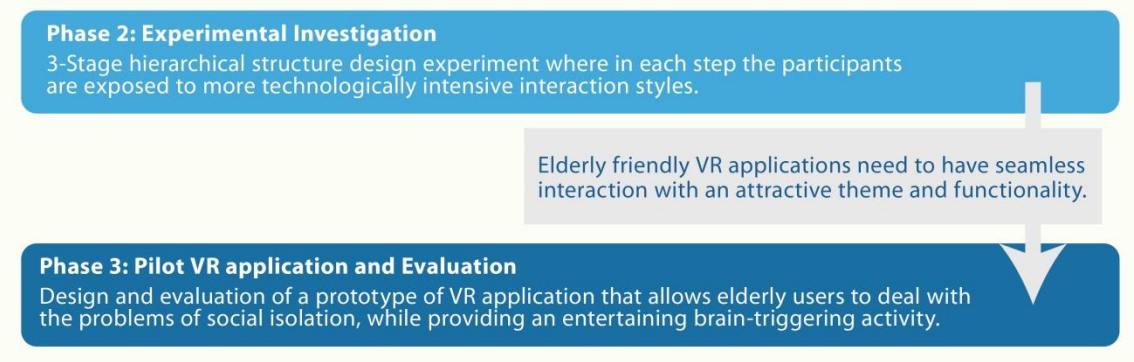

Figure 4.1: The main conclusions of phase 2 that guided the work in phase 3.

Below we explain how we targeted each of these requirements:

Functionality: A storytelling application was selected as it provides both interesting functionality for the elderly and at the same time it can provide cognitive health-related benefits to the users. Pecorini and Duplaa (2017) state that Narrative gerontology is recognized for its numerous advantages, enhancing the sense of well-being among older adults through the exchange of experiences across generations, consequently promoting successful aging. Narratives and storytelling offer a valuable framework for individuals to understand themselves, their life experiences, and to forge connections with others. In line with narrative and developmental theories, the significance of storytelling grows with age, as reflecting on, revising, and sharing one's story can cultivate meaningful connections and leave a lasting legacy for future generations (Murphy, 2021). The description of strong memories from the past is one of the activities that most elderly people enjoy, as it gives them the chance to share their memories and experiences with

younger people. Digital storytelling is a nascent method for documenting and sharing personal experiences, with the potential to contribute to well-being, particularly among older adults. However, its efficacy in this context has not yet been comprehensively evaluated through systematic reviews (Stargatt et al., 2022). Given the importance of storytelling for the elderly, the topic of the proposed VR application was chosen to be related to storytelling, ensuring in that way the proposed VR application presents an interesting and beneficial functionality for the elderly users. More specifically users of the application will be given the chance to initiate and narrate stories related to visual stimuli that appear in the virtual environment, providing in that way a form of user-initiated storytelling activity. In particular the use of immersive Virtual Reality for implementing a user-initiated storytelling activity, gives the opportunity to add in the application a virtual audience that could give the user the feeling of having a real audience, providing in that way additional motivation to use the application.

Usability: In order to achieve usability in our application universal design principles (Burgstahler, 2009) were studied. Furthermore, an evaluation study was carried out in which all stakeholders participate to identify problems and solve them through hierarchical design in order to arrive at the specific VR application. This approach will ensure that the important aspect of interface design and usability that emerged during the study described in Chapter 3 is addressed in an adequate way.

Cost: Based on the findings of the experiment described in Chapter 3, equipment cost has emerged as a key factor in relation to the use of VR applications by older users. To address this concern we chose to develop smartphone-based VR applications without additional controllers. Provided that users already possess a VR compatible smartphone, only minimal additional cost is required for obtaining low cost smartphone-based VR headsets.

Based on the factors discussed in the previous paragraphs, the aim of the research presented in this chapter is to produce a VR application that will allow elderly users to deal with the problems of social isolation, while providing at the same time a way to keep them alert, in a way that could prevent effects associated with brain inactivity. The proposed application allows users to interact through pre-animated movements with a virtual audience and enter a memory recalling experience, presenting in that way a VR version of a storytelling experience, that most elderly people treasure. In this chapter,

the prototype of the proposed application is presented along with a preliminary evaluation that provides insights related to the strengths and limitations of the current system, allowing the further development and use of the application as described in subsequent chapters.

4.2 Application Development

4.2.1 Scenario

The proposed application targets the elderly, and more specifically those who suffer the effects of social isolation. The goal is to provide an entertaining application, while allowing elderly users to feel happy and comfortable so that they can open up and start communicating and express their thoughts and memories in the virtual environment. The scenario of the application takes place in a forest where sounds of nature are heard so that the user can relax and feel immersed. The environment chosen for the application portray an imaginary forest setting, rather than portraying accurately the appearance of local forests. The choice of adopting an imaginary environment relies on observations that users tend to show increased levels of immersion and concentration when immersed in an environment that they don’t experience as part of their usual activities (Baka et al., 2018).

Four photographs on billboards with content related to past memories of the users are presented in the virtual environment. An avatar of a young person approaches the user and starts a conversation, which prompts the user to describe the content of photographs and tell relevant stories to the virtual audience, allowing the user to practice memory retrieval and presentation skills in a storytelling task that is enjoyable for the elderly. Typical screenshots showing scenes from the virtual environment used in the application are shown in Figure 4.2.

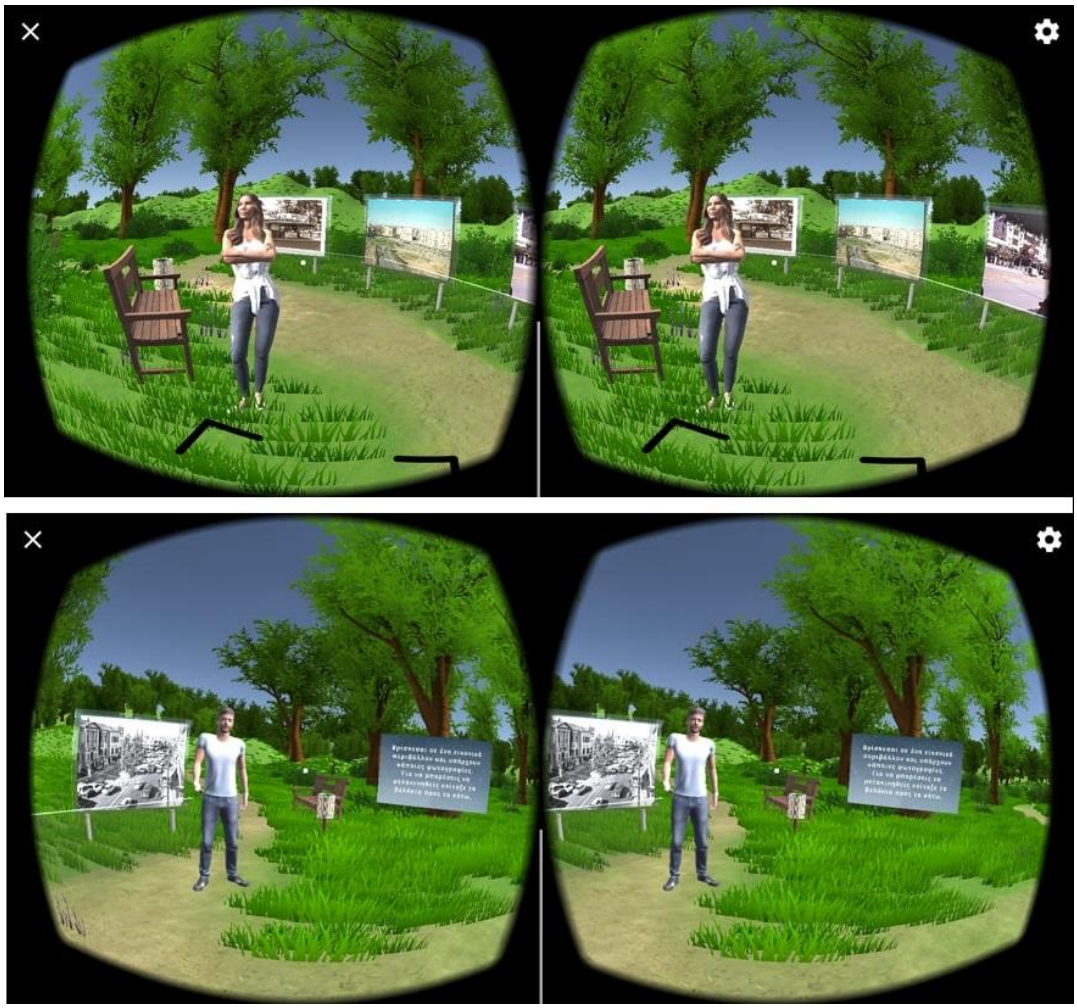

Figure 4.2: Screenshots from the virtual environment of the application.

4.2.2 Implementation Details

a) Platform / Equipment

The application was developed with the Unity3D platform, and can be run on smartphones, allowing the use of the application using low cost portable VR headsets. The only requirement is for a smartphone to have a gyroscope for tracking the head movements of the user. Although there are much better technologies for headset equipment (e.g. Meta Quest) with better resolution and image quality, we chose the low-cost headset equipment so that users can have immediate access without thinking about the cost. The cost for a smartphone-based VR headset ranges approximately from 10 to 50 Euro, while the cost for a compatible smartphone starts at 150 euros. Bearing in mind that most elderly people these days have a smartphone anyway, the minimal

additional cost required will not prevent most elderly users to use this application from their homes. The most important problem associated with the use of low cost VR headset is the increased possibility of experiencing cyber-sickness (Cheiran et al., 2021). To minimize the effects of cyber-sickness in the proposed application, the speed of movement is limited so that sudden changes in viewpoint are avoided. In addition users are expected to use the application from a sitting position.

b) Assets

The application environment as well as some elements of the application has been selected from the Unity Asset Store. The avatars were selected from an online library, and the animation was added from Mixamo.com (see Figure 4.3). The choice of movements selected for this application show typical body movements adopted during a conversation, increasing in that way the fidelity of the virtual audience.

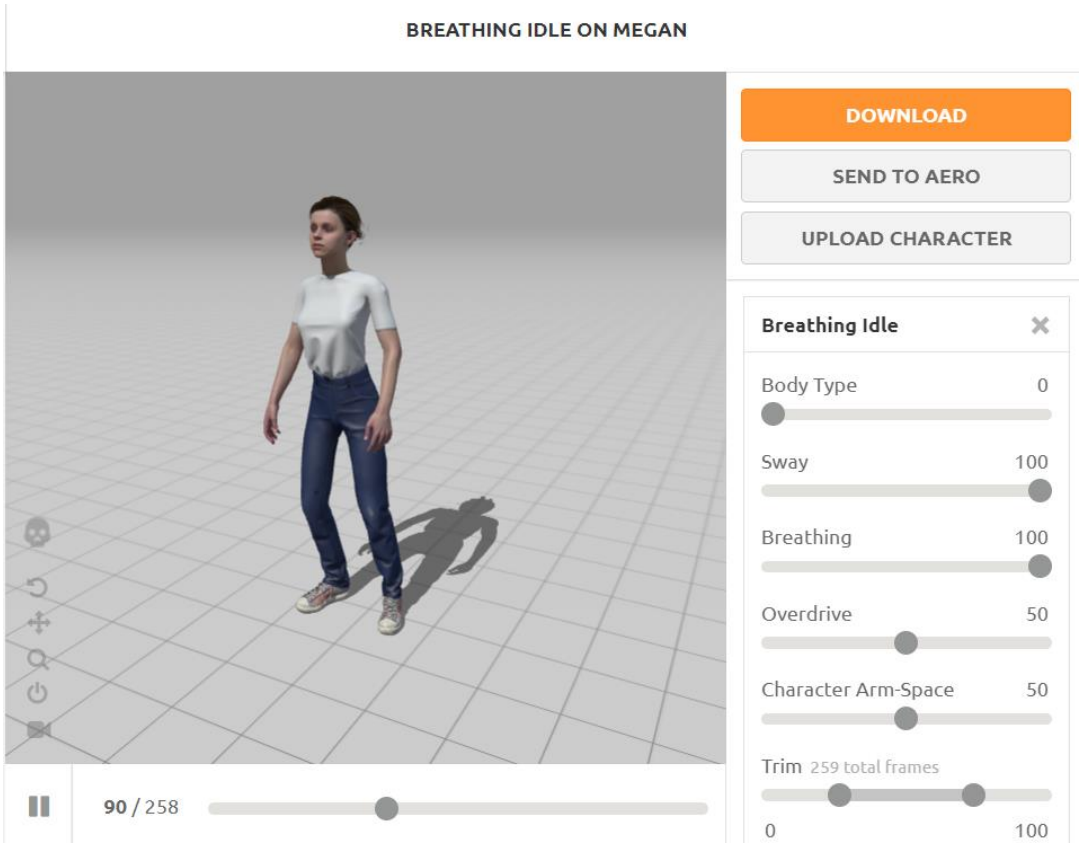

Figure 4.3: Image showing how the selection of animation and character was made by Mixamo.com.

c) Interactions

A first person point of view was adopted in the application allowing users to use gaze-controlled movement to navigate and explore the environment. To make it easier for the users to navigate, four targets (arrows) are placed on the ground to allow users to select the movement direction (see Figure 4.4). The use of a simple interaction mode alleviates the need for extra equipment, increasing in that way the accessibility of the proposed application to a wider community of elderly users, while minimizing the cost for the required equipment.

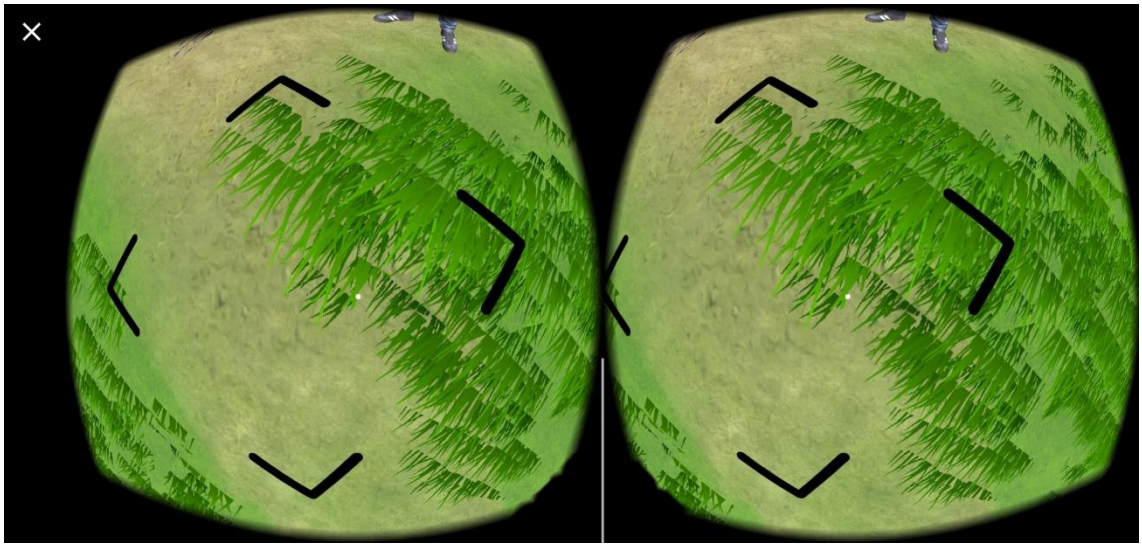

Figure 4.4: Screenshot from the virtual environment of the application showing the four targets (arrows).

4.3 Preliminary Experimental Evaluation

The purpose of the evaluation was to receive initial feedback from experts and potential users on the prototype that will allow the full development of the application. The evaluation was carried out with questionnaires, observations, and interviews.

The following research questions were posed:

RQ1: *Can the VR application help elderly users to deal with the problems of social isolation?*

RQ2: *Do caregivers and expert users believe that the VR application is useful for the elderly?*

4.3.1 Participants

The experiments described in this investigation were performed during the COVID-19 pandemic, and due to the conditions prevailing with the pandemic and for the specific target group we were targeting, the participants were limited to eight users, three male and five female. To ensure the usefulness of the feedback received, the participants who took part in the evaluation were selected from three specific groups: The first group includes four users from the target audience of the elderly with ages greater than the usual retirement age of 65 years old, so that direct feedback from typical future users is collected. The second group includes two caregivers for the elderly that include health professionals such as doctors, nurses, and caregivers. Users from this category, who interact regularly with elders, are well aware of the needs and limitations faced by elderly users allowing them to express important views related to the usefulness and suitability of the proposed application. The third group includes two VR experts with expertise in the design, development, evaluation and use of VR applications. Participants from this group could provide feedback, regarding the technical aspects of the application that includes the interaction, visualization, and information presentation. The evaluation process is shown schematically in figure 4.5.

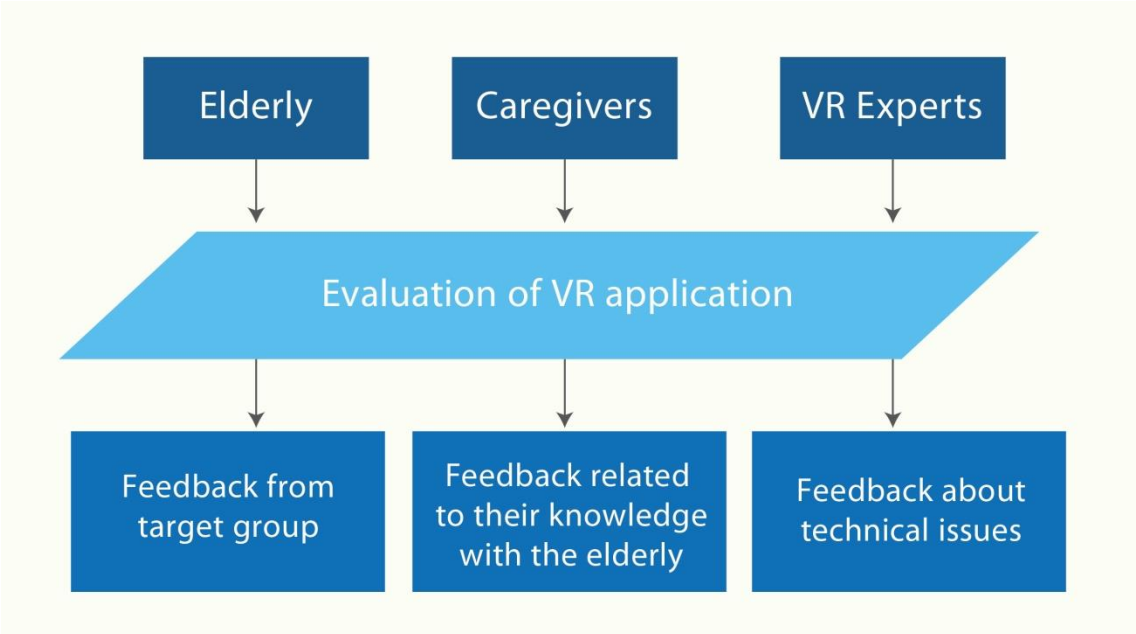

Figure 4.5: Block diagram showing the main steps of the evaluation process.

4.3.2 Evaluation Process

To achieve triangulation during the evaluation, questionnaires, interviews, and observations were used to register the impressions of the users. The questionnaire was given after the evaluation where users registered their demographics and then completed a short version of the User Experience Questionnaire (2022) (see Appendix II) with just eight items (see Table 4.1) where the scales of the questionnaire cover a comprehensive impression of user experience. Both classical usability aspects (efficiency, perspicuity, dependability) and user experience aspects (originality, stimulation) are measured. At this stage of the initial evaluation we opted to use a standard human computer machine questionnaire rather than using a dedicated VR application questionnaire, as the aim was to get initial and general comments about the prototype application, rather than investigating VR related issues such as immersion and presence (Servotte et al., 2020). Observations and interviews with some indicative questions during the experiments were also conducted to confirm the findings and to reveal points that would not otherwise have been possible to reveal using a standard set of questions. The evaluation process, that includes the interaction with the application and the interviews, were recorded, and notes registering the participant's reactions and responses were kept, allowing the further analysis of the overall participant's experience and responses.

Figure 4.6: Sample of elderly users while using the application.

4.4 Results

4.4.1 Questionnaire

The results of the questionnaire (see Table 4.1) aim to get a first idea of the factors considered in the questionnaire. Overall results show that users found the VR application supportive, interesting, original and innovative. On the other hand, the issues of efficiency and simplicity received lower scores, indicating that there is room for improvement for these aspects. Through the results we obtained from the three groups it was observed that the results of the expert users differ in relation to the elderly and caregivers since it was observed that the application was considered easy, clear and exciting for this group. Given the small number of users, the results obtained from the questionnaire were mainly used to obtain an initial reaction of the members from the three groups, so that the answers would form the basis for initiating further discussions during the interview process.

Table 4.1: Mean Scores for the item a of the total number of participants (N = 8).

Item	All	Elderly	Caregivers	Expert VR Users	Negative	Positive
	Mean Score					
1	6.25	6	7	5.5	Obstructive	Supportive
2	5	5	4	6	Complicated	Easy
3	4.62	4	5	5.5	Inefficient	Efficient
4	4.87	4.25	4.5	6.5	Confusing	Clear
5	5.37	5	5	6.5	Boring	Exciting
6	5.87	5.75	6	6	Not Interesting	Interesting
7	6	6	6.5	5.5	Conventional	Inventive
8	6.62	7	6.5	6	Usual	Leading Edge

4.4.2 Interviews

Volunteers from the elderly group (see Figure 4.6) used the application for about eight minutes before participating in the interviews. The main conclusions derived from the interview process per age group are:

Feedback from Elder Users

A positive feature from all users was the audio instructions that allow users to listen the instructions without having to resort to the written instructions, which could be difficult to read, especially for people with reduced vision. Furthermore, all users reported that they did not feel the need to see their own avatar in the virtual environment as they typically pointed out that from the moment they entered the application their purpose was to explore the space. In addition, the open space in the forest where they could move freely provided a relaxing atmosphere. Bearing in mind that the evaluation took place close to periods of enforced social isolation due to the COVID-19 pandemic, few users stated that the chance to visit an open space without fear of contracting a virus, was satisfying. As a result it was quoted that the application provided a nice way to escape isolation in an enjoyable manner. Another positive feature was the fact that most users expressed the will to use this type of application as part of their daily activities, but pointed out that they will prefer to have the ability to easily change the photographs displayed in the application. Also, most users from the first group stated that they would prefer to have more avatars with increased interactivity in the audience. More specifically, the positive and negative comments from elder's users are shown in detail in Table 4.2.

Feedback from Caregivers

Users from the group of caregivers were positive towards the implementation but pointed out some issues for further study in the redesign of the application. Specifically, they suggested that a smaller number of photographs are shown in the application so that the elderly can spend more time on each photo without getting tired. Also, in agreement with the elderly users, users from the caregivers group believe that more virtual characters with more interaction will help the user to have a more attractive experience that could trigger the elderly users to engage more intensively in storytelling activities.

Feedback from VR Experts

Users from the VR Experts group provided feedback regarding technical features of the application that need to be applied in the redesign of the application, such as the transfer of the character via teleport so that motion sickness is limited, and the possibility to

adopt an interactive way to change the photographs displayed on billboards. However, in general they were positive about the main functionality and design of the application. They pointed out that his choice of the environment is satisfactory in offering relaxation to the user, so that users will be attracted to using the application frequently.

Table 4.2: Positive and negative feedback from elderly users.

Positive	Negative
1. Started to narrate stories "I think the photos are from around 1970. When we were in high school we came on a trip to Larnaca here in Finikoudes, all the students were shouting for us to leave because they didn't like it. "	1. He mentioned that he might find it difficult to upload photos and would prefer to have someone else upload them or have the app ready to use.
2. The user found it positive that the instructions were also audible because he did not see the written ones at all.	2. Instructions were needed from the researcher on how to move in the space. Because the user was sitting when doing the assessment it was not easy to see the character speaking. He could not read the letters of the instructions.
3. He found the application pleasant and would like to have photos from familiar places (house, square he frequented, neighborhoods where he grew up).	3. He would like there to be more characters in the space.
4. Started to narrate stories "Specifically he mentioned "Here there was a pastry shop in 1960 where we came every Sunday and had sweets with the whole family." "These are the small tables of Evangelos and at the end of the street there was a cinema"	4. He faced difficulties in movement (he couldn't move in space, he had to repeat looking down several times to move).
5. He would like it if he uses the app more often and the photos and environments change (eg forest / mountain / sea).	5. When he finished the evaluation, he mentioned that he felt dizzy.
6. He would prefer an album instead of a print to see the photos in the application to pass his time more pleasantly.	6. He felt that the avatar was very foreign, he kept a lot of distance. He would prefer to show us the images and have an interaction.
7. He would like to see old photos (eg old Miltonos airport) compared to today.	7. He feels that people are isolated, but someone who is home alone all the time will surely find it useful.
8. Although he is claustrophobic, he was not afraid at all when he was in the application.	
9. He found no difficulty at all in moving in space and there was no feeling of dizziness even with the screen.	
10. She felt great in the environment offering her peace and relaxation.	

4.4.3 Observations

Observations of the activities of the users using the application revealed that about half of the users had difficulty moving in the virtual space since the evaluations were done in a sitting position, and as a result they could not turn over 180 degrees to find the billboards. Although some users initially experienced discomfort and dizziness when first using the headset, it was observed that they ultimately enjoyed using the application. In addition, it was observed that during the first contact with the use of virtual reality, users began to look at the virtual space by themselves and move in it. Despite the initial challenges, these users engaged with the application in a positive and enthusiastic manner once they became accustomed to the device. After being guided by the researcher they could navigate the area without difficulty. Regarding the narration, all elderly users started to explain what they saw in the photos, they discussed the location portrayed in the photographs, and they estimated the date that the photograph was captured. This is an important observation, as it indicates that the use of the application motivated users to engage in storytelling. Specifically, users typically mentioned various memories they had from their youth in relation to the location portrayed in each photograph. Based on the observations and the interviews that followed the testing of the application, it was observed that despite the difficulty faced by the elder users to navigate in the space, the same users were the ones who stated that they would like to use the application on a daily basis because it offered them a relaxing experience in a contemporary application.

4.4.4 Discussion

The main limitation for the evaluation process was the number of volunteers who took part in the experiment, due to the prevailing situation with the pandemic (Morens et al., 2020). However, since the evaluation included interviews and questionnaires with a selected group of users that were in a position to provide valid feedback, important conclusions were derived despite the small number of participants. According to the evaluation, some common elements have been observed from the three groups of users that need redesign. Specifically, additional virtual characters need to be placed in the virtual space with increased interactivity (Ryan, 2011). Also, regarding the user's navigation in the environment, the placement of the billboards and photographs in a

central position will ensure their visibility (Van Bilsen and Poelman, 2009), so that the possibility of getting lost in the virtual space (Stankiewicz et al., 2006) without seeing the photos is minimized. The introduction of teleporting will also be useful in this respect. Finally, an important element that will be added is the choice for users to personalize the application by inserting their own favorite photographs in the application.

Based on the discussion above the answers for the research questions are:

RQ1: *Can the VR application help elderly users to deal with the problems of social isolation?*

Based on the results of our research a VR application can help elderly users deal with the problems of social isolation. VR can facilitate virtual meetings with family and friends, making the interaction more immersive and emotionally engaging than traditional video calls. Also, VR therapy can help manage anxiety and depression through guided relaxation exercises, cognitive-behavioral therapy simulations, and immersive environments designed for mental well-being. Furthermore, a VR application can be used in physical therapy to help with exercises and mobility training, making rehabilitation more engaging and less isolating. With thoughtful design and implementation, VR can significantly improve the quality of life for older adults facing social isolation.

RQ2: *Do caregivers and expert users believe that the VR application is useful for the elderly?*

Caregivers and expert users were positive towards the implementation but pointed out some issues for further study in the redesign of the application to be more user-friendly for the elderly. More specifically, both caregivers and expert users generally view VR applications as useful tools for improving the quality of life for elderly individuals. They recognize the potential for social, cognitive, and therapeutic benefits, while also highlighting the need for user-friendly designs, accessibility, and adequate training and support to maximize the effectiveness of VR technology for older adults.

4.5 Concluding Comments

An initial investigation was presented on the development and evaluation of a virtual reality environment aimed at the elderly. In this context, the user had the opportunity to navigate in a virtual environment and view photos from their youth and share their memories with avatars that were in the virtual space. The initial results from the use of the application showed that it could be used as a support tool so that people who are isolated at home or in nursing homes can escape from the routine of everyday life and can narrate memories that may have been lost or were forgotten over time. The results of the initial evaluation will be used for guiding the development of an improved version of the application, as described in subsequent chapters. Furthermore, the application will be evaluated with more volunteers in order to get specific results regarding the overall benefits gained by elder users, usefulness, and also asses the level of immersion, presence, and any discomfort, such as cyber-sickness, associated with the proposed application. Based on the first results, some initial guidelines for designing VR applications for elderly have been identified, but these will be further refined and improved in the future, after a full scale user evaluation is conducted. Some important elements that were observed so far include the need to add a pre-animated audience with several virtual participants, the need to adopt a simple and interactive scenario, and the need to include seamless interaction and navigation to suit a sitting stance often adopted by the elderly while using a VR application. Last but not least, successful VR applications that target the elderly should contain personalized content that motivates the users to the frequent use of the application. All these issues are explored further in the following chapters.

Chapter 5: Refining Design Elements of the VR Application - Determining Optimum Audience for Storytelling VR Applications for the Elderly

As part of our work to provide to elderly a user-friendly, and enjoyable Virtual Reality (VR) application, a prototype VR application that allows elderly to enter a storytelling activity was developed. An important aspect of the application is the virtual audience who listens to the stories presented by elderly users and the type of photographs that are presented in the application. In an attempt to maximize the impact of the VR application, a dedicated study aims for establishing the main characteristics of the virtual audience and the type of photographs to use. The results of this study are important for creating a more engaging experience for elderly users.

5.1 Introduction

According to the results derived from the previous chapter (see Figure 5.1), the aim of our work is to provide to elderly with a user-friendly and enjoyable Virtual Reality (VR) application that incorporates activities for promoting their welfare. As part of this effort, a prototype VR application that allows the elderly to enter a storytelling activity was developed (see Chapter 4). In an effort to optimize the application, we examine design factors for enhancing the user experience providing in that way a more pleasant and rewarding activity. In this chapter, we focus our attention on the virtual audience that participates in the application, in an attempt to specify the optimum audience characteristics. Furthermore, the optimum number and type of photographs, that provide visual stimuli, was investigated.

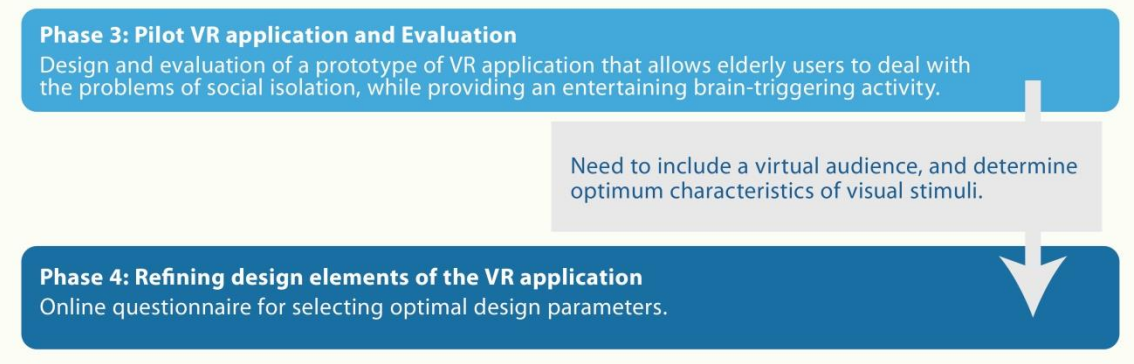

Figure 5.1: The main conclusions of phase 3 that guided the work for phase 4.

5.2 Virtual audience in VR environments

Seniors are exposed to a variety of technologies, aimed at improving their quality of life. Among those technologies, Virtual Reality (VR) can offer elderly users the opportunity to become immersed in virtual worlds where they can interact with their environment, giving them a realistic experience and allowing them to actively participate in creative experiences. Older people often experience a gradual loss of memory about recent events, but they are more likely to remember important events from the past (Levine and Bluck, 1997), which they are keen to share with younger people. Memory recalling storytelling activities offer a way for the elderly to cope with social isolation issues while providing a mental awareness exercise that can help to prevent the effects of brain inactivity.

A virtual audience can play an important role in immersing the user in a virtual space and it also affects the level of interaction of a user. There are many applications related to user's reactions (Anderson et al., 2005) when they interact with virtual audiences in VR applications. Most of these applications target the therapy of users who fear presenting to a real audience (Slater et al., 2006). Chollet et al. (2015) investigate feedback approaches for public speaking instruction grounded in an interactive virtual audience framework. Their research demonstrates that this setup combines heightened engagement and difficulty levels, leading to enhanced public speaking abilities as evaluated by experts.

Audience presence plays a crucial role in public events like sports games, potentially influencing players' performance positively or negatively based on the feedback received. Galani and Vosinakis (2024), use virtual characters in an augmented reality (AR) environment to showcase past craftsmanship and convey the history and heritage of a location. This project investigates the application of mobile AR technology for disseminating intangible heritage associated with existing buildings. Social facilitation theories indicate that audience presence can impact individuals' performance and experiences in such settings. Similarly, in video games, virtual audiences composed of non-player characters often feature prominently, particularly in sports video games, serving as a significant gameplay element. Yet, there remains a dearth of research examining how non-player character audiences affect players' performance and experiences in virtual reality (VR) exergames. To date, no studies have explored the impact of audience feedback on elderly users engaging in VR exergames. Addressing this gap, the research by Yu et al. (2023) aims to provide insights that can inform the design and development of such games tailored for older adults, a demographic increasingly engaging with such technology.

Glémarec et al., (2021), describe an application where participants were tasked with embodying a speaker in a virtual reality setting and devising sets of nonverbal cues to simulate various attitudes. They adjusted the nonverbal behaviors of a virtual spectator to reflect differing levels of engagement and opinion towards them. Subsequently, in a follow-up study, these parameters were utilized to craft distinct virtual audiences adhering to the established nonverbal behavior guidelines. Their findings illustrate the system's capacity to generate virtual audiences portraying three distinct perceived

attitudes: indifference, criticism, and enthusiasm. Furthermore, the analysis yielded a set of recommendations and principles regarding attitudes and expressions for the future design of virtual audiences in applications such as VR therapy and training.

Slater et al., (2019), allows participants to engage in a self-dialogue by articulating their issue to a virtual representation of Freud. They would then embody Freud's perspective, observing and listening to their virtual avatar's explanation, and subsequently offering guidance. Even though embodying Freud with synchronized visuomotor feedback yielded the most favorable results, participants generally experienced an uplift in mood and contentment regarding their personal issues across all experimental conditions. Merely discussing their problems was adequate to induce some level of improvement. This occurrence is recognized as one of the shared elements in psychotherapy. This method, termed Self-Conversation, led to a heightened sense of change and assistance compared to a scripted approach. The findings suggest that Self-Conversation could be a promising strategy for self-counseling.

Glémarec et al., (2022) introduces a fresh approach to managing a Virtual Audience System (VAS) within Virtual Reality (VR) applications, named STAGE. Initially developed for supervised public speaking training in university seminars tailored to the preparation and delivery of scientific presentations, STAGE boasts several key features: 1)A sophisticated API enabling the programming of pedagogical narratives centered on specific public speaking scenarios and training objectives. 2) An interactive visualization interface facilitating user engagement. 3) Computation and visualization of user metrics to track progress and performance. 4) A semi-autonomous virtual audience comprised of virtual spectators programmed to react automatically to the speaker and their surroundings, while adhering to the pedagogical plan. 5) The capability for the instructor to embody a virtual spectator, allowing them to pose questions or provide guidance to the speaker from within the Virtual Environment.

Woods et al., (2022) study aimed to explore if social impact theory (Latané, 1981) applies to using virtual reality in a crowded public space, and whether extroversion and trait anxiety modify these effects. They found that extroverts were less anxious about using VR in public compared to introverts. These results suggest strategies to enhance the accessibility of virtual reality experiences in public spaces and highlight areas for further research to validate preliminary observations.

Yakura and Goto (2020) aim to enhance the sense of co-presence for users attending live concerts virtually by they exploring computational techniques centered on virtual audience avatars. As part of their work they introduce four approaches for presenting avatar movements: mirroring the user's actions, replicating movements of other users, repeating movements synchronized with the beat, and generating movements using machine learning. Through a user experiment, they evaluate the effectiveness of these methods and delve into application scenarios and design considerations that pave the way for novel forms of active media engagement in VR settings.

According to the studies presented above, specific elements that will be helpful for the creation of our own application, such as the interaction of the audience with the user through movement and expressions, were derived Also, another conclusion that helped the present research effort, is related to the observation that a user copes better in the virtual world when he does not see himself (Slater et al., 2019). Finally, it has been observed that the appearance of the virtual audience in relation to age and gender also plays an important role (Woods et al., 2022)

5.3. Pilot VR Application

To study whether a VR storytelling application can really help the elderly, we created a pilot application that offers the user a pleasant experience reminiscing about their younger years as described in Chapter 4. In particular, the scenario of the application takes place in a forest that offers the users the freedom to move in the space listening to natural sounds so that they can feel immersed and relaxed. In front of the user is a billboard with four photos from the decades when the user was young and instructions that the user can read and hear when starting the application. At the same time there is interaction with the virtual audience through pre-animated movements, which includes adults and children, located around the user asking the user to describe the photos displayed on the billboard. The activities featured by the application promote users to practice memory retrieval and presentation skills through storytelling that is enjoyable for the elderly since in real life most seniors like to describe stories about their younger years (Li et al., 2020).

5.4 Methodology

An important feature of this application is related to the characteristics of the virtual audience as well as the photographic material presented in the application. A questionnaire-based study was conducted in order to determine the optimal characteristics of the audience. The aim of the experiment was to collect data according to the preferences of prospective users of such an application so that the final result meets their needs. An attempt was made to collect the data through online questionnaires since the experiment took place during the COVID-19 pandemic, thus members of the target user group, who were more vulnerable, were not available to conduct in person experiments.

The following research questions were posed:

RQ1: *How important is the virtual audience in the VR application?*

RQ2: *What are the optimum characteristics of the virtual audience?*

RQ3: *What kind of visual stimuli do users prefer to see in storytelling VR applications?*

5.4.1 Questionnaire

A dedicated questionnaire (see Appendix III) was set up as a means for obtaining initial feedback regarding the overall application, and more specifically the virtual audience and the type of photographs to be presented. The process we followed was to firstly explain the purpose of our research and then the user could watch a video[1] with the application to understand how the application works, and also see a series of screenshots containing possible variation of design elements of the application (see Figure 5.2). The questionnaire consisted of the first part, where we asked for demographic information about gender, age, and occupation and asked if they had any prior experience with virtual reality, and the second part which consisted of five questions about the application we have created. Specifically, these five questions were measured on a Likert scale and related to the user's preference regarding the application, whether they would be interested in using such an application, and then we get information on

[1] The video that the participants saw before answering the questionnaire: https://youtu.be/DWJLhZCvGdI?feature=shared

whether they would feel more comfortable using the application according to specified factors related to the audience. The last question was related to the type of photographs that could be more suited to this type of application. For the data collection, we created an online questionnaire where it was open to the public but mainly addressed to people who have some knowledge of virtual reality and to people over 60 years old, who are approaching retirement since they are the direct stakeholders of the application we are designing. The questionnaire as measured on a Likert scale with values of 1 representing the highest level of disagreement at each question and 5 representing the highest level of agreement. There were also some screenshots from the application so that the user could understand the content of the application. The sampling technique was done through two groups located on social media where they reach 37000 members in total and the majority of which are over 50 years old. The specific groups concern photos of memories from their cities and thus we considered their topic relevant to the theme of the proposed VR application, maximizing in that way the chances of finding an adequate sample to take part in the experiment.

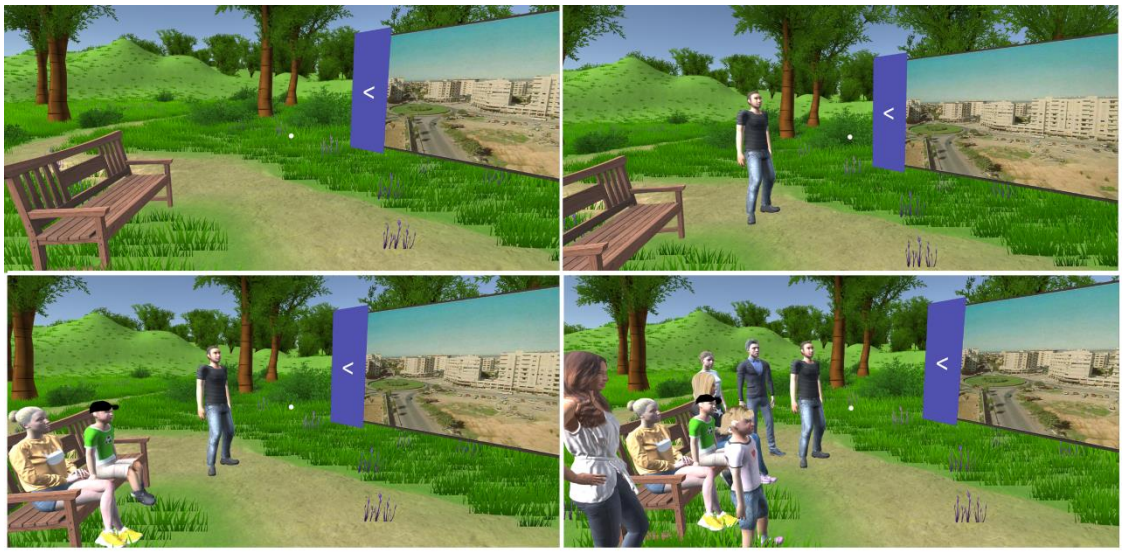

Figure 5.2: Screenshots presented in the questionnaire.

5.4.2 Results

Forty participants completed the questionnaire, 15 men and 25 women. Because our survey was conducted online, the sample included younger people in addition to the elderly. It is understood that the whole sample is useful because even the youngest people can contribute by using comments about the people they have in their family

environment and are elderly telling us their needs. Furthermore, the analysis was done for different age groups, hence conclusions concerning the target age group were derived. Twelve participants were over the age of 60 and were in the "Retired" category, while 4 of the 40 were in the "Employment with Virtual Reality" category. An important factor was that 26 of the 40 participants had never used virtual reality before (see Figure 5.3). On the other hand, although a high proportion have never used a virtual reality application before, 23 out of 40 found such an application interesting and useful (see Figure 5.4), indicating the widespread acceptance of such an application. For the question "Would you feel more comfortable telling a story where there was no virtual audience" the average score was 2 out of 5. In contrast to the question about the presence of a virtual audience of adults and children, the average score was 3, 2 of 5. When comparing the results of these two questions, a p-value of 0.0004 was observed, indicating that there is statistically significant evidence that users favor the presence of a virtual audience (see Figure 5.5).

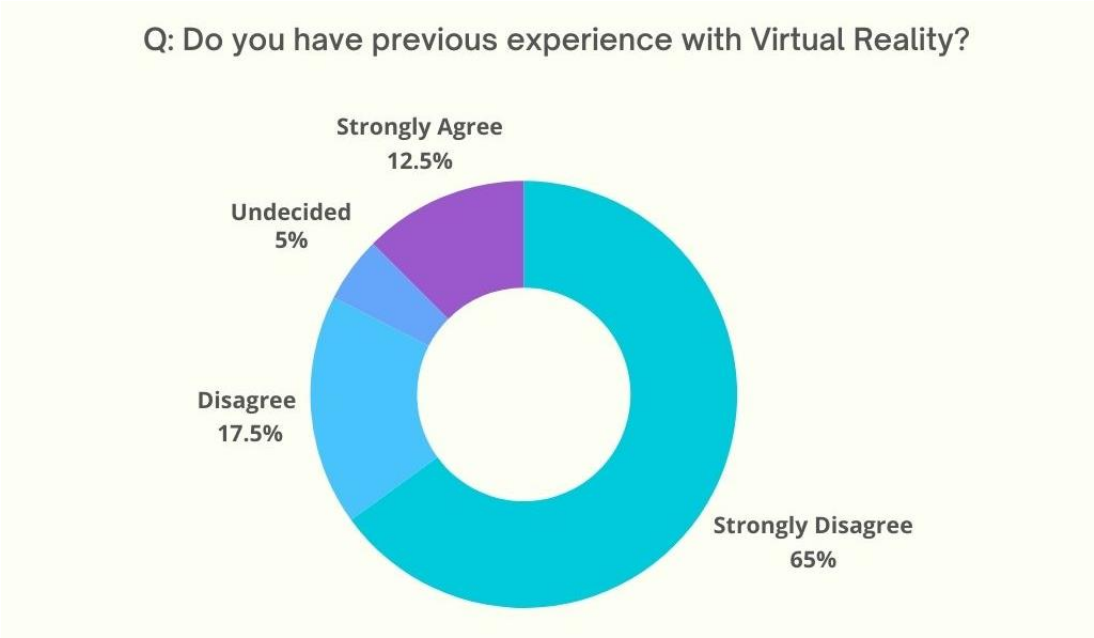

Figure 5.3: Results for question “Do you have previous experience with Virtual Reality?”.

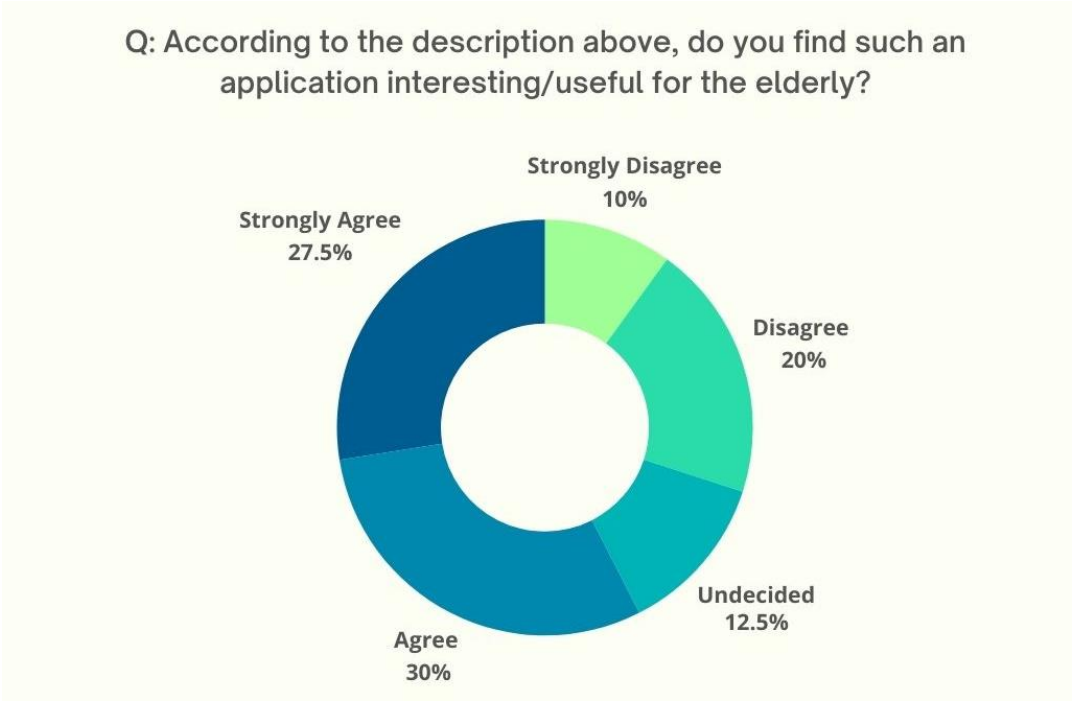

Figure 5.4: Results for question "According to the description above, do you find such an application interesting/ useful for the elderly?".

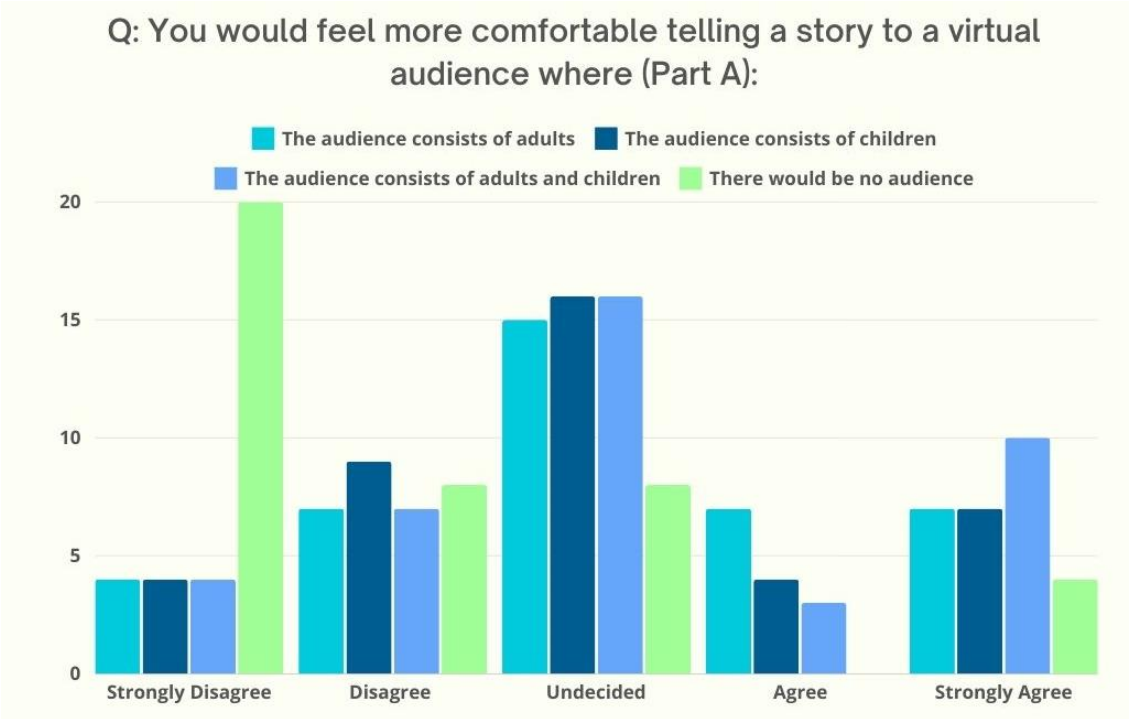

Figure 5.5: Results for question "You would feel more comfortable telling a story to a virtual audience where: (Part A)".

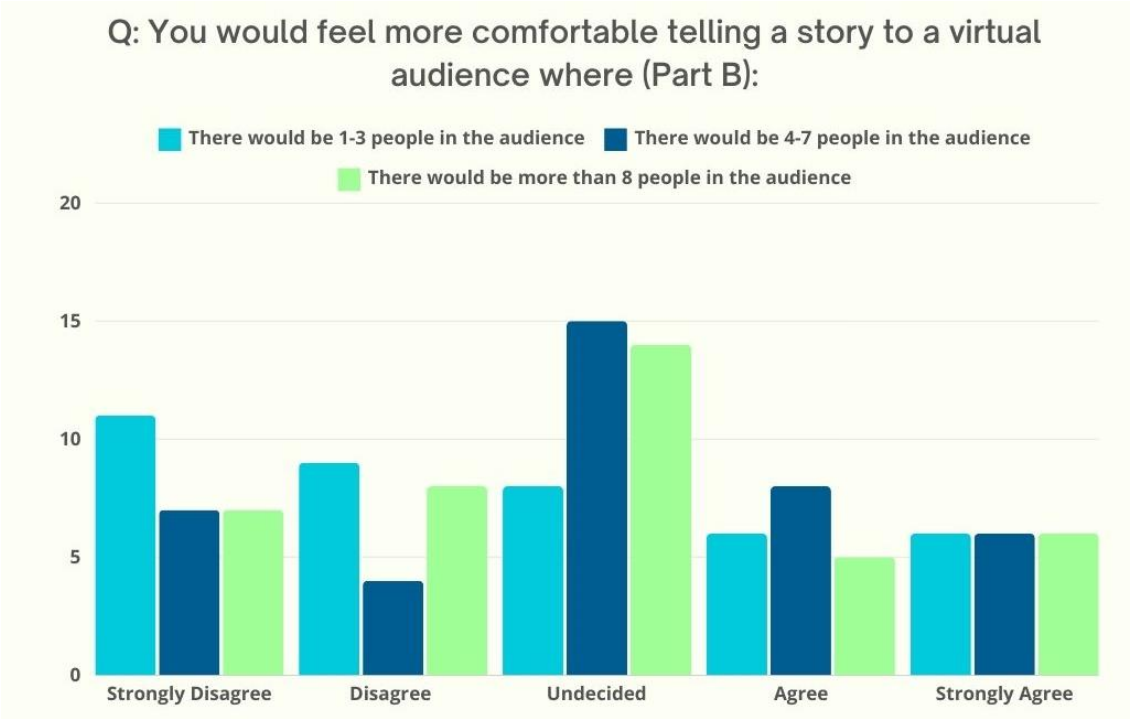

Figure 5.6: Results for question "You would feel more comfortable telling a story to a virtual audience where: (Part B)".

For the audience interactivity question, a score of 3.3/5 was observed for the inclusion of gesture-based audience interaction, indicating that avatars in the virtual audience should not be stationary. For the questions related to the number of people in the audience, the most favorable answer was 4-7 people (mean 3.05/5) (see Figure 5.6).

In addition to the main characteristics of the audience, questions related to other design factors such as the selection of photos to be presented in the app revealed that users preferred to include in a single session of the app five photos that will present landscapes and places from their city from the chronological period 1970-1990 and they mentioned that they would be interested in uploading photos themselves (see Figures 5.7 and 5.8). For each photo, they would like to spend about 1 minute per photo. Figures 5.9 and 5.10 show in detail how the users have answered regarding the amount of photos, where the most common answer was five photos and the time they would like to spend on each photo is one minute.

Table 5.1 shows the results with the mean values and p-values in 3 categories, 1) all participants 2) gender (female / male) 3) age (participants between 18-59 years old /

over 60 years old). The specific categorization was done in order to see if there are significant differences between different categories of participants, and also to derive specific conclusions related to the target group of elder users. In Table 5.2 are the main questions of the part B of the questionnaire.

In the category of gender we notice that only in Question 4 "How much time would you like to spend on each photo?" there is a significant difference with p-value less than 0.05. In particular, it seems that women prefer to spend less time on each photo (2 minutes) as opposed to men who would like more time (3 minutes).

Unlike the previous category, it was observed in the age category that there are several differences. More specifically in the Question 2.3 it is seen that the elderly prefer the audience to consist of adults and children with a p-value less than 0.03. There is also a significant difference in Question 2.6 with how many people they would like the audience to consist of where the elderly preferred it to consist of 4-7 people with a mean score of 3.7 out of 5 in contrast to the young people where they had a mean score of 2.8 out of 5 and with p-value less than 0.04. In addition, in Question 2.8 where it is stated whether the audience would like to interact with the user through hand movements, it appears that the elderly were positive with a mean score of 4.1 out of 5 in contrast to the younger participants who had a mean score of 3 out of 5 and with p-value less than 0.01. Regarding to the Question 3.5, the results show the preference of the elderly to be presented with landscapes of their hometown with a mean score of 3.8 out of 5 and a p-value less than 0.06. As regards how the photos will be uploaded (Questions 3.6 - 3.7) in the application, we notice that they would like to be able to upload their own photos, but also to have defined means in the application with higher percentages from the elderly group and with p-value less than 0.06. Finally, in Question 4 "How much time would you like to spend on each photo?" there is a significant difference with p-value less than 0.02 where it is observed that the elderly group would like to spend more time on the photos in contrast to the younger group.

The results show that in the group of age participants between 18-59 years old / over 60 years old, there are several differences in the results and this prompts us to provide parameterization of the system in relation to the user's profile. For example the age of a user can be used for modifying design elements of the application, that better reflect the

preferences of that group, such as the number and age of avatars in the virtual audience, and the type of photographs presented.

Table 5.1: Mean, Standard Deviations of the mean number of participants (N = 40).

Questions	a) All participants	b) Females / Males Group			c) Ages 18-59 / 60+ Group		
	Mean	Mean	SD	p Value	Mean	SD	p Value
1.1	1.8	1.8 1.7	0.0	0.882	1.4 1.9	0.4	0.277
1.2	3.5	3.4 3.6	0.2	0.5949	3.5 3.4	0.1	0.8811
2.1	3.2	3.0 3.4	0.3	0.3177	3.5 3.0	0.4	0.2358
2.2	3.0	2.8 3.4	0.4	0.1302	3.4 2.9	0.4	0.1831
2.3	3.2	3.0 3.6	0.5	0.1289	3.8 2.9	0.6	**0.0396**
2.4	2.0	2.0 1.9	0.1	0.8025	1.6 2.2	0.4	0.1814
2.5	2.7	2.6 2.9	0.2	0.5159	2.9 2.6	0.2	0.4886
2.6	3.1	2.8 3.5	0.5	0.0635	3.7 2.8	0.6	**0.0445**
2.7	2.9	2.7 3.1	0.3	0.331	3.0 2.8	0.1	0.6925
2.8	3.3	3.1 3.7	0.4	0.1782	4.1 3.0	0.8	**0.0123**
2.9	2.9	2.8 3.2	0.3	0.3236	3.5 2.7	0.6	0.0768
2.10	2.9	2.7 3.3	0.4	0.1821	3.3 2.8	0.4	0.2838
3.1	3.0	3.0 3.1	0.1	0.8136	3.2 2.9	0.2	0.6179
3.2	3.1	2.8 3.5	0.4	0.1385	3.1 3.1	0.0	0.9791
3.3	3.2	3.1 3.5	0.3	0.435	3.7 3.0	0.4	0.2253
3.4	2.9	2.8 3.1	0.2	0.6358	3.3 2.8	0.3	0.3565
3.5	3.2	3.2 3.1	0.1	0.6883	3.8 2.9	0.6	**0.066**
3.6	3.0	2.8 3.3	0.4	0.2096	3.6 2.7	0.6	**0.0686**
3.7	2.9	2.7 3.1	0.3	0.2565	3.5 2.6	0.7	**0.0241**
4	2.6	2.2 3.1	0.6	**0.0546**	3.3 2.3	0.8	**0.0261**
5	3.6	3.5 3.9	0.3	0.4609	3.3 3.8	0.3	0.4519

SD, standard deviation

*Statistically significant change (p value<0,05)

Table 5.2: Main questions of the part B of the questionnaire.

1. According to the description above, do you find such an application interesting/useful for the elderly?
2.You would feel more comfortable telling a story to a virtual audience where:
2.1 The audience consists of adults
2.2 The audience consists of children
2.3 The audience consists of adults and children
2.4 There would be no audience
2.5 There would be 1-3 people in the audience
2.6 There would be 4-7 people in the audience
2.7 There would be more than 8 people in the audience
2.8 The audience would engage each other with hand gestures
2.9 The audience would respond with various expressions
2.10 The audience would aurally reciprocate
3.Would you like the photos in the app to be:
3.1 Photos of the last decade (2010-Today)
3.2 Photos from the decades 1990-2010
3.3 Photos from the 1970s-1990s
3.4 Your personal photos (people/landscapes, etc.)
3.5 Photos depicting landscapes of Cyprus
3.6 Photos that the user can upload
3.7 Designated photos within the app
4. How much time would you like to spend on each photo?
5. How many photos would you prefer to have in the app?

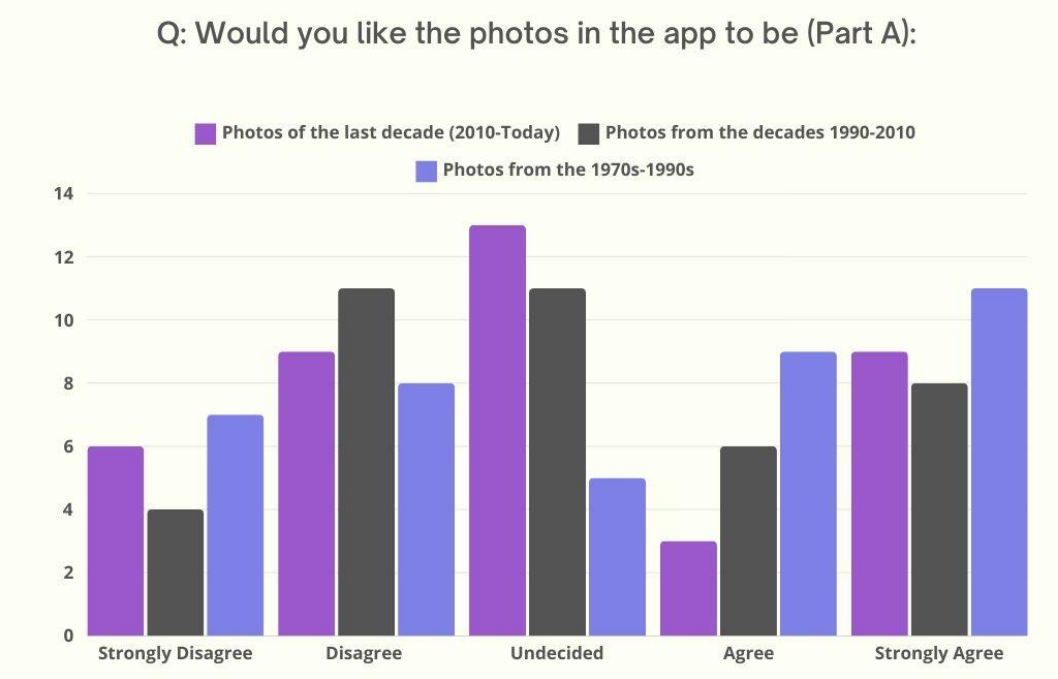

Figure 5.7: Results for question "Would you like the photos in the app to be: (Part A)".

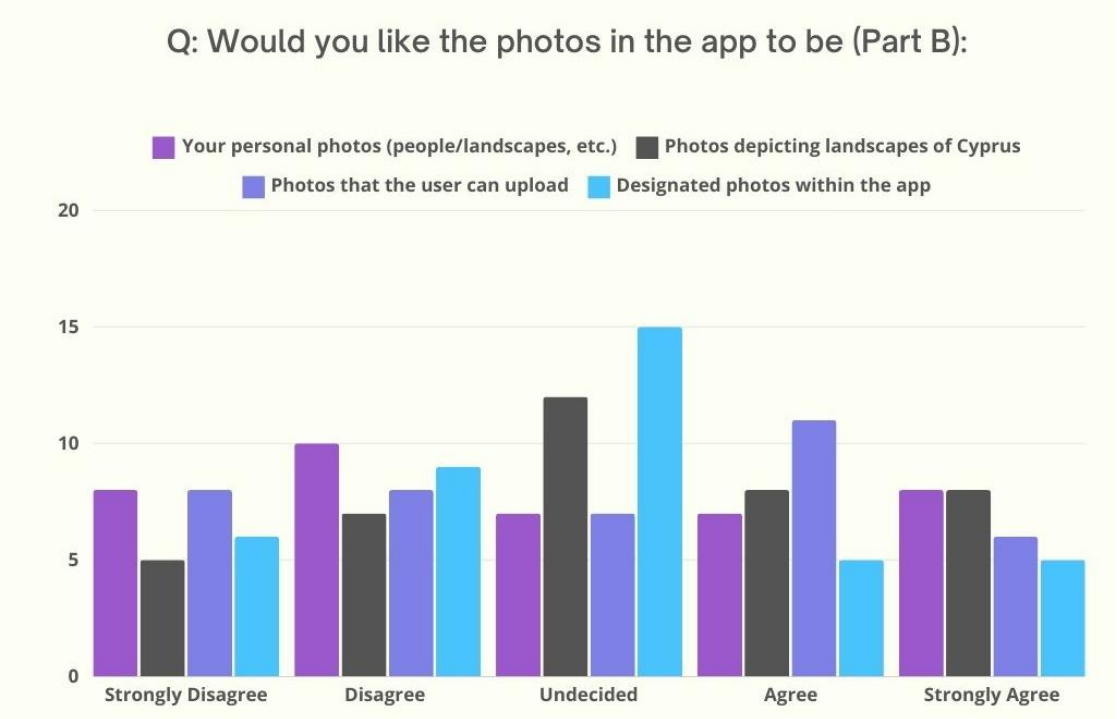

Figure 5.8: Results for question "Would you like the photos in the app to be: (Part B)".

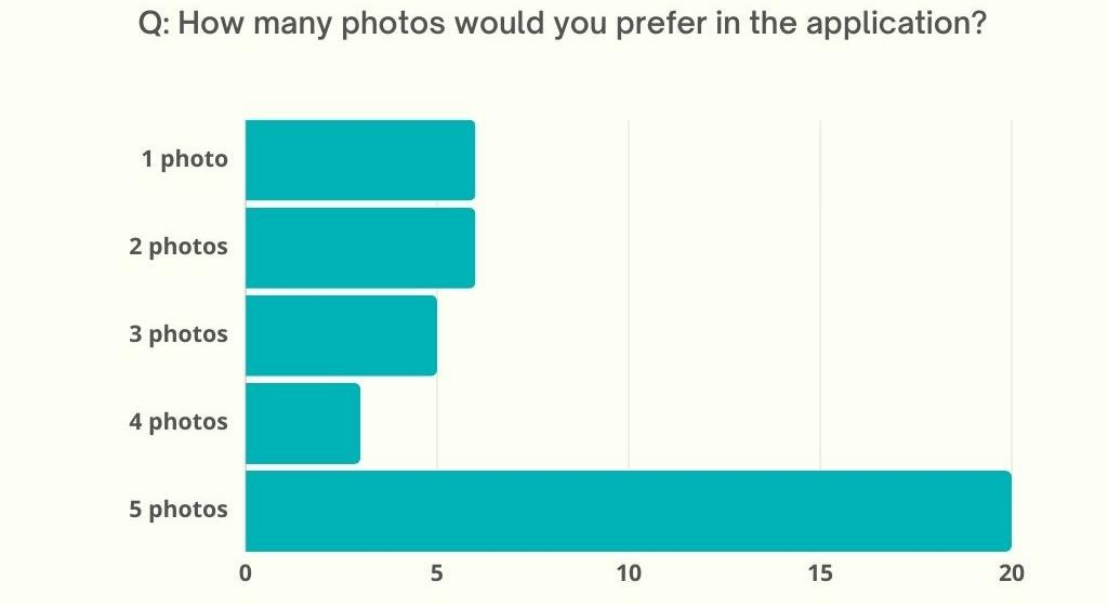

Figure 5.9: Results for question "How many photos would you prefer in the application".

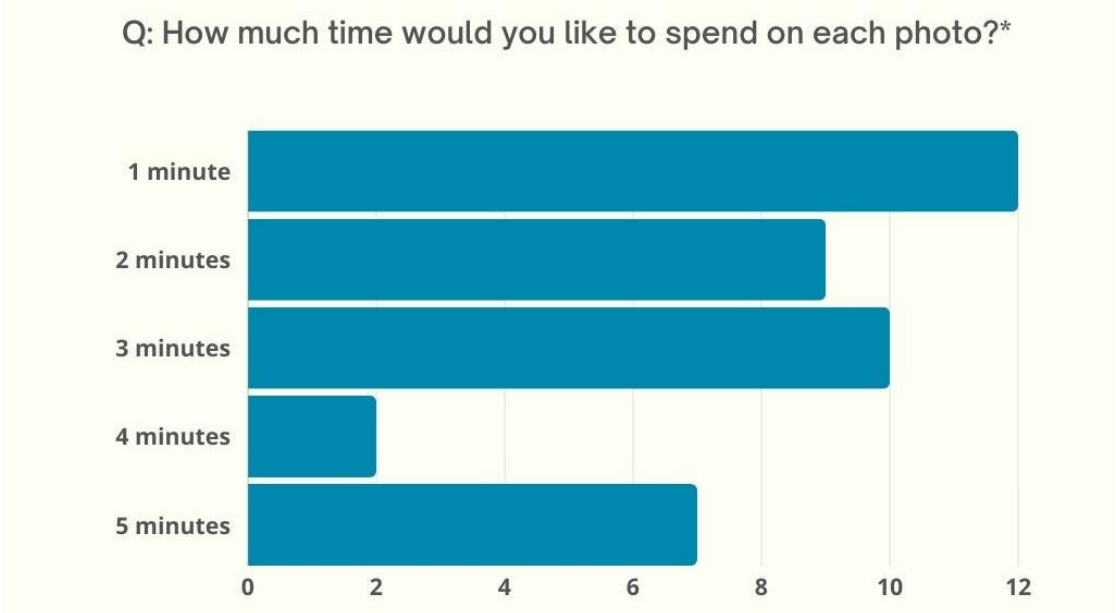

Figure 5.10: Results for question "How much time would you like to spend on each photo?".

5.4.3 Discussion

The main limitation of the evaluation process was the number of volunteers who participated in the experiment, due to the target age group we focus on and the impersonal evaluation process since the users did not have any direct communication with the researcher for further explanation of the application or for additional information of research. Nevertheless, during this first step in the process, we collected an acceptable sample through social networks and by approaching groups made up of a large percentage of elderly people. According to the evaluation, some common elements have been observed that allows the definition of specifications for the final application. Specifically, the virtual audience should include 4-7 avatars adults and children, with increased interaction in the form of hand movements. Finally, an important element that will be added is the preferred number and type of photographs indicated in the responses (five photos showing views of the native country of the users from the chronological period 1970-1990). Apart from the basic set of 'generic' photographs, the user will be given the opportunity to upload their preferred photographs.

Based on the discussion above the answers for the research questions are:

RQ1: *How important is the virtual audience in the VR application?*

Through our research we concluded that virtual audiences in VR applications are important in providing social engagement, emotional support, motivation and engagement for older users to initiate storytelling.

RQ2: *What are the optimum characteristics of the virtual audience?*

Ideal virtual audience characteristics include diversity in characters through age and gender, interactivity so they don't appear static, and accessibility so the user feels like they're in the space with them. By incorporating these features, VR applications can create more immersive and meaningful experiences for older users, contributing to their overall well-being and satisfaction.

RQ3: *What kind of visual stimuli do users prefer to see in storytelling VR applications?*

In VR storytelling applications, users prefer visual stimuli that enhance immersion, evoke emotional responses, and effectively convey the narrative. These includes clean and realistic environments so that there is not too much information and tire the user,

accessible virtual characters that will feel comfortable to tell stories, and lastly most importantly presenting images that will motivate the user to start the narrative through memories of his/her younger years. More specifically, through the results of our research, it seems that users preferred to see photos from the city where they come from, but from the decade when they were young, since they do not have access to this specific category of photos. By incorporating these elements, we aim to create our final application where it will create delightful storytelling experiences that will positively resonate with users in VR.

5.5 Conclusions

The aim of our work is to contribute to improving the daily life of the elderly through the development of dedicated VR applications that target elderly users. To optimize the experience of the end users, the applicability of certain design of the end users, the applicability of certain design factors has been investigated through a dedicated evaluation process. The preliminary results show that there will be a need to redesign our pilot VR application according to the needs of the elderly. More specifically the preferred features of the virtual audience will be added in order to provide a better user experience. As part of the work described in the next chapter, the preliminary observations about the design factors in question will be cross-verified through a rigorous user evaluation of the final VR application under development using user trials, interviews, user observation, and questionnaires to achieve triangulation in data collection.

Chapter 6: Final Application, Evaluation and Discussion

Given the results of the evaluations of the pilot application, and the results of the online questioner regarding design elements of the application, the final application was designed and developed (Anastasiadou et al., 2024). Specifically in this chapter, we are focusing on the redesign of the application and the evaluation. The results of this study are important in order to answer the main research questions posed. In the remainder of the chapter, the multi-phase co-design methodology used for designing and implementing the VR application is presented in section 6.2, and in Section 6.3 the final VR application is described. Section 6.4 focuses on the experimental evaluation of the VR application based on interviews and questionnaires. A discussion about the results of the experiment is presented in section 6.5.

6.1 Introduction

The aim of the work presented in this chapter is to design and evaluate a user friendly and enjoyable Virtual Reality application that can support elder users in dealing with the effects of loneliness and social isolation (Oppert et al., 2023) that are common among the elderly population. The work described in this chapter is based on the results derived from the previous phases of the work (see Figure 6.1). The proposed application presents familiar photographs of elderly users in a VR environment, where apart from the photographs it contains a virtual audience that acts as a virtual companion to the user. Familiar photographs presented aim to awaken emotions, either positive or negative, of the users who are asked to narrate memories from their younger years and discus their memories with the virtual audience though a storytelling experience. Within this context, photographs displayed in the application aim to activate a memory recalling experience, and the presence of a virtual audience aims to motivate users to engage in storytelling, so that the feelings of loneliness and social isolation are compacted.

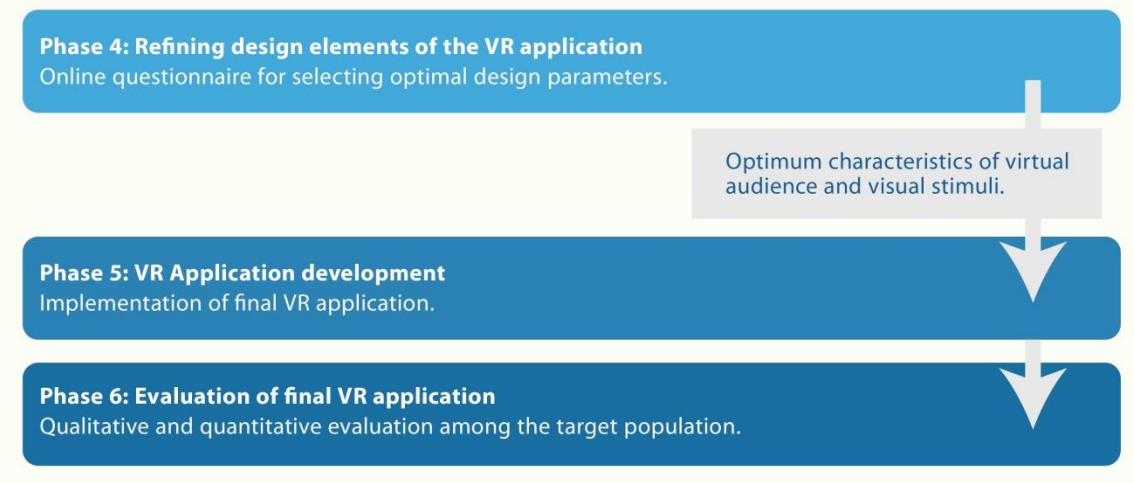

Figure 6.1: The main conclusions of phase 4 that guided the development of the VR application in Phase 5.

The ultimate purpose of the research is to study whether the users of the proposed virtual reality application believe that it has the potential to improve the emotional state of the users with regards to the feelings of loneness, joy and well-being. Experimental results derived through the evaluation of the application by elderly users indicate that the use of the proposed application is well received by the target population since most users were positive on using it to reduce the feeling of loneliness and social isolation.

6.2 VR Application Design Methodology

The development of the proposed VR application followed a multi-phased co-design approach with the active participation of groups of people related to elderly, such as caregivers, medical personnel and elderly users. Furthermore, professionals with expertise in the development of Virtual Reality applications were also involved in the design process. The main phases of the design (see Figure 6.2) include the literature review in relation to user requirements and previous approaches in designing VR applications for the elderly (Chapter 2) an investigation related to the user requirements of the target group (Chapter 3), the design and evaluation of a pilot test application (Chapter 4), the refinement of design elements of the application through a questioner-based approach (Chapter 5), the development of the final application, and the evaluation of the application with the target population of elderly users. This chapter focuses on the last two phases of the design process. However, brief descriptions of the remaining phases are also presented.

Phase 1- Literature Review: The aim of the literature review was to determine the needs of the elderly, and study age-related difficulties and weaknesses that should be taken into consideration for designing an elderly friendly VR application. In addition, previous approaches in developing VR applications for the elderly population were studied.

Phase 2- Experimental Investigation: Three preliminary experiments related to the use of different technologies in the form of smartphones, augmented and virtual reality by elderly have been completed (Anastasiadou and Lanitis, 2021). The design of the experiment is based on a 3-stage hierarchical structure where in each step the participants are exposed to more technologically intensive interaction styles starting

with the use of a common smartphone application and gradually moving on to immersive environments.

Phase 3- Pilot VR Application and Evaluation: The design and development of a prototype Virtual Reality tool that allows elderly users to deal with the problems of social isolation, while providing an entertaining brain-triggering activity. An initial user evaluation provided information related to the strengths and limitations of the prototype application that guided the process of optimizing the application for elderly users (Anastasiadou, 2022).

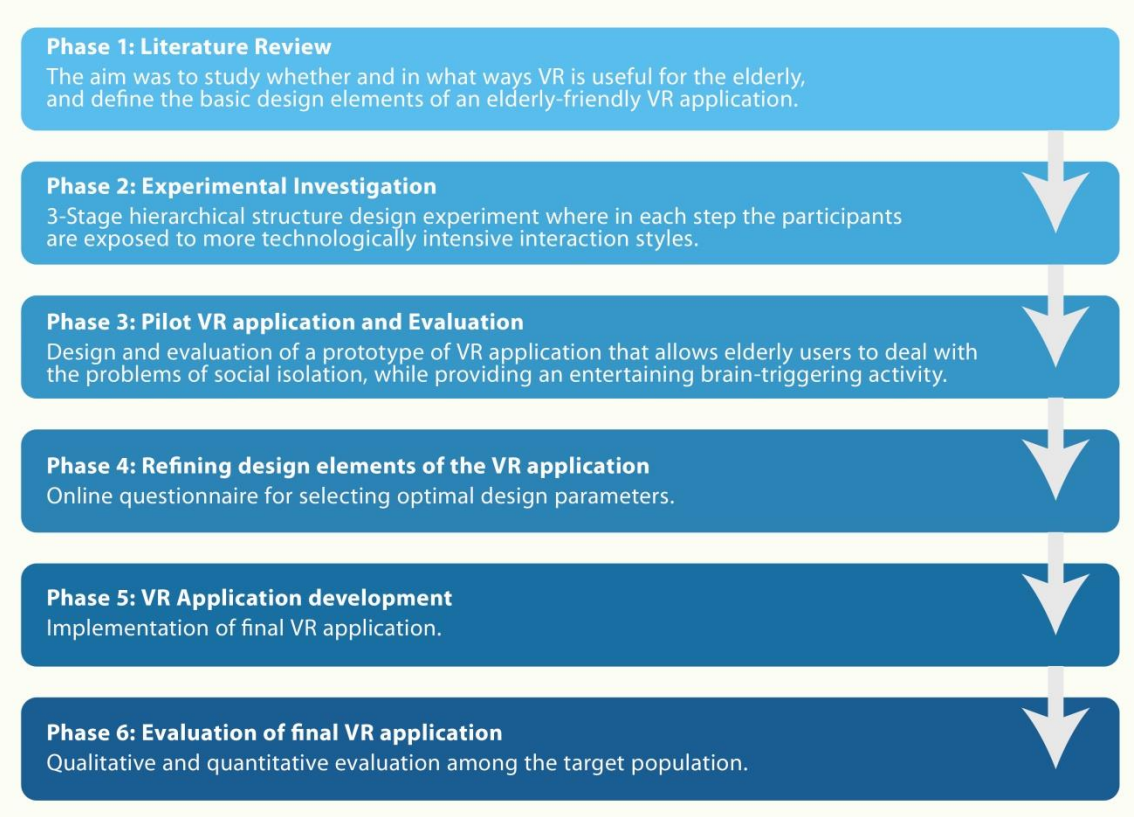

Figure 6.2: Block Diagram of the multi-phased co-design approach used for designing the VR application.

Phase 4- Refining Design Elements of the VR Application: Based on the outcome of the evaluation of the pilot application, several design elements were refined through a questionnaire-based data gathering process, where participants rated different design options for the final application. Design elements under evaluation included the choice of the subject, number, and chronological period of the photographs portrayed in the application. Also another important parameter studied in this phase was the

characteristics of the virtual audience that appears in the VR application so that the impact of the application is optimized (Anastasiadou, 2023).

Phase 5- Application Development: Having collected information's that identified the target audience's needs, the final application was developed.

Phase 6- Evaluation of Final Application: A comprehensive evaluation of the final application by members of the target population was carried out, and conclusions related to the effectiveness of the application were derived.

More details of Phases 5 and 6 are presented in subsequent sections.

6.3 VR Application Description

In this section a description of the operation of the final VR application is presented. The VR application runs on VR-compatible smartphones in conjunction with the use of low cost VR headsets. The only requirement is for a smartphone to have a gyroscope for tracking the head movements of the user. Bearing in mind that most elderly people these days have a smartphone anyway, the minimal additional cost required will not prevent most elderly users to use this application from their homes. It is important to emphasize at this point that the choice of the low-cost headset is mainly made so that more users can access it by sacrificing the image quality that we could get from a high-cost headset. The application was developed with the Unity3D platform. Unity3D is a powerful and versatile platform that supports a wide range of applications beyond just game development, including simulations, architectural visualizations, automotive design, and even more (Unity, 2024).

Four billboards with photographs attached are placed in a circular order so that user is able to view all photographs just by turning his/her head around 180 degrees (see Figure 6.4) without having to move in the virtual space. When compared to the prototype application, the photograph location was changed to a circular order, so that to restrict the movements of the users, preventing them from losing their way and orientation in the virtual space.

In line with feedback obtained during the design process, the virtual audience consists of seven avatars depicting of adults and children (see Figure 6.5) so that the group resembles a family gathering. In this version of the application, the actual appearance of

the avatars was random, and does not resemble actual persons familiar to the user. The choice of using random avatar appearances minimizes the computational cost in implementing/running the application. In addition, the use of avatars portraying real persons could pose legal issues that would prevent the use of the application. As part of our future work of turning the application into a collaborative multi-player application, we plan to investigate the benefits of using virtual audience that resemble familiar persons.

Avatars are placed near the user so that continuous optical contact between the user and the audience is ensured. Bearing in mind that elder users are more prone to nausea effects when immersed in a VR environment (Ijaz et al., 2022) both the user and the virtual characters do not move around so that effects of nausea (Cheiran et al., 2021) for the user are minimized. However, the virtual characters perform animations so that the user gets the feeling of dealing with real (live) humans (Cheng and Wang, 2024). To minimize the effects of nausea the proposed VR application, the speed of movement is limited so that sudden changes in viewpoint are avoided. In addition users are expected to use the application from a sitting position.

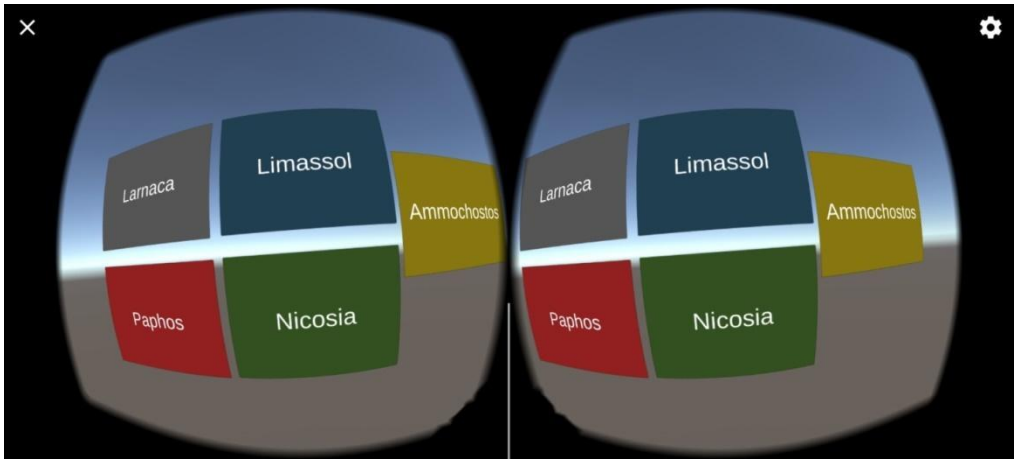

Figure 6.3: Screenshot of the application showing the main menu that allows the user to select his/her place of origin.

Figure 6.4: Screenshot of the VR environment showing the photos and avatars.

Figure 6.5: Screenshot of the virtual audience as seen from the user's point of view.

To use the audio instructions of the virtual audience, the Narakeet tool (2023) was used so that the voices of the avatars sounded realistic. The Narakeet tool give us the possibility to make realistic audio instructions in Greek through the text given by us choosing whether we want the voice to be male or female. The application environment as well as some elements of the application has been selected from the Unity Asset Store. The avatars were selected from Unity Asset Store, and the animation was added from Mixamo.com (2023). The choice of movements selected for this application show typical body movements adopted during a conversation, increasing in that way the fidelity of the virtual audience. Samples of characters with different poses from the Mixamo webpage are shown in the figure 6.6.

Figure 6.6: Samples of character with different poses, Images source: www.mixamo.com.

6.4 Scenario of the application

When starting the application, the user is presented with a screen where five cities are displayed and he/she can choose the city of his/her origin. As soon as the user chooses a city, he/she enters a virtual space where four photos are presented in a circle. The user is in a forest and relaxing music is playing. Seven pre-animated characters (the virtual audience) also appear in the environment. After some time, the audio instructions from the characters start, prompting him/her to start the narration. Then the user can choose any of the photos that appear in circular order, and start the narration. When he finishes the narration then the process is completed.

6.5 Experimental Process

During the evaluation, users followed the following steps were executed:

1. Instructions were provided to the user by the researcher, explaining how to use the VR application. The user is in a sitting position, and if for any reason the evaluation of the application needs to be ended, the headset can be freely removed.
2. When the application starts, the user is asked to indicate his/her place of origin so that appropriate photographs can be selected (see Figure 6.3).
3. The user is then instructed to place his/her smartphone in the VR headset.

4. When the headset is worn by the user, he/she is immersed in a scene showing a forest, billboards displaying the selected photographs, and a virtual audience.
5. In order to facilitate interactions with the user, audio instructions from the virtual audience are heard to encourage the user to start the narration. At the same time, low-pitched nature sounds are heard in the background to enhance immersion and relaxation for the user.
6. The narration is begun by the user according to the photos seen in the virtual space.
7. When the narration is finished, the headset is taken off by the user, and the evaluation process is completed by filling out the third part of the questionnaire and then completing the interview.

6.6 Experimental Evaluation

The aim of the evaluation was to assess the impact of the application on elderly users. More specifically the aim was to determine whether elder users believe that the proposed VR application could help them to reduce the feelings of social isolation and loneliness, could offer and stimulate the interest to start telling stories from their younger years and finally to study whether the application could improve their overall sense of well-being. Other issues related to the usability and attractiveness of the application was also investigated. The following research questions were posed:

RQ1: *Are elderly people willing to use the proposed storytelling virtual reality application?*

RQ2: *Do elderly people believe that the proposed VR application can help to overcome feelings of loneliness and improve wellbeing?*

6.6.1 Participants

Fifty volunteers participated in the experiment. To collect a sample of 50 users, we had to attend places frequented by the elderly such as village squares, cafes, churches, rehabilitation centers and nursing homes (see Figure 6.6). The data collection process was not easy since it was a time consuming process to find participants who were willing, and were able to do the evaluation. For example users with serious vision, hearing, and other related health problems were not able to participate in the process.

The data collection phase lasted three months. Concerning the participants, 19 (38%) were males, and 31 (62%) were females, with the highest percentage of participants aged 79 years and above. More specifically seven participants were 55-59 years old, nine participants were 60-65 years old, 11 participants were 66-69 years old, three participants were 70-75 years old, and 20 participants were 79 years old and above. With regards to participants' occupation and mobility level, 76% of them were retired, and 28% had a mobility problem that makes it difficult for them to move. Prior to taking part in the experiment all participants were informed about the purpose of the study and the experimental procedure was explained. Furthermore, the volunteers were informed that they had the right to withdraw their consent to participate in the study at any time. The conduction of the experiment received approval from the National Bioethics Committee, ensuring that all ethical considerations were taken into account during the experiment.

Figure 6.7: Sample of users during the evaluation in their place.

6.6.2 Methodology and Instruments

At the beginning of the experiment, the operator presented the subject with the research protocol. The protocol includes information on the purpose of the study, the headset installation procedure, and the VR immersion time. All participants were free to ask any questions they deemed necessary. The researcher informs the participant that they will be in a seated position and if for any reason they wish to terminate the application evaluation they are free to remove the headset. Figure 6.7 shows users during the experimental evaluation procedure. For data collection, user observation, interviews, and questionnaires were used. The questionnaire used consisted of three parts (part A, B

and C), with closed-ended questions. Part A concerned mainly demographic data (gender, age, work status and physical mobility). Questions in Part B and C of the questionnaire were based on existing loneliness (Russell et al., 1978), well-being (Wright, 2008) and usability (Brooke, 1996) questionnaires. A number of questions from the aforementioned questioners were selected so that a customized questionnaire that suits the research questions of the experiments was formulated. The first nine questions (see Table 6.1) of Part B and C of the questionnaires were identical so that differences in responses before and after the intervention were quantified. In addition to the common questions, Part C of the questionnaire contained questions related to the attractiveness/usability of the application, the immersion levels of the users, and also included questions related to the overall impression of the users towards the application. Participant responses were on a 1-5 Likert scale from "Strongly disagree=1" to "Strongly agree=5" with closed type questions to enable grouping and analysis of results. All questions used are show in Appendix IV.

Figure 6.8: Sample of participants using virtual reality application.

At the beginning of the evaluation process, participants completed Part A and Part B of the questionnaire, and afterwards they had the chance to use the VR application for about 3-7 minutes. Upon completing the use of the application, users completed Part C

of the questionnaire (see Table 6.2). Then the researcher conducted an open-ended interview based on the comments they mentioned during the use of the application in order to develop more comments and thoughts to improve the application. The total duration of the interviews ranged from 5 to 20 minutes.

For the data analysis, the package SPSS was used. In the analysis, both descriptive and inferential statistics were applied for exploring the differences amongst the groups and utilizing statistical tests, paired sample t-test, and independent samples t-test. Then followed the analysis of the interviews, where some phrases/keywords were grouped to see the opinions of the users quantitatively. At the same time, important reports and comments reported by users have been recorded.

Table 6.1: The common questions from part B and C of the questionnaire presented to the users before (Part B) and after (Part C) the intervention.

Number	Question
B1/C1	Would I be interested in using a virtual reality application in my daily life to socialize with other people?
B2/C2	There are people I feel close to in the physical and/or virtual environment.
B3/C3	I feel alone.
B4/C4	There are people I can talk to in the physical and/or virtual environment.
B5/C5	I believe there are VR applications that help me not feel alone.
B6/C6	I feel healthy.
B7/C7	I have happy memories from the past.
B8/C8	I am very happy.
B9/C9	I am satisfied with everything in my life.

6.6.3 Quantitative Results

The results of the paired sample t-test before and after the intervention are presented. This test is used because the samples are depended since it has to do with the same persons in different circumstances (before and after the interference). The null hypothesis (H0) is that there is no significant statistical difference regarding the responses of the participants before and after the intervention and the alternative (H1) is that there is a statistically significant difference with regard to the responses of the users before and after the intervention. Based on the results (see Table 6.3) there is statistically significant difference with a p-value smaller than 0,05 for the pair of

questions B5-C5 “I believe there are virtual reality applications that help me not feel alone”. For the remaining pairs of questions, although there is a difference in the mean values, no statistically significant differences were recorded before and after the intervention.

The results of the non-parametric Wilcoxon Sign Rank Test before and after the intervention are presented. This test is used because the samples are paired, and the data are in ordinal scale since it has to do with the same persons in different circumstances (before and after the intervention). Tables 6.4, 6.5, and 6.6 shows the results of the analysis for each group, and the pairs of questions where statistically significant difference was observed.

Table 6.2: The remaining questions from Part C of the questionnaire presented to the users' after the intervention.

Number	Question
C10	I would like to use this app often.
C11	The app was easy to use.
C12	I thought I would need the support of a technical person to be able to use this app.
C13	The audio instructions were helpful in the application.
C14	Interaction in relation to site navigation was sufficient.
C15	I felt very confident using the app.
C16	I felt like I was in virtual space.
C17	When using the app I still paid attention to the real environment.
C18	On a scale of 1 to 5 (1=Poor app, 5=Excellent app) I would rate the app with

With reference to the results of the questionnaires, it was observed that in all the participants but also in the results of each group only in question B5/C5 “I believe there are VR applications that help me not feel alone.” There was a significant p value for all groups (Table 3). We can justify this because people who have never had contact before have come into contact with virtual reality, since it helped them understand what a virtual environment is and what it offers them. It was observed that many people were willing to use the application if they had the VR headset and smartphone equipment. A large percentage were positive about using a VR app, but not for everyday use. As observed in the age group of 70 and over there is a significant p value of .022 for question B1/C1 “Would I be interested in using a virtual reality application in my daily

life to socialize with other people" and correspondingly for question B5/C5 the p value is .000. This indicates that older people realized what virtual reality is useful as a means of enhancing socialization. Given that the proposed application is not a collaborative application, it is implied that the users considered the presence of a virtual audience as a step towards socialization.

Table 6.3: Mean, Standard Deviations of the mean number of participants (N = 50).

Question	All participants		
	Mean	**SD**	**p Value**
B1	3.140	1.6164	.537
C1	3.260	1.5493	
B2	4.200	1.3553	.103
C2	4.280	1.3099	
B3	1.760	1.2707	.569
C3	1.820	1.3045	
B4	4.380	1.0476	.537
C4	4.320	1.0962	
B5	3.180	1.5996	**.000***
C5	4.260	.9858	
B6	3.640	1.3516	.197
C6	3.780	1.4886	
B7	4.260	1.1031	.293
C7	4.380	1.0280	
B8	4.160	1.0174	.642
C8	4.200	.9258	
B9	4.280	1.0506	.533
C9	4.200	.7825	

SD, standard deviation

*Statistically significant change (p value<0,05)

It was observed that people who did not have someone near them in the physical environment were more positive to use the app more often if they had the equipment. For question B6/C6 "I feel healthy" for the age group of 55-69 years there was a significant p value of .035. The specific age group has the ability to socialize with colleagues and family, mobility meaning they have the ability to move for their needs and have more direct contact with technology, meaning they are in better physical condition than the 70 and over group and using virtual reality on a daily basis is not their priority. In question B9/C9 "I am satisfied with everything in my life" there was a

significant p value .049 in the Non-Disability Group with the difference in answers decreasing in the second part of the questionnaire. We believe this is justified because after using the application, a reflection was made on the expectations they had set in the first part of the questionnaire, with the result that they recalled memories from their young years and upon completion of the application came to the present day and came into contact with the present day difficulties they may face due to age.

Table 6.4: Mean, Standard Deviations of the mean number of participants and the results of the non-parametric Wilcoxon Sign Rank Test with regard to the participants between Groups 55-69 years and 70-79 years old (N = 50).

Question	Group 55-69 years			Group 70-79 + years		
	Mean	SD	p Value	Mean	SD	p Value
B1	3.556	1.5525	.501	2.652	1.5843	**.022***
C1	3.370	1.3629		3.565	1.5616	
B2	4.741	.8590	.157	2.261	1.5141	.317
C2	4.815	.7863		3.826	1.2668	
B3	1.333	.8321	.180	2.565	1.5616	.206
C3	1.222	.5064		3.217	1.4446	
B4	4.852	.4560	.317	3.957	1.0651	1.000
C4	4.741	.5257		3.783	.9980	
B5	3.704	1.4627	**.033***	3.913	1.2400	**.000***
C5	4.185	1.1107		3.130	1.7659	
B6	4.000	1.1767	**.035***	3.652	1.5258	.951
C6	4.259	1.1959		2.522	1.5917	
B7	4.519	1.0874	.157	3.826	1.3702	.541
C7	4.593	1.0834		4.348	.8317	
B8	4.481	.9352	.655	3.217	1.6225	.405
C8	4.444	.8473		4.130	.9197	
B9	4.593	.7473	.206	3.913	.9493	.943
C9	4.444	.6980		3.913	.7928	

SD, standard deviation

***Statistically significant change (p value<0,05)**

Table 6.5: Mean, Standard Deviations of the mean number of participants and the results of the non-parametric Wilcoxon Sign Rank Test with regard to the participants between Groups of Non- Retired and Retired (N = 50).

Question	Non retired Group			Retired Group		
	Mean	**SD**	**p Value**	**Mean**	**SD**	**p Value**
B1	3.583	1.6214	.457	3.000	1.6108	.161
C1	3.250	1.2154		3.263	1.6552	
B2	5.000	.0000	. 1.000	3.947	1.4695	.102
C2	5.000	.0000		4.053	1.4322	
B3	1.000	.0000	1.000	2.000	1.3755	.796
C3	1.000	.0000		2.079	1.4023	
B4	5.000	.0000	.317	4.184	1.1355	.712
C4	4.917	.2887		4.132	1.1894	
B5	3.583	1.6214	**.025***	3.053	1.5930	**.000***
C5	4.417	.9003		4.211	1.0176	
B6	4.583	.5149	**.** 083	3.342	1.4003	.470
C6	4.833	.3892		3.447	1.5544	
B7	4.667	.4924	.157	4.132	1.2119	.541
C7	4.833	.3892		4.237	1.1255	
B8	4.750	.4523	.157	3.974	1.0777	.317
C8	4.583	.5149		4.079	.9968	
B9	4.917	.2887	.102	4.079	1.1242	.839
C9	4.583	.5149		4.079	.8181	

SD, standard deviation

***Statistically significant change (p value<0,05)**

Table 6.6: Mean, Standard Deviations of the mean number of participants and the results of the non-parametric Wilcoxon Sign Rank Test with regard to the participants between Groups of Disability and non-Disability (N = 50).

Question	Disability Group			Non- Disability Group		
	Mean	**SD**	**p Value**	**Mean**	**SD**	**p Value**
B1	2.929	1.5915	.204	3.222	1.6408	.931
C1	3.286	1.6375		3.250	1.5376	
B2	3.214	1.8051	.317	4.583	.9063	.180
C2	3.286	1.8157		4.667	.7928	
B3	2.214	1.5281	.655	1.583	1.1307	. 1.000
C3	2.286	1.6375		1.639	1.1251	
B4	4.214	1.1217	.096	4.444	1.0266	.557
C4	3.857	1.3506		4.500	.9411	
B5	2.786	1.6257	**.014***	3.333	1.5856	**.000***
C5	4.000	1.1767		4.361	.8993	
B6	2.357	1.1507	**.**720	4.139	1.0731	.096
C6	2.500	1.6053		4.278	1.1113	
B7	4.571	.7559	.083	4.139	1.1989	.084
C7	4.357	.7449		4.389	1.1283	
B8	3.500	1.2860	.317	4.417	.7700	.739
C8	3.714	1.2044		4.389	.7281	
B9	3.714	1.3828	.276	4.500	.8106	**.049***
C9	4.071	.7300		4.250	.8062	

SD, standard deviation

***Statistically significant change (p value<0,05)**

According to the results of the part C of questionnaire (see Table 6.7), it is observed that questions referring to the overall usability of the system (questions C11, C13 and C14) had the highest scores. In particular, the users seem to have found the application easy to use, they were satisfied with the audio instructions where they were helpful and the interaction in relation to navigating the space was sufficient. At the same time, it seems that users are willing to use this application according to the answer to question C15 with an average of 3.64. A total score from a scale of 1 to 5 in question C18 was 3.88 where they seem to be satisfied overall.

Table 6.7: Mean, Standard Deviations of the mean number of participants (N = 50) from part C of questionnaire.

Question	Mean Score	Standard Deviation
C10	2.9	1.3439206
C11	4.64	0.72167605
C12	2.3	1.6567734
C13	4.46	0.70595138
C14	4.46	.95211901
C15	3.64	1.4674704
C16	3.34	1.6612019
C17	3.04	1.5902766
C18	3.88	1.0028531

6.6.4 Qualitative Results

During the interviews/observations participants expressed several interesting views regarding the application. There were participants where recounting their youthful memories evoked feelings of emotion, joy, nostalgia, and sadness. In particular, the oldest participant, who was 100 years old with excellent mental perception and vision, mentioned that such an application would make him forget the daily life of living in the rehabilitation house and felt a thrill to be able to see again and discuss photos from his home town. There were also people who stated that they would like to use this app frequently and select different photographs every time they use it. It was also observed

that some participants living in rehabilitation houses were reluctant towards virtual reality technology as most of them did not have compatible smartphones and did not want to learn anything new about technology. Overall based on user feedback it seems that users were positive towards the first contact with VR and if they had the equipment they would like to use it again.

As for the observation during the use of the application by the participants, it appears that several users had difficulty seeing clearly due to the low cost of the headset. However, most were unaware of this and continued with the evaluation, while a very small number of users reported it as an unpleasant experience at first. It was also observed that the users were free to move their head without having any further questions during the evaluation. This tells us that they felt immersed and wanted to discover more through the new virtual reality experience.

For the analysis of the interviews the most frequent keywords/phrases mentioned by the participants were registered (see Table 6.8), the most frequently mentioned keyword is “They don't feel lonely in everyday life (26/50 participants)” hence for most participants it was not necessary to use the VR applications as a means of compacting loneness. In particular, most people mentioned that at their current age, they have family close to them (spouses, children, and grandchildren) and prefer to socialize with them instead of using virtual reality. The keyword "Useful for people who feel alone (21/50)" comes in second place implying that although most users believe that it is not necessary for them to you the application, they realize the importance of the application for older people who live alone and don't have someone to talk to. Several positive keywords related to the application such as “Easy to use” (18/50), “Nice Interface” (17/50), “VR Positive” (17/50), and “immersion” (16/50) was registered indicating the acceptance of the users towards the design and functionality of the application. Also, some users reported that they found it enjoyable that there was a virtual audience because it encouraged them to start the storytelling. Examples of negative keywords registered are “blurred vision” (15/50) which concerns both the quality of the equipment and the reduced vision of the participants due to age, "VR Negative (13/50)" and "Not interested in VR (9/50)" where it was mostly from people who are not interested in using virtual reality since they prefer to socialize with their family members. Finally, the last keyword was "Feeling

lonely (8/50)" where elderly people who may live in nursing homes or live alone reported feeling lonely and would like someone to talk to.

Table 6.8: Results of the most frequently positive and negative encountered keywords/phases.

	Keywords /Phrases	Participants
Positive	1. VR Positive	17/50
	2. Useful for people who feel alone	21/50
	3. Easy to use	18/50
	4. Immersion	16/50
	5. Nice Interface	17/50
Negative	6. VR Negative	13/50
	7. Blurred vision	15/50
	8. Not interested in VR	9/50
	9. They don't feel lonely in everyday life	26/50
	10. Feeling lonely	8/50

6.7 Discussion

According to the quantitative and qualitative results obtained by exposing elderly users to a memory recalling storytelling VR application, it is observed that elderly users believe such an application can be useful for improving their overall wellbeing. An important factor is that they can use the equipment themselves so that they do not need the support of another person in contrast to the work of Luijkx et al., (2015) where it mentions the involvement of the whole family for the use of a virtual application. Based on the research questions posed the following conclusions are reached:

RQ1: *Are elderly people willing to use the proposed storytelling virtual reality application?*

From both the qualitative and quantitative results, it was observed that the majority of the elder users are willing to use the virtual reality application. This is especially true for the participants' group of 70-79 + years, who mention that would be interested in using a VR application in their daily lives to socialize with other people. However, a percentage of the users expressed their unwillingness to use the VR application due to

their lack of knowledge of new technologies (Baker et al., 2020). We believe that if elder people are provided with training towards the use of new technologies (Bauer and Andringa, 2020), the acceptance of elderly users for VR technology (Shao and Lee, 2020) will be increased.

RQ2: *Do elderly people believe that the proposed VR application can help to overcome feelings of loneliness and improve wellbeing?*

Elderly believed that the specific application can indeed reduce the feeling of loneliness felt by the elderly. In particular, they mentioned that through the application they forget that they are in the real environment and it motivated them to start the narratives in the virtual audience. We believe that two characteristics of the application contributed to this observation. Firstly, the ability to enter a storytelling experience (Langellier and Peterson, 2011), and secondly the presence of the virtual audience that motivated further the users to start the storytelling according to the interviews. Since storytelling is among the favorite activities for elderly (Scott and DeBrew, 2009), storytelling in a VR environment proved to be a feasible alternative when direct contact with a real audience is not feasible.

Most users had positive feelings during the use of the application. This is in line with the observation of other researchers (Seabrook et al., 2020) who mention that after the use of VR application increased positive affect and mindfulness. Overall, even the people who said that they would not like to use the application at this time because they do not think it is necessary either because of their age or because they have people close to them in their family environment, said that it will be useful and enjoyable for people who they feel alone to escape their loneliness (Van Houwelingen-Snippe et al., 2021).

6.8 Concluding Comments

The aim of the present research was to study whether elder people believe that the proposed virtual reality application could help the elderly cope with feelings of loneliness and social isolation. For this purpose, the final application designed according to the results derived from the previous phases of the research, was evaluated by members of the target user group. Through the use of the application, the factors that influence users on how receptive they are to a new application were also studied. As a

general picture, it can be noted that users are positive towards this technology but would like to use it only when they really need it, that is, when they feel lonely and would like to have someone to talk to. More importantly, elder users believe that the use of this application can help them to improve their wellbeing, and definitely this is an important finding that can guide future work in developing VR-applications for the elderly. Certainly, there are many parameters that should be studied and modified in the future but as a general picture we have received positive results in the relationship of the elderly and the use of virtual reality. This observation, can be highly bemeficial for future efforts in designing and using elderly friendly VR applications.

Chapter 7: Conclusions and Future Work

This chapter presents the conclusions derived from the findings of this dissertation. Moreover, the chapter presents the contribution of the research and the limitations that were encountered during the process. Furthermore, it presents the future direction of this work and new research ideas and techniques that could be used in future applications.

7.1 Summary - General Description

This thesis aimed to evaluate the potential of exploiting the use of contemporary technologies, in the form of virtual reality, by elderly users. More specifically the aim of the work was to provide an elderly friendly application, and investigate the acceptance of the application, and whether elderly users regard such applications beneficial for their overall wellbeing. Among different contemporary technologies, VR was chosen because its transformative power allows people to see other people's perspectives or transport them to imaginary places and scenarios where they can learn and take the place of another person but and find themselves in imaginary places where they would not have the possibility to visit in real life. These aspects make it a medium that can help in trying to change life attitudes by offering innovative and original experiences.

As part of the work described a five-phase design process was adopted. During the first phase a literature work (Chapter 2) concerning the most common characteristics of the physical and mental condition of elders, allowing the readers to understand the main difficulties faced by elder users of Virtual and Augmented Reality was completed. Definitions of Virtual and Augmented Reality applications were presented also. Furthermore, a review of Virtual and Augmented Reality technologies that target the elderly population, with emphasis on applications that target users suffering from dementia, and applications that aim to compact social isolation, especially concerning the recent COVID-19 pandemic was completed.

During Phase II (Chapter 3) three preliminary experiments that aimed to assess the willingness of elder users to use virtual and augmented reality technologies and derive conclusions related to the main issues that attract or deter elder users from using those technologies were carried out. The experiments were performed with groups of seniors to get results on the relationship they have with virtual and augmented reality technologies through evaluation of questionnaires and through the use of dedicated VR and AR applications.

During Phase III (Chapter 4) the design and development of a prototype Virtual Reality tool that allows elderly users to deal with the problems of social isolation, while providing an entertaining brain-triggering activity. An initial user evaluation provided

information related to the strengths and limitations of the prototype application that guided the process of optimizing the application for elderly users.

Phase IV (Chapter 5) was concerned with the refining of design elements of the prototype application as emerged by the outcome of the preliminary evaluation. Several design elements were refined through a questionnaire-based data gathering process, where participants rated different design options for the final application. Among other elements, the optimum characteristic of the virtual audience, and the desirable type of visual stimuli were determined.

During Phase V (Chapter 6), the final application was developed and evaluated by members of the target population, so that conclusions related to the effectiveness of the application were derived. The individual conclusions of each experiment were presented in the respective sections.

In this section, we will summarize the conclusions drawn from the whole of this study, in conjunction with research questions raised.

7.2 Research Findings

The aim of this dissertation was to provide elderly people with a user-friendly and enjoyable VR application that incorporates memory recall and storytelling activities that could promote mental awareness in an attempt to contribute in preventing so that negative side effects associated with brain inactivity. An important aspect of the proposed VR application is the presence of a virtual audience that listens to the stories presented by elderly users and interacts with the user, motivating in that way users to engage in a storytelling activity that is treasured by most elder people (Charise et al., 2022).

As part of the work carried out, a number of secondary research questions related to the relationship of the elderly with VR technology, what factors prevent them from using such technology, and whether they are willing to use the virtual reality application were addressed. Eventually, the main research questions that constitute the fundamental core of this thesis research project were answered as described below:

RQ1: *Are elderly users willing to use Virtual Reality applications?*

Regarding the intention of the elderly to use virtual reality, the findings of this thesis showed that there is an interest on the part of the elderly and they are willing to include virtual reality in their lives. In particular, a large percentage is positive and willing to use this kind of application in their daily life through proper information from an expert. In addition, another group of elderly people seems to be willing to use such an application in their daily life but in a future phase where they will feel lonelier since they consider it a way to escape from the loneliness of everyday life through the socialization of other people in the virtual environment.

However, a percentage of users expressed their reluctance to use the VR application due to their lack of knowledge of new technologies. To solve this problem, the elderly can be provided with training on the use of new technologies, so that the acceptance of elderly users for VR technology can increase.

Previous research by Lai et al. (2019) mention in their results that that participants had more positive valence and higher arousal of emotion when they were playing the VR application, especially applications related to tourism and easy-to-play games was favored by the elderly. Based on these reports it was indeed observed that the elderly people who did the evaluations in our experiments were happy about the simplicity that the application offered them since they did not feel pressured how to handle a complex application through a specific learning process.

Healy et al., (2022) mention that key features of immersive VR can assist older adults in their everyday lives, providing opportunities for health promotion and tackling social isolation and loneliness. Based on this research, we aim, through the use of virtual reality, to offer the elderly a better quality of life by integrating them into society so that they do not feel isolated but can also have a more pleasant quality of life.

With technological advancements, people now have the option to utilize virtual reality for home workouts, freeing them from outdoor limitations and weather concerns. Moreover, these virtual activities offer greater accessibility compared to traditional leisure pursuits. Among older adults, the ease of use, utility, safety, flexibility, and enjoyment of such experiences notably impact their overall experience and intention to

continue participating (Yeh et al., 2019). Based on our own conclusions obtained in phase 2 (Chapter 3) we conclude that it is a driving force for the elderly and the subject of the application they will use to interest them and attract their attention.

RQ2: *Do elderly people believe that Virtual Reality can help to increase their well-being?*

Through our research elderly believed that VR application can indeed contribute in reducing the feeling of loneliness. The main characteristics of the application that contributed to this observation were firstly, the ability to enter a storytelling experience, and secondly the presence of the virtual audience that motivated furthers the users to start the storytelling. It's important to mention that storytelling in a VR environment proved to be a feasible alternative when direct contact with a real audience is not feasible, as happens most of the time in the specific target group due to reduced mobility encountered in the elderly population.

Innovative technologies like video games, augmented reality, and virtual reality offer a means to alleviate the monotony often associated with repetitive exercises necessary for older adults. They also offer real-time feedback on movements, enhancing both the quantity and quality of rehabilitation efforts (Zhang et al., 2026). Previous research by Lee et al. (2019) mention that social isolation continues to be a significant issue for older adults, but the appropriate content to increase their social wellbeing is insufficient, although many commercial products have been developed. This is mainly because applications that target the needs of the elderly are not widespread yet. Through a research process where the main concern is to fulfill the needs of the elderly population, the work carried out in this thesis indicates that elderly users believe that a dedicated virtual reality application could potentially contribute to reducing the effects of social isolation, contributing in that way to the wellbeing of the elderly population.

Hassandra et al. (2021) mention that ensuring an independent and healthy lifestyle for the aging population across developed countries has become a key social issue and a global public health priority. To achieve a society where the elderly will not feel isolated we must target and listen to their needs. Through our research it was observed that the virtual reality application really helps people who feel socially isolated whether they are alone at home or in a nursing home since through the application they can get

in touch with virtual people and start telling memories reducing the feeling of loneliness.

7.3 Contributions

From a methodological and technical point of view, the contribution of the present research work lies in the introduction of a new approach for the design and use of virtual reality that offers the elderly the possibility of storytelling and reducing the feeling of social isolation. In addition, the research contributed to the enhancement of existing knowledge through the multi-phase co-design methodology adopted for the design of the elderly-friendly VR application. Also, our research contribute through the design factors considered for making user-friendly VR apps and the actual end application that offers a simple and effective way to get elder people to use the VR application.

Previous research by Ijaz et al., (2022) that has been done emphasizes that a well-designed application has been linked to positive user emotions, taking into account the dynamics, time and situation of the experience. Additionally, older adults who are internet savvy are reported to be willing to use VR technology. Older adults rate VR experiences positively in terms of enjoyment and satisfaction. However, they emphasize that best practices and guidelines for designing VR applications for older adults are scarce despite the variability of abilities and interests. Such guidelines can help designers consider the entire spectrum of older people, increasing accessibility to those who might otherwise be left out. It should be noted that apart from the literature review and the evaluation experiments, a significant part of the effort in this work was devoted to the actual implementation of the applications used as part of the experiments described in this thesis. The work described in this thesis, capitalizes on the work presented by Ijaz et al., (2022) through the design of a simple and user-friendly application that fulfills the requirements of the elderly population.

The findings of this thesis have highlighted some design guidelines that have been shown to be effective in changing attitudes and can be recommended to the academic community to achieve similar research objectives in future studies. The recommended guidelines are:

1) Simplicity: An important element in the application is the simplicity of the virtual environment which emphasizes a relaxing atmosphere with only the absolutely necessary elements in the environment. In this way, the user remains focused on his goal, causing him positive emotions in the virtual reality experience.

2) Ease of use: Placing the participants' first point of view helped users feel immersed even if they couldn't see their 3D avatar, therefore it is an important element that can be used in future research. In addition, the fact that there was an easy transition to the point and the limited movements that the user had helped him not to get dizzy when transporting to the point but also not to get lost in the virtual space and cause negative associations.

3) Scenario: By providing the user with a simple and understandable scenario we helped them to feel safe and know what to do in every move. In addition, it was found that the use of virtual reality made participants want to use it as they were in a calm and relaxing environment that took them out of the routine of real life.

4) Interact with a virtual audience: Important to participants' narrative initiation was the presence of a virtual audience that offered the possibility of having an audience for their narratives. As we mentioned above, the presence of the virtual audience offers users motivation to continue the narrative where it offers them positive experiences. Given that a significant amount of elder people require companion, the presence of a virtual audience seems to provide a way to avoid the effects of social isolation.

5) Connecting visual stimuli with previous experiences: Finally, by providing users with the connection of visual stimuli through the photos presented in the app, and references from past experiences, it provides the user with the ability to recapture memories that they may think have been forgotten. According to the research of Kosti et al., (2024) these findings are consistent with the design requirement related to the type of photos, as elderly users want customized content to appear in the VR application, where in our case it is photographs.

6) Audio Guidance: Finally, the element that seems to have helped older users while navigating VR is the audio guidance. With this feature, the user does not rely on his vision, which may be impaired due to age, to follow the instructions and thus has a more useful and positive experience.

Apart for technical contributions of this thesis, we believe that the most important contribution of this work is the social service provided to the elderly through the development of an easy-to-use tool, which according to users can have many benefits. The main benefits it offers are the ease of use, the design guidelines we mentioned above and finally the pleasant experience it provides to the user to motivate them to want to use such an application. Hence, the social impact of this work should contribute to the efforts of supporting the elderly simulation, leading to an overall upgrade of modern societies.

Aiming to contribute to the overall effort of making VR accessible to the elderly, parts of the work described in this thesis was published/ presented in different venues in order to promote work in this discipline. The following publications were derived:

- Anastasiadou Z., Lanitis A., & Zavlanou C., (2016, November). Towards the Design of Interactive Elderly-Friendly Pharmaceutical Packaging, Womenpower Symposium, Limassol, CY.
- Anastasiadou, Z. (2016). Development of an interactive application for the understanding of information in medicinal packaging (Master's Thesis). Cyprus University of Technology, Limassol
- Anastasiadou, Z., & Lanitis, A. (2021, July). Assessing the Willingness of Elder Users in Using Virtual and Augmented Reality Technologies. In ACHI: The Fourteenth International Conference on Advances in Computer-Human Interactions (pp. 77-82).
- Anastasiadou, Z., & Lanitis, A. (2022). Development and Evaluation of a Prototype VR Application for the Elderly, that can Help to Prevent Effects Related to Social Isolation. 2022 International Conference on Interactive Media, Smart Systems and Emerging Technologies (IMET). https://doi.org/10.1109/imet54801.2022.9930049
- Anastasiadou, Z., & Lanitis, A. (2023). Determining Optimum Audience for Storytelling VR Applications for the Elderly. 36th International Conference on Computer Animation and Social Agents (CASA 2023).
- Anastasiadou, Z., Dimitriadou, E., & Lanitis, A. (2024). Design and Evaluation of a Memory-Recalling Virtual Reality Application for Elderly Users. Multimodal Technologies and Interaction, 8(3), 24.

7.4 Plans for Future Work

The work described in this thesis can be expanded in several ways. In this section a discussion of the plans of possible future research directions is presented.

Based on feedback that was received by participants during the studies, the development of new scenarios, and the expansion of the current ones is definitely a future priority. More specifically, according to the needs of the users, in the future we plan to provide more customization options of the application, so that users can select dynamically the type of the photos which are presented in the virtual environment by uploading their favorite photos. Furthermore, users will have the opportunity to change the landscape of the virtual environment and the soundtrack so that each user can experience the application in his/her optimum environment. It's important to mention in this point, that the main value of the work is not the application itself, but the knowledge gained in terms of the design guidelines that can influence the efforts of designing user-friendly VR applications.

Bearing in mind, that the most significant parts of this research effort were carried out during the COVID-19 pandemic that limited the accessibility of volunteers from the target age group, the number of volunteers who took part in the experiments could have been higher. In the future we plan to stage extended evaluations of the proposed application, so that more thorough and accurate conclusions related to the adoption of the application can be derived. In order to achieve the optimal result of the application, in the future users should provide continuous feedback on the improvements of the application after using it in an immersive model so that through frequent evaluations the needs of the users are met and any weaknesses are identified.

In the future, we also plan to explore the possibilities offered by technology to empower the virtual audience through AI to support dynamic interaction with the users (Li et al., 2024). This can provide more realistic user interactions, improving the fidelity of the virtual audience. However, given that speech recognition can be affected by different accents (Tatman and Kasten, 2017), the use of dynamic interaction may be obstructed by the availability of accurate speech recognition engines, the use of dynamic interaction may be obstructed by the availability of accurate speech recognition engines, especially when dealing with elder users who speak only a local language (i.e. Greek)

with specific accent. In general, in the modern interconnected global landscape, the variety of languages presents obstacles to effective communication, especially evident in virtual gatherings. Real-time speech-to-speech translation for virtual meetings Karunya et al., (2023) could present a solution to this problem.

In addition, another element that we can study and include in future plans for our research is the provision of game based -rewards based on the quality of storytelling provided by the users. As part of this, and in line with previous research on body language assessment (Dimitriadou et al., 2023) a system that assesses the body language of the users can be incorporated so that rewards are given to users who engage in high quality storytelling activities, providing in that way incentives for engaging in high quality storytelling.

Finally, in the future the possibility of adopting a multi-user VR environment will be investigated. Advancements in multi-user display and tracking technologies have enabled traditional projection-based immersive setups to accommodate group immersion for co-located users, providing each individual with personalized stereoscopic views while minimizing visual distortions (Chen, 2015). In this way we will be able to compare in the future the storytelling experience between virtual audience and real audience via teleconferencing. As part of this comparison we aim to compare the reactions of users to storytelling in from of a real and virtual audience.

7.5 General Conclusion

In conclusion, this research presents a systematic approach to the design of an elderly-friendly virtual reality storytelling application. By considering the unique needs and preferences of elderly users, such as accessibility, ease of use, and engaging content, the developed application aims to enhance their overall experience with virtual reality technology. Through a combination of user-centered design principles, iterative prototyping, and usability testing, the application's interface and interaction mechanisms have been tailored to cater to the cognitive and physical capabilities of older adults, promoting inclusivity and usability.

Furthermore, the findings of this research highlight the potential of virtual reality storytelling as a valuable tool for promoting cognitive stimulation, social interaction, and emotional well-being among elderly individuals. By immersing users in rich narrative experiences that are specifically designed to resonate with their interests and life experiences, virtual reality storytelling has the capacity to foster a sense of connection, nostalgia, and empowerment in older adults. Moving forward, continued research and development in this area can further refine the design principles and content creation strategies for elderly-friendly virtual reality applications, ultimately contributing to the improvement of elderly care and quality of life.

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APPENDIX I

Questionnaire used for the Evaluation of a pilot augmented reality application by elderly users (Chapter 3, Section 3.3):

Part A		
Age:		
Gender:		
Medical Condition(Select below):		
• None	• Heart disease	• Cholesterol
• Thyroid disease	• High blood pressure	• Bone and joint problems
• Cancer	• Diabetes	• Kidney disease
• Lung disease	• Liver disease	• Other
Medicines:		
• Prescription drugs	• Vitamins	• Natural health products (Organic)
• Administering medications for others		
The highest level of education:		
• High school	• University	•Postgraduate
Computer use:		
• Daily	• Weekly	

• Monthly	• Rarely
Tablet use:	
• Daily	• Weekly
• Monthly	• Rarely
Smartphone use:	
• Daily	• Weekly
• Monthly	• Rarely
Part B Please select: Strongly Disagree (1) – Strongly Agree (5)	
1. The overall reaction to the application has been satisfactory	
2.It was difficult to read characters on the screen	
3.The app's information organization was clear	
4. The text in the app was easy to read	
5. It was easy to remember the information displayed on the screen	
6. Performing actions in the application was complex	
7. The application is designed to meet the needs of users	
8. I was able to quickly complete tasks and scripts using the app.	

9. The information contained in the application is clear.	
10. I would like to use the application in my daily life.	
11. What reasons would make you use such an application:	
Functionality	
Ease of use	
Aesthetically pleasing interface	
Cost	
Number of existing users	
User reviews	

Questionnaire used for the Evaluation of the use of a virtual reality application by the elderly (Chapter 3, Section 3.4):

Part A	
A1. Age:	
A2. Gender:	
A3. Do you have any Medical Condition: YES / NO	
A4. A4. If you answer yes, do you use drugs: YES / NO	
A5. I have used a virtual reality (VR) application again : YES / NO	
If you answer yes, with which device:	
Part B	
B. Please complete the following according to the following: 5 = I ABSOLUTELY AGREE, 4 = I AGREE, 3 = NEUTRAL OPINION, 2 = I DISAGREE, 1 = I ABSOLUTELY DISAGREE.	
B1. I believe that VR applications are intended for entertainment. B 2. I believe that using VR can improve my daily life. B3. I believe that I can integrate the use of VR in my daily routine. B4. I would like to use the VR to practice on health issues. B5. I think the VR is useful for older people.	
PART C (After the use of VR application	
C. After you have completed your navigation in the virtual space please fill	

in the following according to the following: 5 = I ABSOLUTELY AGREE, 4 = I AGREE, 3 = NEUTRAL VIEW, 2 = I DISAGREE, 1 = I ABSOLUTELY DISAGREE
C1. It was easy for me to navigate the VR area. C2. My experience with the VR was enjoyable. C3. I believe that I have learned about the resuscitation position (RECOVERY POSITION) and I can apply them in my life. C4. The experience in the VR makes me dizzy. C5. I had a hard time figuring out what to do. C6. I managed to complete the process. C7. I would like to use the VR to practice on health issues. C8. I think the VR is useful for older people.
D1. Mention 3 computer or mobile applications that are used in your daily life:
Application 1: Application 2: Application 3:
D2. Note if you would like the specific applications mentioned above to be in VR. Please complete the following according to the following: 5 = I ABSOLUTELY AGREE, 4 = I AGREE, 3 = NEUTRAL OPINION, 2 = I DISAGREE, 1 = I ABSOLUTELY DISAGREE.

Application 1: Application 2: Application 3:
D3. What would you like to change in the way you interact about the VR?
D4. What applications would you be interested in having in the VR? Please complete the following according to the following: 5 = I ABSOLUTELY AGREE, 4 = I AGREE, 3 = NEUTRAL OPINION, 2 = I DISAGREE, 1 = I ABSOLUTELY DISAGREE.
Sport : Health : Entertainment : News : Education :
D5. What elements would you like to improve to use the AR? Please complete the following according to the following: 5 = I ABSOLUTELY AGREE, 4 = I AGREE, 3 = NEUTRAL OPINION, 2 = I DISAGREE, 1 = I ABSOLUTELY DISAGREE.
Cost: Interface (Design): Interaction:

Equipment: Quality: Other:
D6. Would you be interested if you had the opportunity to attend training seminars to find out what the VR offers? YES / NO

APPENDIX II

Short Version of the User Experience Questionnaire (UEQ-S) used for experiment in Chapter 4:

attractive	o o o o o o o o	supportive
complicated	o o o o o o o o	easy
insufficient	o o o o o o o o	sufficient
confused	o o o o o o o o	clear
boring	o o o o o o o o	exciting
indifferent	o o o o o o o o	interesting
conventional	o o o o o o o o	inventive
ordinary	o o o o o o o o	pioneer

APPENDIX III

Questionnaire used for the evaluation of the pilot VR application (Chapter 5):

Dear Sir/Madam,

As part of my doctoral thesis, I am asked to collect data through this research. This research studies the relationship between the emotions and behaviors of teenagers, with the ultimate goal of enhancing their mental well-being. The process is simple, answering the questionnaire online. It takes about 5 to 10 minutes and is completed anonymously. A necessary condition for participation is that each participant has electronically signed the information and consent form.

In case you need more information about this research, or would like to know the results of this research, please contact the researcher at zx.anastasiadou@edu.cut.ac.cy.

Thank you in advance for your valuable input.

If you wish to participate in the study, you give your consent by ticking the box below.

I understand that my participation is voluntary and that I can withdraw at any time without giving any reason.

I agree to take part in the research in question and to be evaluated on the data provided.

Sign: _____

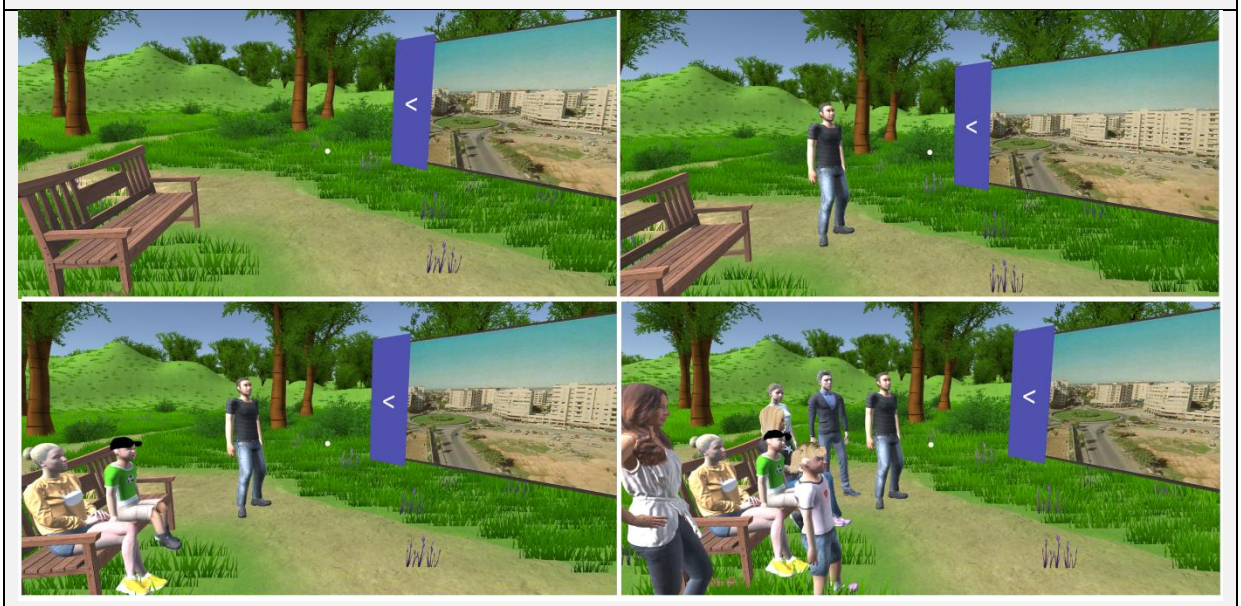
PART A	
Gender	
Female	Male
Age	
18-25	26-45
46-59	60-69
70+	
Capacity	
Retired	VR Expert
Other:	
1. 1 Do you have previous experience with Virtual Reality?	
Strongly Disagree	
Disagree	
Undecided	
Agree	
Strongly Agree	
PART B	
Through Virtual Reality we have created an application where the user will feel that he is in a virtual space (you can see an example of the application here: https://youtu.be/DWJLhZCvGdI). The purpose of the application is to present the	

user with some photos on a sign, and for the user to be able to describe the photo to a virtual audience.

When starting the application, the user sees in front of him a sign with instructions and by pressing the arrows right and left he can see the photos that exist. There is also an audience in the space as you can see below.

The ultimate goal is to create a fun application to combat loneliness.

Regarding the proposed application, please answer the questions below.



1.2 According to the description above, do you find such an application

interesting/useful for the elderly?	
Strongly Disagree	
Disagree	
Undecided	
Agree	
Strongly Agree	
2.You would feel more comfortable telling a story to a virtual audience where:	
Strongly Disagree / Disagree/ Undecided / Agree / Strongly Agree	
2.1 The audience consists of adults	
2.2 The audience consists of children	
2.3 The audience consists of adults and children	
2.4 There would be no audience	
2.5 There would be 1-3 people in the audience	
2.6 There would be 4-7 people in the audience	
2.7 There would be more than 8 people in the audience	
2.8 The audience would engage each other with hand gestures	

2.9 The audience would respond with various expressions	
2.10 The audience would aurally reciprocate	
3.Would you like the photos in the app to be:	
Strongly Disagree / Disagree/ Undecided / Agree / Strongly Agree	
3.1 Photos of the last decade (2010-Today)	
3.2 Photos from the decades 1990-2010	
3.3 Photos from the 1970s-1990s	
3.4 Your personal photos (people/landscapes, etc.)	
3.5 Photos depicting landscapes of Cyprus	
3.6 Photos that the user can upload	
3.7 Designated photos within the app	
4. How much time would you like to spend on each photo? Please select between: 1 /2 /3/ 4/ 5	
5. How many photos would you prefer to have in the app? Select between: 1 / 2/ 3/ 4/ 5	

APPENDIX IV

Questionnaire used for the evaluation of the final application (Chapter 6):

RESEARCH INFORMATION FORM

Dear participants,

You are invited to participate in the research being conducted as part of my doctoral thesis at the Department of Multimedia and Graphic Arts of the Cyprus University of Technology.

The purpose of the present research is to provide the elderly with a user-friendly Virtual Reality application that incorporates activities to promote their well-being. As part of this effort, a prototype VR application was developed that allows users to participate in a storytelling activity. In an effort to optimize the application, we consider design factors to improve the user experience thereby providing a more enjoyable and rewarding activity.

For this purpose, you will be asked to fill in the first part of a questionnaire before using the application and then when you finish using the application you will answer the second part of the questionnaire by discussing some open-ended questions with the researcher. It is expected that your participation in the survey will last approximately 30 minutes.

The survey is anonymous and the answers to the questionnaires and interviews will be used exclusively for the purposes of this survey, including the necessary methods of recording such as photography and audio recording. No risks arise from your participation in this research.

Your participation is completely voluntary and you can withdraw your participation from the survey at any time without any necessary justification or explanation.

Please make sure you read the research information form carefully before signing the consent form.

Thank you for your response and cooperation.

Yours sincerely,

Zoe Anastasiadou

PhD Student

Department of Multimedia and Graphic Arts

Cyprus University of Technology

Email: Zx.anastasiadou@edu.cut.ac.cy

PARTICIPANT CONSENT FORM

I certify that (please put ✓ in the corresponding box):

1. I have read and fully understood the information about this research.	
2. I have been given the opportunity to ask questions and get complete answers about my work and participation.	
3. My participation is purely voluntary, without monetary reward.	
4. I have the right to withdraw my participation at the beginning, during, at the end of the specific research without any necessary justification and the withdrawal does not include any consequence.	
5. Confidentiality and confidentiality procedures have been analyzed and fully understood (eg use of names, pseudonyms, anonymous data, photos that follow the method of altering/hiding faces or edited photos, etc.).	
6. The publication collection, exchange and data storage process have been fully analyzed and understood.	
8. I fully understand that the information to be given to the researchers, including visual and audio recording methods for the purpose of analysis and possible publication in research articles, will be treated in complete confidentiality with all the conditions I have consented to.	
9. Understanding the above conditions and after consultation with the Researcher, I agree and sign the participation consent form.	☐

Participant

Signed:
_____

Date:
_____
(MM/DD/YYYY)

Researcher

Signed:
_____

Date:
_____
(MM/DD/YYYY)

PART A

Please answer part A of the questionnaire BEFORE using the virtual reality application.

Mark what applies:
Gender: Male / Female
Age: 55-59 / 60-65 / 66-69 / 70-75 / 76+
Professional Status: Employed / Retired / Other:
Do you have a long-term illness, health problem or disability that limits your daily activities or the work you can do? Yes / No / I don't know

Mark your answer accordingly: 1= Strongly Disagree, 2= Disagree, 3= Neither Agree/Neither Disagree, 4= Agree, 5= Strongly Agree	1	2	3	4	5
1. Would you be interested in using a virtual reality application in your daily life to socialize with other people, like the one you have used?					
2. There are people I feel close to in the physical and/or virtual environment.					
3. I share my interests and ideas with those around me in the physical and/or virtual environment.					
4. There is no one I can turn to in the physical and/or virtual					

environment.					
5. I can find companionship when I want it in the physical and/or virtual environment.					
6. I don't feel alone.					
7. There are people I can talk to in the physical and/or virtual environment.					
8. Do you think there are virtual reality apps that help you not feel alone?					
9. I don't have fun with other people.					
10. I don't feel particularly healthy.					
11. I don't have particularly pleasant memories from the past.					
12. I am very happy.					
13. I find beauty in some things in my life.					
14. I am satisfied with everything in my life.					

PART B

Please answer part B of the questionnaire AFTER using the virtual reality application.

Mark your answer accordingly: 1= Strongly Disagree, 2= Disagree, 3= Neither Agree/Neither Disagree, 4= Agree, 5= Strongly Agree	1	2	3	4	5
1. Would you be interested in using a virtual reality application in your daily life to socialize with other people, like the one you have used?					
2. There are people I feel close to in the physical and/or virtual environment.					
3. I share my interests and ideas with those around me in the physical and/or virtual environment.					
4. There is no one I can turn to in the physical and/or virtual environment.					
5. I can find companionship when I want it in the physical and/or virtual environment.					
6. I don't feel alone.					
7. There are people I can talk to in the physical and/or virtual environment.					
8. Do you think there are virtual reality apps that help you not feel alone?					
9. I don't have fun with other people.					
10. I don't feel particularly healthy.					
11. I don't have particularly pleasant memories from the past.					
12. I am very happy.					
13. I find beauty in some things in my life.					
14. I am satisfied with everything in my life.					
15. I would like to use this app often.					

16. I found the application unnecessarily complicated.					
17. The app was easy to use.					
18. I thought I would need the support of a technical person to be able to use this application.					
19. Audio instructions were helpful in the application.					
20. The interaction in relation to the switching of photos was sufficient.					
21. Interaction in relation to site navigation was sufficient.					
22. Most people will learn to use this application very quickly.					
23. I found the application very cumbersome to use.					
24. I felt very confident using the app.					
25. I needed to learn a lot of things to be able to continue with this app.					
26. I felt like I was in virtual space.					
27. When using the app it felt like I was only seeing images.					
28. When I was using the app I was completely captivated by the virtual world.					
29. When using the app I still paid attention to the real environment.					
30. When I used the app The virtual world seemed more realistic than the real world.					
31. On a scale of 1 to 5 (1=Poor app, 5=Excellent app) I would rate the app with:					