Augmented Reality Photo Album for People with Dementia

Bachelor Thesis Creative Technology

Jonne Schoneveld

Supervisor: Dr. K.P. Truong

Critical Observer: D.S. Nazareth

July 2020

UNIVERSITY OF TWENTE.

Abstract

This thesis aims to provide insight on and explore how Augmented Reality can engage people with dementia to participate in stimulating activities. The use of Augmented Reality is a fairly new domain, especially compared to Virtual Reality. Inspired by the life story book, Reminiscence Therapy and Multi-Sensory Stimulation treatments, an Augmented Reality photo album prototype has been developed with the aid of dementia experts and extensive iterative design methods. The Augmented Reality photo album is a physical book with an accompanying Android application to see the Augmented Reality content. The prototype is meant as a facilitator for communication between a person with dementia and their caregiver, family member or friend. The prototype aims to evoke more details and elements of a memory and contribute to additional discussion material. Low fidelity prototypes have been tested with experts in the field of dementia; a high fidelity prototype has been tested and evaluated with proxy testers: *i)* healthy elderly (65+) people and *ii)* people who are familiar with a person with dementia. The prototype has shown positive results regarding the use of Augmented Reality as a facilitator for communication for people with dementia.

Acknowledgements

I wish to thank the following people for their time and support invested in completing this thesis.

First of all, I would like to thank my supervisors, Khiet Truong and Deniece Nazareth for their valuable guidance, feedback and support throughout the project.

Next, I would like to thank the CreaTe staff for providing all necessary methods, tools and possibilities to still be able to work on a graduation project during the COVID-19 restrictions.

Finally, I would like to thank my family and friends for their ongoing support during some difficult times.

List of figures

List of tables

Index

List of Abbreviations

AR	Augmented Reality
VR	Virtual Reality
RQ	Research Questions
MSS	Multi-Sensory Stimulation
RT	Reminiscence Therapy
BPSD	Behavioral and Psychological Symptoms in Dementia
MR	Mixed Reality
Hi-Fi	High Fidelity
Lo-Fi	Low Fidelity

1. Introduction

Dementia is a general term for severe chronic brain dysfunctions and influences the brain in such a manner that multiple areas of cognitive functioning are compromised in every-day life [1]. In The Netherlands alone there are over 280.000 people diagnosed with dementia, with the prognosis that this number will rise to half a million in the coming 25 years [2]. The most common cause of dementia is known as Alzheimer's disease. People suffering from dementia experience it in multiple ways and it is affecting their lives differently; in a general sense they have problems with, memory loss, concentration, language and orientation, among other things [3]. These symptoms have a direct influence on the quality of life. Accordingly, many patients with dementia are suffering from depression [4].

There is no cure for dementia, but healthcare solutions can be developed to reduce and help with the symptoms. Widely implemented intervention techniques have been developed to reduce and cope with the symptoms, i.e. Reminiscence Therapy (RT) and Multi-Sensory Stimulation (MSS) techniques, to name a few. By making use of assistive technology, these interventions may be complemented, more personalized and/or better suited to function for people with dementia.

One potential effective assistive technology is Augmented Reality (AR). The more popular *Mixed Reality* (MR) counterpart, Virtual Reality (VR), has been more widely adopted in healthcare solutions. One of the reasons is that AR is viewed as more complicated and difficult to implement and design with. However, AR technology is getting more and more traction within the healthcare sector, as well on the consumer market, which makes it more accessible for wide implementation. Nonetheless, the amount of the AR solutions for people with dementia is limited and mainly focussed on prompting tools, i.e. live instruction to perform actions or to indicate what certain objects are.

This research explores how AR can be used as assistive technology for people with dementia. More specifically, this research aims to provide insight on using AR technology to stimulate people with dementia in an active way by developing an AR prototype. Research shows positive effects of activity on reducing agitation and engendering a sense of well-being in people with dementia [5], [6]. In addition, Participation in activities is important for stimulating and maintaining cognitive and social skills [7]. Furthermore, finding safe, stimulating activities that engage people at all stages of dementia are beneficial not only to them but also to their caregivers [8]. Before developing a prototype, it is important to review which interactive stimulating activities are relevant and what design guidelines are important to keep in mind for designing an AR solution for people with dementia.

Some challenges are expected when designing such a prototype. Dementia is experienced in various ways, which makes it complicated to use a broad solution that will work for every patient [9].

This means that something needs to be developed that can provide a personal experience per patient. Dementia is also more common among elderly people, therefore it is important that the technology is not too obtrusive and should be easy to comprehend [10]. By making use of a theoretical framework, consisting of a literature review and a state-of-the-art research, a concept will be proposed through extensive ideation and iteration. This concept consists of an interactive prototype to engage patients with dementia in a meaningful way, by making use of Augmented Reality technology.

The following questions will be answered:

- *How can Augmented Reality engage people with dementia to participate in stimulating activities?*
    - *Which interactive stimulating activities are relevant and appropriate with AR?*
    - *Which design guidelines are important for enhancing the user experience by making use of AR for people with dementia?*

2. Literature Review

This section covers multiple aspects that are relevant to provide answers to the research questions. A literature review will be conducted to gain insight on dementia, its symptoms and current approaches to reduce and cope with these symptoms. Further, the implementation of AR for people with dementia will be explored. Secondly, in the State-of-the-Art section, an overview of existing products and solutions will be given. Finally, interesting findings from the literature review and State-of-the-Art research will be discussed.

2.1. Methods

Several scientific databases were used to conduct this literature review, including Google Scholar, PubMed, UT Library and Scopus. All articles were sorted on relevance and date. By skimming abstracts, a multitude of articles were selected to find other relevant keywords that could be used within this research. The following keywords were combined and/or used to find all applicable references: '*dementia*' and '*symptoms / reminiscence therapy / multi-sensory stimulation / snoezelen / augmented reality / mixed reality / assistive technology*'.

2.2. Relevance

The popularity of AR has increased tremendously in recent years, doubling its market size in 2020 compared to 2019, with projections for 2023 to triple that share [11]. AR is a relatively new form of assistive technology for people with dementia, especially compared with Virtual Reality (VR). However, AR systems might be able to provide interesting applications for people with dementia due to its ability to stimulate multiple senses whilst not being as obtrusive as wearing VR goggles. The implementation of AR is viewed as more complicated and more difficult, however, due to the increase of popularity of AR, this view might change in the near future.

2.3. Dementia

Dementia is a general term of severe chronic brain dysfunctions, currently affecting over 46 million people worldwide. Dementia influences the brain in such a manner that multiple areas of cognitive functioning are compromised in everyday life, leading to changing behaviour [1]. The most common type of dementia is known as Alzheimer's disease. People suffering from dementia experience it in a multitude of ways and it is affecting their lives differently; common symptoms include agitation, depression, sleep problems, loss of short-term memory and wandering behaviour. There is no conclusive proof which

symptoms are more recurrent or has the most impact on quality of life [12], but 'these symptoms are among the most complex and stressful [...] aspects of care and lead to poor patient health outcomes [13]'. There is no cure for dementia, but healthcare solutions have been developed to reduce and help with the symptoms. Widely implemented intervention techniques are adopted to tackle these symptoms, i.e. Reminiscence Therapy (RT) or Multi-Sensory Stimulation (MSS) techniques, to name a few. By making use of assistive technology, these interventions may be complemented, more personalized and/or better suited to work with people with dementia.

This literature review aims to provide a review of the implementation of AR as assistive technology for people with dementia; and current intervention techniques of RT with AR systems.

2.3.1. Symptoms of dementia

Many common symptoms for dementia patients will be present simultaneously for patients and clustering these symptoms may therefore be beneficial for health care solutions to tackle them at once. Unfortunately, because of the complex causes of Behavioral and Psychological Symptoms in Dementia (BPSD), a "one size fits all" solution does not exist [14]. Despite the efforts, there is yet to be an established model to be formed and the lack thereof is probably the result of 'a complex play of psychological, social, and biological factors' [15]. This is in accordance with findings from Kales *et al.* [14] who observes that there is an absence of clear agreement in the field about how to categorize non-pharmacologic interventions. Nonetheless, Khales *et al.* [14] have proposed linking the symptoms to their model (*Figure 1)* of factors associated with BPSD and grouping them into three categories: those targeting the person with dementia, those targeting the caregiver, and those targeting the environment. These categories are not to be seen as a clustering of symptoms, but as intervention techniques to deal with the issues related to the symptoms.

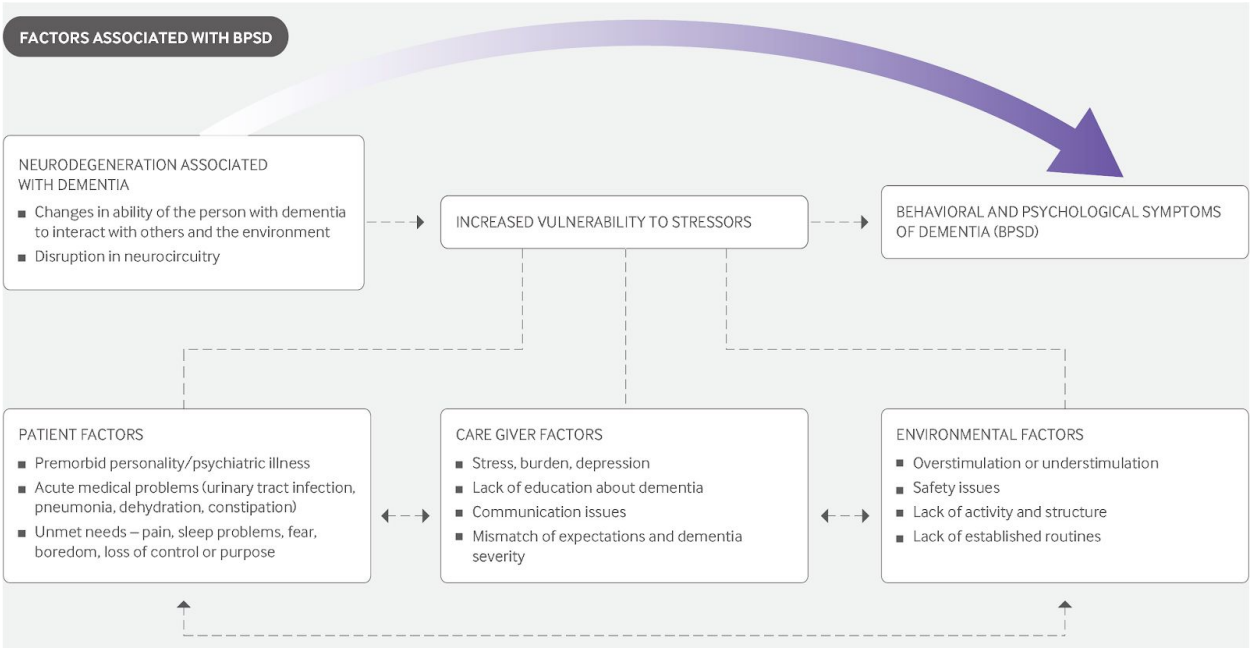


Figure 1: Conceptual model by Kales et al (2015) [14] describing how interactions between the person with dementia, caregiver, and environmental factors cause behavioural and psychological symptoms of dementia (BPSD).

2.3.2. Reminiscence Therapy

Reminiscence Therapy (RT) is one of the treatments that copes with the symptoms of dementia. It involves the discussion of past activities, events and experiences from the past. It aims to evoke memories, stimulate mental activity and improve well-being and is usually done with the aid of tangible prompts such as photographs, household and other familiar items from the past, music and sound recordings [16], [17]. Woods *et al.* [16] suggests that there is some evidence to support that RT is effective in improving mood in older people without dementia and that its effects on mood, cognition and well-being in dementia are less well understood. In later research, Woods *et al.* [17] shows evidence that RT actually can improve quality of life, cognition and communication and possibly mood in people with dementia in some circumstances, although all the benefits were small. Subramaniam & Woods [18] obtained more compelling evidence for the benefits of RT by suggesting that 'individual therapy that included a life review process, used specific memory triggers and resulted in the production of a life story book has been associated in trials with outcomes suggesting psychosocial benefits for people with dementia.'

A personalized intervention approach is important for RT sessions. This personalized approach of using RT has been shown effective by Sarne-Fleischmann & Tractinsky [19]. They investigated a personalized multimedia system for RT and found high user-satisfaction levels from the experiences with

the system and that the system was found effective in prompting conversations and evoking personal memories. This conclusion is in accordance with findings from Testad *et al.* [20], who found 'a growing body of evidence indicating specific effects of different personalized psychosocial interventions on individual BPSD and mood outcomes'. Other studies confirm that a personal perspective of RT has the most impact as well [18], [21]. Examples of personalization include: listening to their favourite music; looking at photos of themselves, friends and family; smelling familiar scents and participating in tactical activities.

2.3.3. Multi-Sensory Stimulation

Another approach to cope with dementia symptoms is Multi-Sensory Stimulation (MSS), or previously known as *Snoezelen* [22] and was originally meant as a leisure activity for people with learning disabilities. Using MSS with people with dementia has become more popular, especially in so-called Multi-Sensory Stimulation environments (MSSe) in the form of a specific sensory room [23]. Although MSS has become increasingly popular, a lack of specific principles regarding the approach of MSS seems to exist. Baker *et al.* [24] have proposed the following criteria to better define MSS interventions:

- Visual, auditory, tactile and olfactory stimulation is offered to patients, often in a specially designed room or environment using a variety of lights, gently stimulating music, aromas and tactile objects
- Staff work one-to-one with individuals, adopting a non-directive, enabling approach in which they follow the patients' lead. Patients are encouraged to engage with sensory stimuli of their choice.
- Stimuli used are non-sequential and unpatterned, experienced moment by moment without relying on short-term memory to link them to previous events. They present few specific attentional or intellectual demands on the patient with dementia.

The effects of using MSS are promising. Patients who experienced a session in a MSS environment showed that they were talking more spontaneously, related better to others, did more from their own initiative, were less bored and were more happy, active or alert [25]. This is also described by findings from Jakob & Collier [26] who reported that patients, who found sensory rooms enjoyable and relaxing as well, also show positive changes in mood and behaviour and an increase in attention to their surroundings.

Unfortunately, these benefits are supposedly only noticeable during or short after a sensory session. Contrary even, suggest Bakert *et al.* [25], the benefits seem to have a reversal effect where the gains were lost very quickly. Sánchez *et al.* [27] suggest the same thing, noting that MSS seems to provide evidence of immediate positive effects on the behaviour and mood but found no conclusive data about their long-term effectiveness. However, Maseda *et al.* [28] has shown some long-term positive effects, although this was mainly a significantly higher improvement in physically non aggressive behaviour. Using MSS techniques are not to be used for long-term gain, but may be beneficial to improve the cognitive ability of dementia patients during a specific time period.

Due to the amount of senses to be stimulated, a lot of factors are important to keep into account with implementing MSS techniques. Certain key values are listed by Marti *et al.* [29], specifically: *i*) stimulation of multiple senses; *ii*) dynamic tuning to optimal levels; *iii*) engaging patients; *iv*) supporting intrinsic motivation; *v*) emergence of the patient's personal interpretation; and *vi*) patient's active participation. Marti *et al.* also noted that from a therapeutic point of view, a dynamic, flexible environment is the key factor for obtaining an optimal stimulation tailored to the specific needs for each patient. Riley-Doucet [30] suggests that if one is able to get the level of intensity of stimulation just right, there may be a potential to influence neural reorganisation. By tuning the optimal level of stimulation, it is crucial to not cause overstimulating. If people with dementia are getting overstimulated, they can become even more confused, anxious and agitated [31].

Unfortunately, the number of stimuli to achieve a suitable multi-sensory experience is unclear, but research done by Hairston *et al.* [32] suggest that MSS is definitely preferable to uni-sensory stimulation. Jakob [26] supports the key factors listed by Marti *et al.* [29], yet notes that the approach should be age appropriate and usable, as well.

2.4. Augmented Reality

Augmented Reality (AR) is a view of the real, physical world in which users find elements enhanced by computer-generated input. AR systems involve designing to add layers of digital elements over real-world views [33]. AR is often mistaken with Virtual Reality (VR), but AR is a form of VR [34]. In VR environments, users are immersed in a simulated environment in its completeness, whilst with AR the users are looking at the real world with added layers that are seamlessly interwoven with the real world, see *Figure 2.*

Figure 2: the difference between Virtual Reality (left) and Augmented Reality (right), demonstrated by Primitive Social [35].

AR can be used with either special AR goggles, like the Microsoft HoloLens [1] or via a smartphone or tablet device. With AR goggles, the digital layer is projected through the goggles on the real world. With a smartphone or tablet, the internal camera of the device is used and the projections will be visible via the device's screen.

Existing solutions with AR have been shown to be effective already for dementia health care. AR opens up the possibility of over-laying 3D information onto the real world, which could improve how well prompting works for people with dementia [36], resulting in an increase of functional independence and decrease of caregiver burden. Tsao *et al.* [34] found in their AR/VR system that elderly people engaged in visual-audio interactions evoked by nostalgic elements, confirming the applicability of the designed system for reminiscence therapy. The reminiscence therapy session was confirmed to enable sufficient memory recollection and cognition in elderly people, thereby potentially being worthwhile for people with dementia as well. Ferreira *et al.* [37] also found AR systems to work effectively with reminiscence therapy in their study. The study included people with dementia at an initial to moderate stage of dementia. They tested several game-like activities, by making use of a floor projection setup and PsEye camera to track interaction. The games included were creative painting, a categorization game, object searching and a knowledge quiz. By blocking the projection on specific indicated markers, the participants were able to interact with the system. The participants were able to remember and share interesting information regarding past events of their life. This suggests that the participants were engaged while doing the tasks and that the activities developed can be used for stimulation purposes. Another interesting note from this study is that most of the activities could have been done from a touchscreen, yet

[1] https://www.microsoft.com/nl-nl/hololens

by using an AR system they were able to use real objects and therefore 'capitalize personal, realistic and tangible objects to perform the tasks more efficiently, and, by projecting on the floor, the mobility of the people with dementia is stimulated'.

Unfortunately, there is an absence of feasibility and efficacy studies with AR applications for people with dementia [38]. Ferreira *et al.* [37] argues that it becomes important to validate, together with health professionals, the efficacy and effectiveness of digital systems explicitly designed for stimulation purposes with people with dementia.

Stimulating activities in Virtual Environments

Stimulating activities for people with dementia has proven itself to be beneficial for themselves, and for caregivers as well, and participating in these kinds of stimulating activities can improve cognitive and social skills [8], [7]. The use of multimedia technology in the form of AR to provide stimulating activities can be linked in various dynamic and flexible ways to promote the user's engagement, by interacting with the material presented in a more lively way than just by looking at text and pictures on a page [6]. However, the question arises how people with dementia are able to use new multimedia technology.

Studies by Astell *et al.* and Alm *et al.* [39], [40] found that people with dementia are comfortable in front of a touchscreen computer and using multimedia technology can be linked in various dynamic and flexible ways to promote the user's engagement by interacting with the material presented in a more lively way than just by looking at text and pictures on a page. Alm *et al.* [6] tested the experience of VR environments with people with dementia, where all participants in the study shared positive feelings about the experience. The authors also tested Virtual Activities in the VR environment. Here; the users were enthusiastic as well. Overall, healthcare professionals and people with dementia noted that these virtual environments were very interesting and evidence shows that they were able to work with the system independently, given the adequate prompting. Although these studies are about VR instead of AR, it shows that people with dementia do have positive feelings about the virtual experience. As VR is even more obtrusive as AR, this might be an indicator that people with dementia are also positive about AR systems.

2.5. State-of-the-Art

Current solutions with regards to AR for people with dementia will be discussed in this section. Relevant aspects of these findings will be taken into account for inspirational or scientific purposes for the rest of this research. The state-of-the-art research is divided into three sections: *2.5.1*) Reminiscence Therapy solutions, this sections provides current products that are used during reminiscence therapy sessions; *2.5.2)* AR solutions for people with dementia, this section provides current applicabilities of AR for people with dementia; *2.5.3*) AR solutions for non-dementia, this sections provides AR projects that do not target people with dementia, but are relevant to this research.

2.5.1. Reminiscence Therapy solutions

Life story book

Making life story books is a common approach in the aid of reminiscence therapy for people with dementia [41]. In such a book, personal memories are constructed together with the people with dementia and are highly valued [42]. Such a life story book can take many forms, but are mainly represented as a physical book. Other forms may include: photo collages, video's, memory boxes or mobile apps. Evaluations showed the value of life story books in triggering memories, positive emotions and improving the relation with the person with dementia. Also, significant improvements were found on autobiographical memory, depression, mood and quality of life [43].

Interactive multimedia book

The interactive multimedia book, developed by Huldtgren *et al.* [44] aimed to provide insight into how tangible user interfaces can support reminiscence and communication between a caregiver and a person with dementia and considerations to be taken into account. One of the design cases was an interactive multimedia book. In the initial exploration, they found that photo books, or postcards, were one type of artifacts that often serve as reminiscence triggers; and that images alone require people with dementia to perceive the content through one sense only (vision), which can lead to frustrating situations if the person does not recognize the content. However, sound and/or music has a stronger effect on people's memories. Therefore, the choice was made to let the user trigger the sound of the multimedia book. The interaction is made by letting the user trigger the sound through simple touch gestures on the pages. The book can be made very personal, as the sound files on a page are stored on a SD card that can be swapped per user. An Arduino was used, together with a RFID reader. The book was tested in eight people with dementia (early stages) and four caregivers.

None of the applicants seemed to be afraid of the new technology. Implications they found were that most of the users were in a wheelchair, which made it difficult to look at the books which were put on a table. For some people, it was not clear what the buttons were and they tried to push other things. Some caregivers also noted that there was some cluttering of graphics present that confused the people with dementia, and recommended that fewer graphical elements per page should be used. The book shows positive results as a medium for reminiscence therapy for people with dementia, but also as a communication tool.

Figure 3: Interactive multimedia book [44].

2.5.2. AR solutions for people with dementia

Augmented paper in dementia care

An augmented book is being developed by Ferraz [45]. The goal is to give the book to caregivers, family members and the people with dementia themselves so that it can be used in the context and communication between them. A multi-sensory approach to interaction, such as digital storytelling can be used to recall life history events. Unfortunately, not much can be found about its workings and limitations due to the new concept.

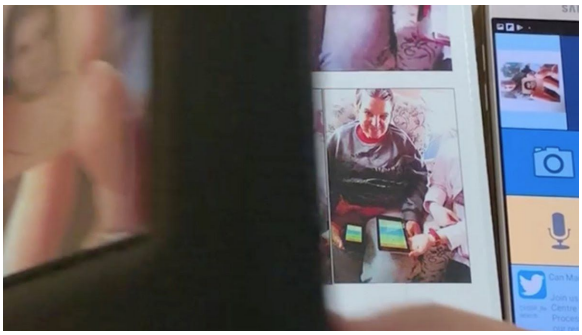


Figure 4: Augmented story book [46]

cARe

cARe [47] is an AR framework built for caregivers for people with dementia. The goal of the study is to describe the design process and implementation of an AR support system for dementia and cognitively impaired patients by presenting insights into challenges during the iterative development process. The system can take over certain tasks for outsourcing purposes. This will increase the person's independence and decrease the caregiver burden. The patients are getting navigated within the program via animated arrows to perform step-by-step instructions, whilst wearing the HoloLens. The patient can go through the instructions by saying 'next' or 'back'. The system was tested by asking patients to cook something with two constructions. The application could work for any tasks where step-by-step instructions are involved, but tasks where parallel actions need to be performed are not in place. This was a limitation of the framework, according to the authors. Participants also wanted to skip steps to get an overview of what it was all about; such a dedicated system was not in place yet. In future work, the authors will include context recognition and implicit navigation between instructions upon completion. Currently, the authors are experimenting the efficacy and efficiency of the concept compared to regular paper-based cooking.

Figure 5: Instructions for the cARe framework [47]

Mixed Reality Technology applications

A multitude of Mixed Reality Technology (MRT) are explored by Desai [48] to identify current applications of MRT, such as AR and VR. The goal of the study was to identify barriers and facilitators to interactions of people with dementia with MRTs, as well as measuring the immersion in the technology for people with dementia. The authors performed tests by letting ten participants with dementia, (MoCA[2] > 18) play four games with MRT. Observations were done during the test and participants were asked to fill out a questionnaire about the experience.

[2] https://www.mocatest.org/

The games included were: Young Conker on the HoloLens; Stack AR on the iPhone X; Tangram for Osmo and the game of bowling on the XBOX Kinect. The use of a HoloLens and AR kit by playing games has been shown effective for memory recollection with people with dementia. They found that more research needs to be done in the topics of sensory modalities of prompts and determining when these prompts should be generated.

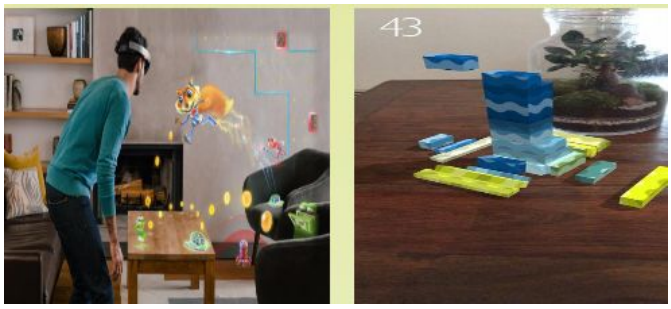


Figure 6: the HoloLens and AR kit games [48].

HoloLens-based Mixed Reality Experiences

Aruanno *et al.* [49] explored the use of the HoloLens as a new form of treatment for people with Alzeheimer's disease. They developed an application with the HoloLens and Unity 3D[3] to provide three kinds of activities inspired by traditional cognitive training approaches. The application aims to train (short-term) memory; an object is shown and the user should try to remember that object. The second activity is inspired by the *memory game* that consists of finding two identical objects. The third activity is similar to the second activity, yet it also includes spatial memory and has to remember where the objects were. The activities were tested with healthy subjects, aged between 64-67, which is the average age that Alzheimer's disease will manifest. A neurologist in their project team noted Alzheimer's disease does not affect a person's functional capability of interacting with a device, thus, the assumption was made that the usability evaluation could be performed with subjects who are age compatible with the one of their main target group but not suffering from Alzheimer disease. The users of this game manifested positive feelings towards the HoloLens and the application, and that the third activity was difficult for memory but very engaging.

Figure 7: Memory game in Augmented Reality form [49].

[3] Unity is a cross-platform-game-engine

2.5.3. AR solutions for non-dementia

AR navigation interface

Tsao *et al.* [34] developed a system by using AR as a form of Reminiscence Therapy. The idea is a navigation interface to enable elderly people to capture or scan specific images through mobile devices. The system then combines an interactive visual-audio system with a motion guidance system that leads users to any scene or object inside a historic house that they can experience with a VR headset. The real life pictures are portrayed in the virtual world, which makes it a combination of an AR and VR system (or: *mixed reality)*. The diverse visual changes displayed by the system can trigger memories of past events among eldery users, thereby improving the effectiveness of the therapy through triggering more conversation topics. The goal of the study was to examine the applicability of reminiscence therapy with nostalgic physical items, images, video and music by making use of immersive media, being AR and VR techniques.

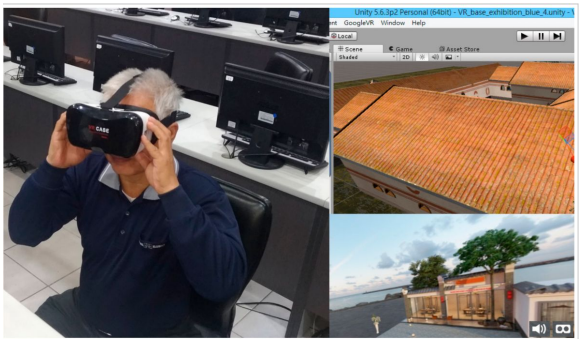


Figure 8: VR/AR system for reminiscence therapy [34]

Projection-based AR

A projection-based Augmented Reality system was proposed by Ro et al. [50], to address the difficulties of wearing AR goggles like the HoloLens. The HoloLens needs to be worn all the time, can cause dizziness and the HoloLens has a narrow viewing angle. The proposed solution is to use projections, the system can construct an AR environment in any space and provide life support, care and therapy. Next to that, the system supports mental acare aids such as spatial art therapy and memory photo reproduction, in addition to physical support and memory assistance activities. The system can analyze the space and track the patient within it to project things in it.

This system is built on using the SLAM algorithm by making a 3D map of the space. This was done by using a RGB-D camera. Multiple applications are proposed by the author to work within their system that include: monitoring / User Identification / Personal Assistant / Media Services / Spatial Arts. Currently, the authoter are working on the validation of the system by demonstrating said applications with experts and patients.

Figure 9: Projection based personal assistant [50].

The MagicBook

Billinghurst *et al.* [51] explored how a physical object can be used to smoothly transport users between reality and virtuality, or between co-located and remote collaboration. As a real life example, they created the MagicBook, which is an AR interface. The Magicbook experience uses normal books as the main interface object. By using AR goggles, they were able to see the objects displayed in the books to become visible in 3D space. The authors pointed out that viewing objects from an AR viewpoint works perfectly for viewing and talking about the model, when size and immersion is not the key element. They also found that by using a book, the technology part became 'invisible'. The book is already a familiar item and using glasses to look at the book, feels more like using reading glasses. The MagicBook was demonstrated at a conference, where 2500 people tried the book. Feedback on this system was that the models could have more details and should be more life-like. This constraint was mainly due to the graphic card performance of that time (2001). The attendees who tried the book also found that the interactivity was lacking and expected some sort of game, instead of passively watching the objects.

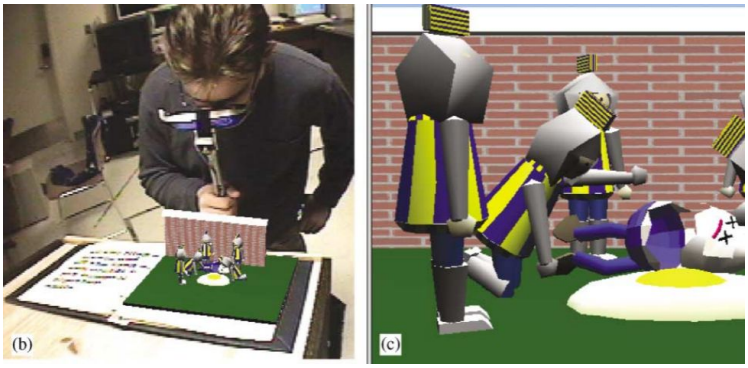


Figure 10: The MagicBook [51].

2.3. Discussion and conclusions

While using AR as assistive technology for people with dementia is a relatively new tool, research studies have shown positive results and its effects are promising. Yet, not many AR solutions that include a form of RT are existing, to the best of the author's knowledge. Current AR solutions for people with dementia are targeted on prompting, facilitating communication and training memory; only the augmented book of Ferraz [45] shows some insight on using RT in an augmented form. The AR navigation interface by Tsao *et al.* [34] is developed as a form of RT, yet it has been tested on eldery people and not people with dementia. While the life story book is an effective method for RT, with the interactive multimedia book [44] being a concise example of such a book, an augmented life story book does not seem to exist yet. Interestingly, the MagicBook [51] does provide a clear example and insights on how such an augmented book might look like. This background information on current dementia treatments, AR implementations and State-of-the-Art projects, will form the basis to develop an AR prototype for people with dementia.

3. Methods

In this section, an overview of methods and techniques will be given. A short description of the methods will be given, with its applicability within this project.

3.1. Creative Technology design process

This thesis is part of the bachelor graduation project of the program Creative Technology at the University of Twente. During this programme, iterative design methods are used. These can be summarized as the 'Design Process for Creative Technology [52]. The different phases of the process can be found in *figure 11* and will be elaborated on below. This research will use this method to answer the research questions established in the introduction (*section 1*).

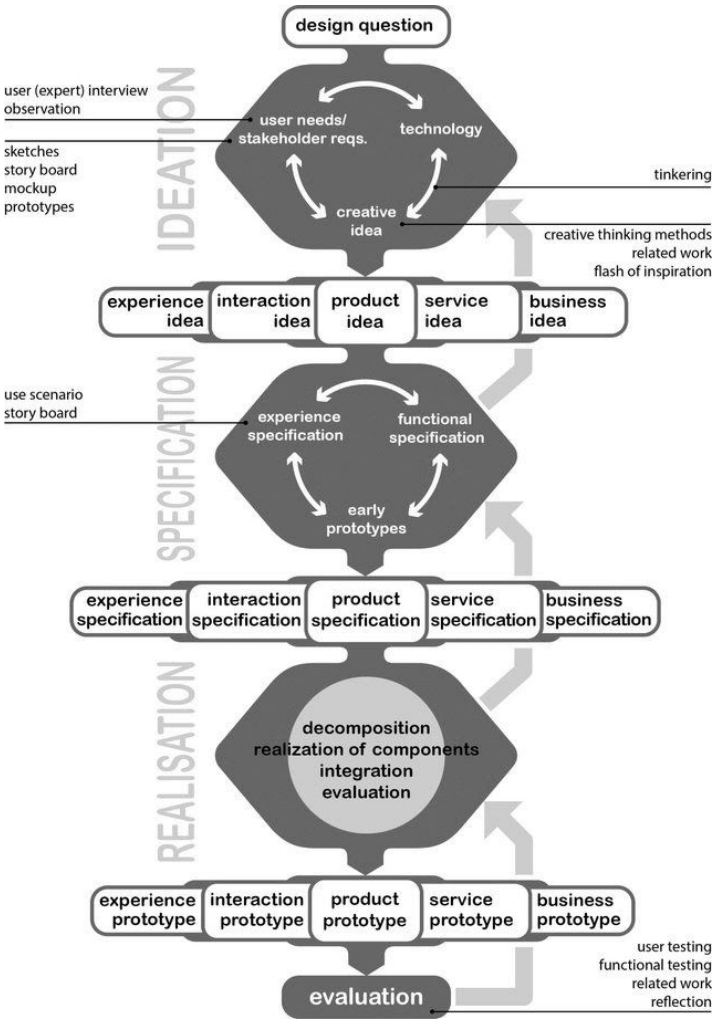


Figure 11: Design Process for Creative Technology.

3.1.1. Ideation

To be able to provide adequate answers to the research questions, the ideation phase will make sure that all preliminary observations are done. These observations consist of a stakeholder analysis, expert interviews and defining user requirements. The stakeholder analysis will provide an overview of parties involved in this research and prioritize them by the degree of involvement. Next, four experts in the field of dementia will be interviewed to gain insight on which activities are stimulating for people with dementia and design guidelines clarification. By doing so, a certain framework consists that defines the boundaries of the space where the creative solutions lie. The findings from the experts' interviews will then be combined with findings from the literature review (*section 2*), to establish a set of design guidelines and requirements. This list will be prioritized using the MoSCoW method. By using the guidelines and requirements, a multitude of potential solutions will be generated. One idea will be chosen to be specified to be developed into a prototype.

3.1.2. Specification

The generated idea from the ideation phase will be specified with detail by looking into possible ways of developing said idea. Because of the iterative design process, some elements will be linked back to the ideation phase to confirm certain outcomes. By making use of personas, which are fictional characters that represent the target group, the idea can be specified even more. With the personas, a use case scenario will be generated to find additional findings that are relevant for the solution. With the specified idea in place, a low fidelity (Lo-Fi) prototype will be created with the goal to turn the idea into a testable product. This lo-fi prototype will be discussed with the experts to collect and analyze feedback on the idea and its usability. Afterwards, a set of technical requirements will be specified that are limited to this idea to develop a high fidelity (Hi-Fi) prototype.

3.1.3. Realisation

In this phase, the development of a Hi-Fi prototype will start. It combines all requirements, features and constraints found in the ideation and specification phase. This phase goes more into detail about the technical solutions, workings, execution of the prototype, Further, the implementation of AR; what means and what assets are used and what the interaction entails will be explained. After an adequate Hi-Fi prototype is developed, it can be tested with users, experts or any other stakeholder involved.

3.2. Evaluation

The following schematic in *figure 12* will provide an overview of the three design processes; prototype iterations and how and by whom they are evaluated.

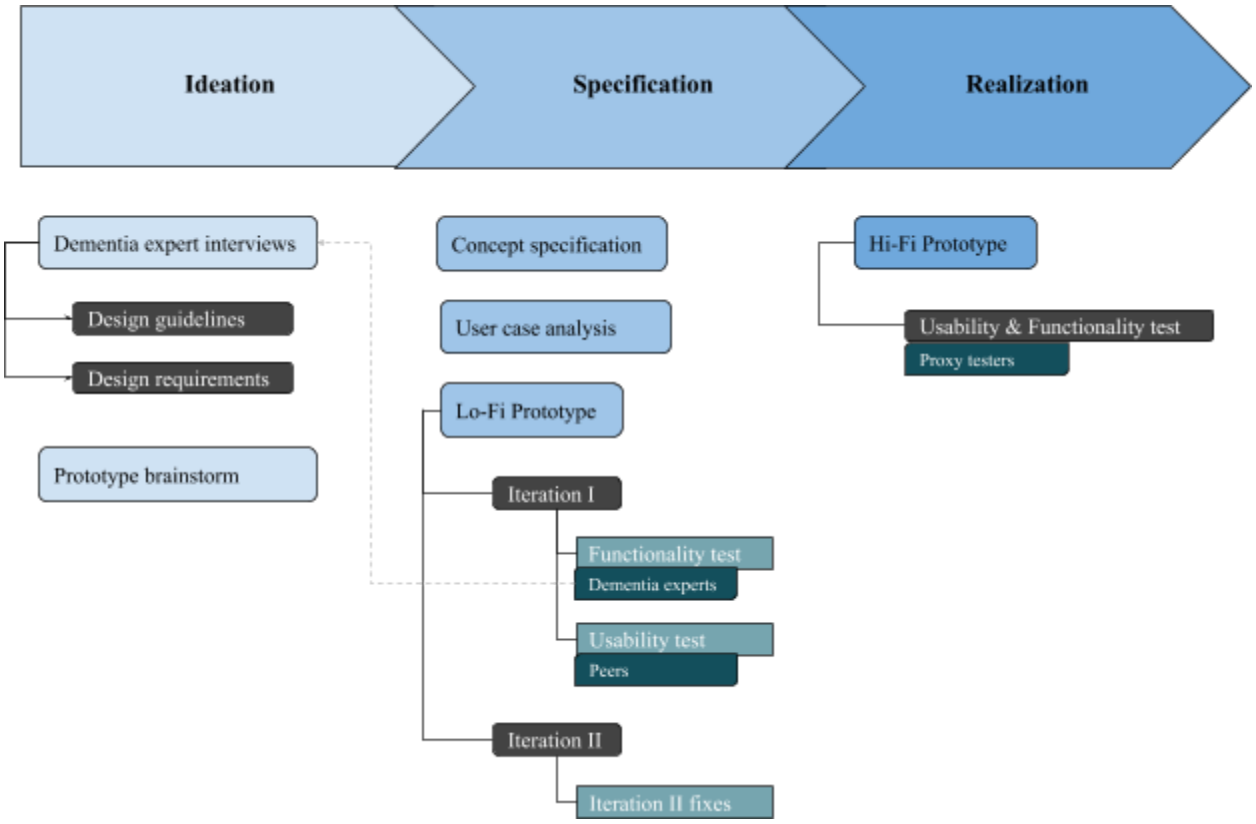


Figure 12: schematic of methods, techniques, iterations and evaluations of this research.

4. Ideation

In this chapter, the ideation phase of the project will be explained. This will consist of an analysis of stakeholders, interviews with the experts in the field of dementia, a set of design guidelines and requirements and a brainstorm to find the most fitting solution to the research question. The ideation phase follows the structure in *figure 13*.

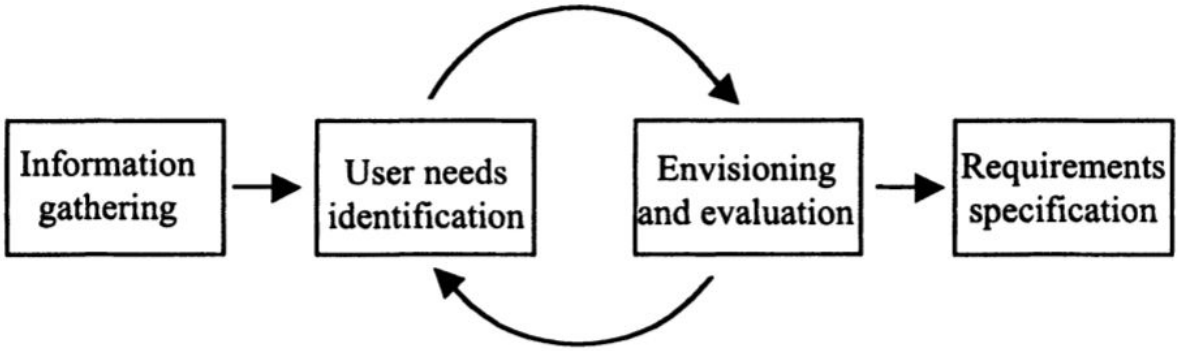


Figure 13: ideation phase to gather user requirements, envisioned by N. B. M. Maguire [53].

4.1. Stakeholder analysis

The following stakeholders are part of this research:

- University of Twente
- People with dementia
- People close to a person with dementia
- Nursing home facilities

To be able to make the right decisions, the stakeholders are classified in different categories based on priority, adapted from Mendelow [54]. See *Table 1*.

Stakeholder	Category	Participation
University of Twente	Decision-maker	Keep satisfied
People with dementia & people close to a person with dementia	User	Manage closely
Dementia care facilities	User	Keep informed

Table 1: Stakeholder prioritization.

University of Twente

The University of Twente, represented by Khiet Truong and Deniece Nazareth, is a decision maker in this project. The University has legislation power and is therefore important to keep informed and satisfied about this project. However, the University does not represent the target group, nor is it involved in the final development of the solution.

People with dementia & people close to a person with dementia

People with dementia and people close to a person with dementia are the target group and end users of the solution. Their take on the solution is decisive in the way that they determine if the solution is successful or not. This stakeholder should be managed closely, which will be done via experts in the field of dementia and usability tests.

Nursing home facilities

The solution is highly likely to be used within a dementia care facility. Therefore, it is important to keep into account what impact the solution has on caregiving and that it should not obstruct the daily affairs in such a facility.

4.2. Expert Interviews

To gain further insight on how AR can be used for people with dementia, several experts in the field of dementia have participated in a qualitative semi-structured interview. The experts are not one of the stakeholders as their opinion does not necessarily play a decisive part of the final solution. These interviews were approved by the Ethics Committee of the faculty of electrical engineering, mathematics and computer science at the University of Twente. A consent form (*Appendix A*), research brochure (*Appendix B*), an additional brochure on AR specifically (*Appendix C*) and a video of a lo-fi prototype has been sent to all participating experts. All participants provided consent and allowed the inclusion of quotes from the interviews for this research. The interviews were held via Skype and took between 30 to 60 minutes per person. The audio (.wav) of the Skype calls were recorded, transcribed, anonymized and stored on a secure hard drive. The raw audio files were deleted, once transcribed.

In total, four experts in the field of dementia participated in an one-to-one interview. The four experts consist of two scientific researchers working actively in fields concerning Human-Computer Interaction, Intelligent User Interfaces and Socially Interactive Technology and two PhD students with an academic and personal interest in dementia. As the interviews were semi-structured, a set of basic topics questions were prepared beforehand, yet, the main part of the interviews went more into detail on specific

responses and ideas. The list of questions can be found in *Appendix D*, the process and topics of the interviews are listed below.

Topics

- Personal, background and interest in dementia
- Familiarity with AR, or another form of MR
- Design constraints for people with dementia
- Design functionality for people with dementia
- Discussion of Lo-Fi prototype (in video form)
- Ideation brainstorm

Procedure

All four experts were familiar with AR in the sense that they knew what the technology entails, but have not been actively been involved with the development of an AR prototype. However, three of them do have academic experience with VR technology, two with VR and dementia, which is closely related to this research.

When talking about general design constraints, functionality and usability; all four experts agreed on certain aspects that concluded that 'cognitive stimulation is important and a personal approach to reminiscence does have the most potential.' Two experts noted that 'the emotional aspect of such a solution would be critical to be successful'. Further, all four experts agreed on the notion that 'an AR solution would have the most impact on people with a mild form of dementia and designing for this sub-group would be a logical starting point'. One of the experts also noted that 'many approaches to aid people with dementia, is geared towards two persons: the person with dementia and a family member, a friend or caregiver.' This remark was confirmed by the other experts and two of them added that 'if there is any interaction involved, the person with dementia should perform the interactions if capable.' Another interesting remark made by two of the experts on interaction is that 'there needs to be meaningful interaction involved to keep it interesting, but if the interaction is too complex, it can be confronting.'

The two experts who are familiar with the applicability of VR for people with dementia, were asked to provide insight on their view on the pros of AR in comparison with VR. Both of them stated that 'wearing VR goggles can be an obstruction and is heavy to wear. While it is fully immersive, it can also be overstimulating when there is a lot of interaction involved. With AR, there is the possibility to use it via a smartphone or tablet. This makes it more easily accessible and it lowers the barrier of using the solution.' The other expert, who is familiar with VR as well, does note that 'many people with dementia

are getting familiar with digital technology but sometimes do not understand the causality of a touchscreen.'

All four experts agreed that music, or sound, can contribute tremendously to an AR solution. One expert noted that 'it should be there in a meaningful way, which makes sense and contributes to the experience you want to create.' Two other experts noted something similar: 'by playing music whilst presenting personal memories, these memories are generally more detailed and present by the aid of music The music used could be songs from their childhood, for example.'

Next, the experts were asked to open and watch the video of the lo-fi prototype if they had not seen it already before starting the interview. As this part of the interviews is more found on the specification phase of this research, the discussion and brainstorm of this lo-fi prototype will be discussed in *section 5.3*. Feedback and notes on this lo-fi prototype will therefore not be included in the design guidelines and requirements of this section, but will be covered in *section 5.4: technical requirements*.

4.3. Design Guidelines and Requirements for an AR solution for people with dementia

Based on the literature review (*section 2*) and the expert interviews (*section 4.2*), a set of design guidelines and requirements can be generated by using quotes from the dementia experts and interesting findings from the literature review. that are important for developing an AR solution for people with dementia. These guidelines and requirements are important for developing an AR solution for people with dementia and make sure that the prototype is developed in the best way possible. As such a list is never complete, finished and feasible for a prototype, they have been classified by making use of the MoSCoW method [55]. The method uses four categories: must have, should have, could have and won't have. *Table 2* shows what each category entails.

Must have	Critical for success, if one item in the *must have* is not met, the project can be seen as a failure.
Should have	These requirements are important, but not necessary for the project within the current time frame.
Could have	Desirable requirements that are not important per se, but could improve the user experience.
Won't have	Least critical or not appropriate (at this time) items that might be dropped.

Table 2: overview of the MoSCoW method categories.

The following items in the tables with requirements are in no particular order of priority.

Must have	
Requirement	Source
The solution must be engaging.	Key values of implementing MSS techniques by Marti *et al. [29]*.
The solution must be easy to use.	Expert interviews.
The solution must add something to the experience/session.	Expert interviews.
The solution must have meaningful interactions.	Expert interviews.
The solution must serve as a medium for communication.	Expert interviews.

The solution needs to be cognitively stimulating.	Expert interviews.
The solution must feel safe to the user and the user must be comfortable to use it.	Expert interviews.
The solution must not cause overstimulation.	Cleary *et al.* noted that if people with dementia are getting overstimulated, they can become even more confused, anxious and agitated [31].
The solution must work one-to-one, adopting a non-directive, enabling approach in which a family member/friend/caregiver follows the patient's lead.	MSS principles proposed by Baker *et al. [24]*.
Stimuli used must be non-sequential and unpatterned, without relying on short-term memory to link them to previous events.	MSS principles proposed by Baker *et al. [24]*.
The level of stimulation must be tuned to an optimal level for that specific person.	Key values of implementing MSS techniques by Marti *et al. [29]*
Interacting with the solution must emerge from the patient's personal interpretation	Key values of implementing MSS techniques by Marti *et al. [29]*
The solution must require the patient's active participation.	Key values of implementing MSS techniques by Marti *et al. [29]*
The solution must incorporate a demo page and/or clear instructions.	Expert interviews

Table 3: Must have requirements using the MoSCoW method.

Should have	
Requirement	Source
The solution should be personalized best as possible when using RT techniques.	A variety of sources by Sanne-Fleischmann & Tractinsky [19], Tested *et al.[19], [20]*, Subramaniam & Woods [18], Hashim *et al. [21]* and expert interviews.
The solution should use the physical and augmented layer together, one should not disturb the other.	Expert interviews
The solution should be designed in such a way that it can be used by the person with dementia.	Expert interviews

The solution should be designed in such a way that it can *also* be used by the caregiver of the person with dementia.	Expert interviews
The solution should have audio components that can add to the experience.	'Sound and/or music can have a strong effect on people's memories [44] .' Expert interviews
The solution should not contain too many graphical elements.	Too many graphical elements can be confusing [44].
The solution should contain room for language and communication.	Expert interviews.

Table 4: Should have requirements using the MoSCoW method.

Could have	
Requirement	Source
The solution could have multiple personalization options.	Expert interviews
The solution could make use of personal physical objects to interact with the solution.	Expert interviews

Table 5: Could have requirements using the MoSCoW method.

4.4. Brainstorm

After evaluating the design guidelines and requirements (*section 4.3*) and feedback sessions with the supervisors of this research, a brainstorm session was exercised to come up with four potential solutions. For the four ideas, a list of pros and cons has been drafted. After evaluating the pros and cons, one of these four ideas will be selected for prototyping.

One additional requirement and constraint that was crucial during the brainstorm, is that the idea must be developed from home and be testable independently of the physical presence of the researcher without a handover of a device/physical prototype; due to the COVID-19 restrictions in place during this research. For this reason, the choice was made to only look into AR implementation in the form of a mobile AR application that can (more) easily be tested from a distance and no external device like a HoloLens is needed.

In *section 2.2: State-of-the-Art*, it has become clear that life story books are an effective method to use in RT for people with dementia [43] and that, next to the project of Ferraz [45], little has been done to implement AR technology in life story books. Furthermore, research from Desai [48] and Aruanno *et al.* [49] show that mini games show effective memory recollection and training by making use of AR systems. This is why the choice has been made to brainstorm about potential solutions with these two categories in mind:

- Implementation of AR inspired by the life story book
- Implementation of AR by providing a set of mini games

An individual fifteen minute brainstorm session was set up to write as many ideas as possible for one category. Afterwards, another fifteen minute brainstorm session was held for the other category. Then, a total of five ideas per category were chosen that fit the requirements of *section 4.3* the best. Next, three out of five ideas were eliminated after looking into feasibility options for prototyping, time and practicality. The two ideas inspired by the life story book and the two ideas inspired by a set of mini games will be discussed below.

4.4.1. Implementation of AR inspired by the life story book

Augmented life story book

The idea was to use existing physical life story books of people with dementia and add AR functionality to it. A QR code can be placed within the life story book. A mobile application will register this QR code and display 3D augmented objects and sounds that fit the specific memory of the image in the book. The animations can range from simple to more intense, which means it might work for people with a mild to a more severe case of dementia. See *table 6* for the pros and cons of this idea.

Pro	**Con**
Some people already have a life story book, which means that no additional book needs to be developed. That would make implementing easier.	Every person's book needs to be analyzed, scanned and augmented elements might need to be custom made per person. This would make it very time and resource intensive.
The recollection of the memory in the life story book might be more rich and detailed because of the additional elements. Especially, when music or sound effects are used.	It might be confusing to use a book that the person is already somewhat familiar with, to alter it in such a way.
For research purposes it would be interesting to see what has the most effect: the life story book with or without extra stimuli in the form of augmented elements.	There is no clear way of interacting with the book, besides pointing a device to the book. so a strong case needs to be made to still be able to answer the research question on stimulating activities.

Table 6: pros and cons of the Augmented life story book idea.

Mini photo album with fitting augmented animations

Instead of using an actual life story book, a smaller and more compact edition will be made. The contents will not follow a chronological 'life story', it will use specific time-independent themes, instead. The book can then be used in the form of a template, which can be personalized by putting the user's own pictures in there. An augmented animation will appear by pressing a button, that is fitting to that particular picture or memory to enhance the experience of reliving the memory. The interactivity can range from simple to more intense, which means it might work for people with a mild to a more severe case of dementia. See *table 7* for the pros and cons of this idea.

Pro	Con
Specific books for the solution instead of using an existing book helps avoid confusion.	Generic items in the form of themes need to be incorporated, which might not work for everyone or is not personalized enough.
Personalization possible, yet also generic elements to implement it easier for more people.	The templated book needs to be purchased, potentially besides an already existing life story book. This might be confusing.
Audio elements can be incorporated in a fitting way to work with the animations and specific memories.	Interaction will be by pressing a single button, this level of interaction might not be adequate and is yet dependent on the richness of the animation.

Table 7: pros and cons of the mini photo album with fitting augmented animations idea.

4.4.2. Implementation of AR by providing a set of mini games

Mini memory game in AR

The idea here was to build further on the project of Aruanno *et al. [49]*, but instead of using the HoloLens, a smartphone or tablet will be used. Instead of using pre-existing items in the memory game, objects that are relevant to a specific person could be used to, next to memory training, also revoke memories. In the study of Arunno *et al.* they did not mention any involvement of audio in the project, it would be interesting to see how that has an effect as well. Such a solution would likely only work for people with a mild to moderate case of dementia. See *table 8* for the pros and cons of this idea.

Pro	Con
Memory games are a good training for people with dementia, this way they might find more joy in the game due to more stimuli.	Not sure how an augmented variant yields better results than the physical memory game.
The augmented elements can be made personal instead of generic objects.	Using games they are already familiar with in a different format might be confusing and result in frustration.
The game can be played everywhere, as long as s smartphone or tablet is present and no further physical items are needed.	Will most likely not work for people with a more severe type of dementia.

Table 8: pros and cons of the mini memory game in AR idea.

Book with AR games

A little book of all sorts of mini games that can be played via the smartphone, as games with Mixed Reality (AR or VR) were found enjoyable by people with dementia [48]. These games can be familiar ones that the people with dementia already know, or new games. Every page is another play field of a game and the user can interact with the game by using the phone sensors. For instance, a roll-a-ball game would work where the ball is rolling around the book and you can score by putting the ball in a hole. This book will contain multiple graduations of difficulty so that it could work for multiple stages of dementia. See *table 9* for the pros and cons of this idea.

Pro	**Con**
Mini games are a good stimuli.	Not sure how augmented layer adds to physical mini games.
Multiple graduations of interactivity.	Interaction possibilities with AR systems are at this time very limited, which would make some games hard to play.
Can be personalized by only selecting the preferred games.	The games need to be played on a physical book. Depending on the size of the book, this might provide some difficulties if the games do have many elements or are displayed too small.

Table 9: pros and cons of the book with AR games idea.

4.5. Evaluation

After evaluating the pros and cons of the four possible solutions and some discussions with the supervisors of this project, the choice has been made to develop and specify the idea of a mini photo album with fitting augmented animations, inspired by the life story book..

The reason for this choice is that it was a strong candidate for the requirements given and has an interesting combination of interactivity, augmented elements and the way personal pictures can be added to the system. This idea can also implement RT techniques, as multiple memories are incorporated in the book and audio can be used to enhance the memories even more. Below, the *must have* and *should have* requirements that are established in section 4.3 are listed again, with a remark of the potential of meeting the requirements. The *could have* requirements are not mentioned, as they did not play a role in determining which idea was chosen

Must have	
Requirement	Implementing the requirement
The solution must be engaging.	The AR objects in the book are animated and triggered by the user, which can engage the user.
The solution must be easy to use.	Looking at a book with photos and looking at a screen are familiar activities.
The solution must add something to the experience/session.	The AR objects and animations add to the experience of revoking a memory.
The solution must have meaningful interactions.	The animation can be played via a button.
The solution must serve as a medium for communication.	By revoking memories, the person with dementia can talk about it with the person next to him/her.
The solution needs to be cognitively stimulating.	The solution targets the memory and stimulates interactivity with a product.
The solution must feel safe to the user and the user must be comfortable to use it.	Needs to be user tested.
The solution must not cause overstimulation.	Needs to be user tested.
The solution must work one-to-one, adopting a non-directive, enabling approach in which a family member/friend/caregiver follows the patient's lead.	The person can determine how long he/she talks about a memory or how long an animation will play.

Stimuli used must be non-sequential and unpatterned, without relying on short-term memory to link them to previous events.	Every animation on any page can be looked at / experienced independent on other pages.
The level of stimulation must be tuned to an optimal level for that specific person.	Needs to be user tested.
Interacting with the solution must emerge from the patient's personal interpretation.	There is no direct path what to talk about or which memory needs to evoke, it only serves as the medium.
The solution must require the patient's active participation.	There will be no interaction with the solution if the person with dementia does not actively use it.
The solution must incorporate a demo page and/or clear instructions.	A demo page can be added to explain the interaction with the solution.

Table 10: Must have requirements using the MoSCoW method with the implementation of the requirement.

Should have	
Requirement	Implementing the requirement
The solution should be personalized best as possible when using RT techniques.	Yes. Personal pictures can be inserted within the template.
The solution should use the physical and augmented layer together, one should not disturb the other.	Yes. The 3D objects and animations can be placed on parts of the book where no pictures are inserted or no crucial other stimuli is given.
The solution should be designed in such a way that it can be used by the person with dementia.	Yes. People with dementia would be able to push a button with their finger to interact with the system and no more physical ability is needed for interaction.
The solution should be designed in such a way that it can *also* be used by the caregiver of the person with dementia.	Yes. The same applies as above.
The solution should have audio components that can add to the experience.	Yes. Audio elements can be played via the phone or tablet that complements the animation or is suitable for that specific page.
The solution should not contain too many graphical elements.	Yes. The design of the template and 3D objects can be brought to a minimum.
The solution should contain room for language and communication.	Yes. The person does not continuously have to look at the animation or book and can communicate with the person next to themself.

Table 11: Should have requirements using the MoSCoW method with the implementation of the requirement.

5. Specification

In this section, the generated idea of the mini photo album with fitting augmented animations will be specified into more detail. First, the idea will be conceptualized and details about the idea will be provided. Next, the concept will be looked upon from a user perspective by making use of two personas and a user case scenario. Based on these findings, a lo-fi prototype will be developed which will be reviewed by and discussed with dementia experts. Afterwards, a set of technical requirements will be specified that are limited to this specified solution and are useful for developing a hi-fi prototype.

5.1. Concept specification

The AR photobook is inspired by multiple similar and relevant projects discussed in *section 2.3: State-of-the-Art*. The augmented paper in dementia care by Ferraz [45] provides a similar idea, but unfortunately not much details can be found on this project. Findings from the interactive media book developed by Huldtgren *et al.* [44], such as playing audio after an interaction with the book, and a limitation of the amount of graphical elements per page has been taken into account. The MagicBook by Billinghurst *et al.* [51] does provide an interesting basis by placing augmented 3D objects on the pages of a book. Things that can be learned from this project is that the 3D models should look more lifelike and that the amount of interaction (passively watching) was lacking and participants of the study expected game elements. The first issue was mainly due to the graphic card performance of that time, 2001, which has tremendously improved since then. Since the MagicBook was not developed for people with dementia, the need for a more present interactivity level is not fully applicable.

Elements from life story books will be incorporated, as well. The *Guide to Creating a Life Story for Care Giving* [56], developed by the Kootenay Boundary Dementia Core Working Group, is used to provide some guidance into specificing this solution. This guide presents four sections to a life story book: *i)* life reflections; *ii)* family and home; *iii)* everyday life and *iv)* hopes and dreams. These findings contribute to the way the pages in the book will be categorized.

The AR photo book will consist of two components that make up the solution. The first component being the actual physical book itself and the second component an mobile AR application. As many people are familiar with a photo album/book, the idea is to develop a book that serves as a template. Within the book, empty slots can be filled with personal photographs and pieces of texts to give context to the photographs. With the use of the AR application, 3D objects and animations can be seen coming to life on the pages of the book by pointing the phone or tablet towards the book.

To be able to provide meaningful 3D objects and animations per page that is suitable for a specific memory, the choice has been made to categorize the pages based on certain themes. The different themes are established based on the guide for life story books [56], and expert interviews. The dementia experts were asked to provide interesting ideas for the prototype, the following five themes were mentioned by all of them.

- Pets
- Home environment
- Travel
- Music
- Sports

Note that other themes might be able to work as well and are a great way to personalize this book even more. Furthermore, the augmented 3D objects should not block the view of any photographs or important texts and the book and the objects should be visible at the same time. This is why there is room for photographs and personal pictures on the page on the left, and place for the augmented 3D objects to appear on the right side. These two pages will then form one theme. When the page is turned, another theme will be visible. An example of this is displayed in *Figure 14,* the entire rendition of the physical book can be found in *Appendix E*. Note that the book is not in template form, as pictures are already added by making use of a persona. This will be elaborated more in the next section.

Figure 14: print of the travel page of the book. On the left hand side, two pictures are inserted. On the right, there is a place for the augmented 3D objects to appear.

To interact with the system, a single button per page will be used to start and to end an animation of the augmented 3D object. When the animation is playing, music and/or sound effects will be generated as well.

5.2. User Interaction

To be able to envision the users of the solution and create a user case scenario, two personas were created. The characteristics of these personas are from the researcher's own experience with people with dementia and the literature review.

5.2.1. Personas

Piet

81 years old, married to Hendrika, 3 children

Piet has been diagnosed with Alzheimer's disease since he was 66 years old. His wife, Hendrika, has cared for him at home for multiple years until the disease got too severe. Since then, Piet has been living in a care facility. But, Piet is still very active and present and still recognizes his wife and children.

Figure 15: Piet [4].

Stage of Dementia
Early stage

Former job
Farmer

Hobbies and interests
- Playing piano
- Going on camping trips
- Playing football with his grandchildren

Personality
- Always positive and happy
- Very stubborn
- Cares a lot about his family

[4] © https://unsplash.com/photos/BowRurRX5e8

Hendrika

76 years old, married to Piet, 3 children

Hendrika has worked as a writer for a local newspaper, until Piet slowly had difficulties with working on the farm. Since then, Hendrika has been helping out on the farm as well. Slowly, she also had to care for Piet more and more since he had been diagnosed and they moved away from the farm.

Figure 16: Hendrika [5].

Former job
Writer

Hobbies and interests

- Singing in a choir
- Going on camping trips
- Writing her own fantasy books

Personality

- Modest
- Open
- Always friendly

5.2.2. Use case & scenario

A basic flow of events by using the solutions is demonstrated here. For convenience, the personas of Piet and Hendrika will be used. The main flow of events can be found in *Table 12*, alternations of the flow can be found in *Table 13*.

[5] © https://unsplash.com/photos/VQ2L7t5qt_8

Index	Act
1	Hendrika comes to visit Piet in the care facility.
2	Whilst sitting next to each other, Hendrika struggles to find something to talk about with Piet. Piet experiences the same discomfort.
3	Hendrika sees/takes the mini photo book and places it on the table in front of them.
4	Hendrika opens the book on the first page.
5	Hendrika takes her phone / tablet with the application pre-installed on it and opens the app.
6	Hendrika holds the phone in her hand, aiming it at the book.
7	Hendrika and Piet follow the steps of the instruction page.
8	Hendrika or Piet turn the page.
9	Some photographs in the context of a theme that are meaningful to Piet are visible in the book.
10	Hendrika steers the attention of Piet towards the phone.
11	Piet sees that a 3D object and button has been placed on the book itself.
12	Hendria asks Piet if he will press the button.
13	Piet presses the button on the phone.
14	The 3D object will perform an action in the form of an animation.
15	The animation will also play sound or music
16	Hendrika asks Piet if he can see and understand what is happening.
17	Piet recollects a specific memory or multiple memories due to the stimulation.
17-18	(Optional) Hendrika or Piet presses the button to stop the animation.
18	Hendrika and Piet communicate about the specific memory.
19	Steps 9 to 18 will repeat until all pages are finished.

Table 12: main flow of events in a use case scenario.

Index	Alternative act
3-1	Hendrika places the book in the lab of Piet so he could see better.
6-1	Hendrika hands over the phone to Piet and lets Piet aim it at the book.
6-2	Hendrika places the phone in a standard so no one has to hold it.
7-1	The instruction pages are skipped because they are already familiar with the system and Piet remembers how to use it.
12-1	Hendrika presses the button.
18-1	Or will stop beforehand if it is not effective / too tiresome / time for something else.

Table 13: alternative flow of events in a use case scenario.

5.3. Lo-fi prototype of the AR photo album

By utilizing the personas and use case scenario in mind, a lo-fi prototype has been developed to validate the concept into a testable product. A lo-fi prototype can be described as a quick and easy version of a certain product and to check and test functionality rather than visual appearance. Such a lo-fi prototype, allows for early testing and rapid experimentation of functionalities.

The lo-fi prototype of the AR photo album consists of two iterations. The first iteration was video recorded and sent as a video file to four experts in the field of dementia for review purposes. This evaluation was part of the dementia experts interviews of *section 4.2.*

5.3.1. Iteration I

To replicate the user experience of using a booklet, a small (personal) photo album was used to indicate the concept of the solution, the design of the book was not part of the lo-fi prototype. As already established in *section 4.4: brainstorm* and the arguments by two dementia experts that using a smartphone is more easily accessible than AR/VR goggles, the choice has been made to use a smartphone application for the prototype.

The AR application was made by using Unity[6] (version 2019.3.13f1) for building an Android APK file and inserting and animating 3D objects and the Vuforia Engine[7] (version 8.3.8) to implement AR functionalities. The prototype was built on Window 10.

Two pages of the photo album were used to display AR 3D elements; on the first page a drawer that could open and close; on the second page a living room with animated curtains and teapot. These 3D objects and animations were obtained via the Unity Assets Store. See *figure 17*.

Figure 17: lo-fi prototype.

[6] Unity is a cross-platform game engine to create 3D, VR, AR games, simulations and other experiences
[7] Vuforia is an AR software development kit for mobile devices and works natively within Unity

To activate the animations, a *Virtual Button* had to be pressed. Virtual Buttons are part of the Vuforia AR Engine. This Virtual Button is placed on a specific part of the photo book page, and only exists in the virtual augmented environment seen via the phone. By 'pressing' / blocking this button, the animation is triggered and will keep playing as long as the hand is blocking the button.. By releasing the button, the animation stops. See *figure 18.*

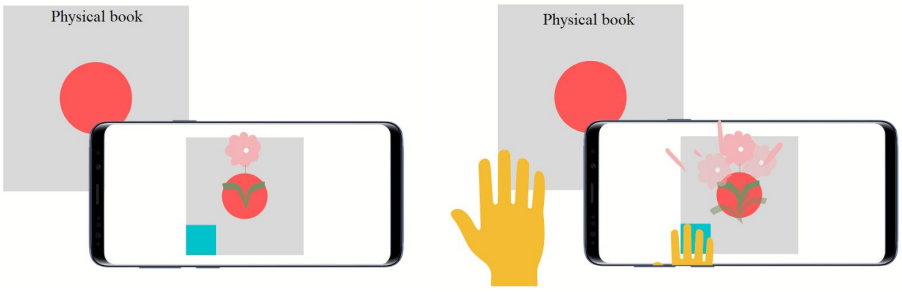


Figure 18: workings of a Virtual Button in the Vuforia Engine. Left: a flower in augmented reality placed on the book. Virtual Button (blue) only visible via the phone. Right: hand covers the part where the button is on the physical book. The augmented system registers this and the flower starts moving.

Evaluation on functionality

A video file of the functionality of the lo-fi prototype was sent to all four dementia experts during a semi-constructed interview of the ideation phase of this project, see section 4.2 for more details on the rendition of these interviews. Multiple experts noted that this is an interesting approach and solution for people with dementia. The experts noted that using such a Virtual Button is an adequate way of interaction, because the user of the system needs to physically put their hand or finger on the book itself. By doing so, this would feel logical as they are familiar with pushing buttons on physical items. Two experts provided the same idea concerning the design of the physical book: 'the interaction might improve if the form of the virtual button was physically printed on the book, so they can see where to put their hand without looking at the phone or tablet. On the other hand, using the touchscreen might be as effective and it would be interesting to see what works better.' About the design of the 3D objects, the majority of the experts agreed that the 3D objects and animation should be as life-like as possible, and not too abstract. One expert made the comment that 'the AR objects are now blocking some of the photographs of the photo album underneath and that this should not happen. The main memory should be visible at all times.' The experts agreed that the usage of themes and general objects might work, given

the right context. Nonetheless, a personal, tailored made, approach to the design of the pages and objects would increase the chances of evoking memories. Furthermore, all experts cited that this solution would be an effective facilitator for communication between the person with dementia and the family member, friend or caregiver.

Evaluation on usability

Due to the restrictions of the COVID-19 pandemic, the lo-fi prototype could not be physically tested with the experts. To test basic usability of the virtual buttons, people in the researcher's direct environment were asked to provide feedback. These people were housemates and family members. The lo-fi prototype was tested by the testers' own smartphone and the photo album was sanitized after every test.

Two issues were noted by all testers:

- The Virtual Buttons are not working all the time
- It feels weird to interact with the physical book whilst looking via the phone to see what you are doing

That the Virtual Button is not always working was a major issue and this issue has not been resolved. Yet, this functionality is an important part of the prototype and needs to work properly to not confuse people with dementia.

5.3.2. Iteration II

In the second version of the lo-fi prototype, one other page was made *augmentable,* besides the drawer and the living room. This page aims to represent an augmented implementation of the *music theme.* This iteration was mainly focussed on the usability of the prototype and to potentially fix the issues found in the usability evaluation of *Iteration I.* This extra page included six buttons, instead of one, to represent six keys of a keyboard. The extra page can be found in *figure 19*.

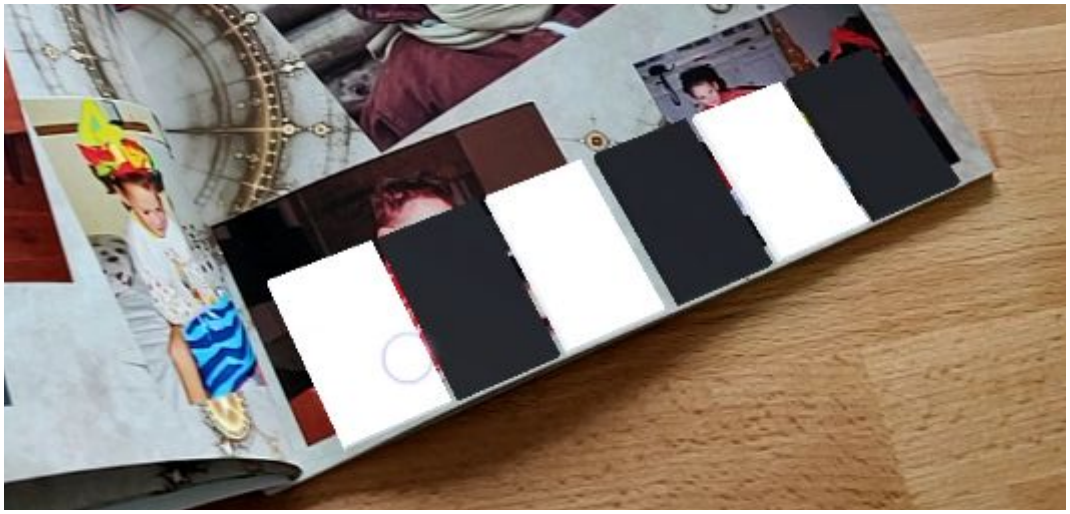


Figure 19: photo book with six buttons, pressing each key/button would play a different piano note.

To address the issues found in *Iteration I*, where the Virtual Buttons were not trustworthy, another approach to the interaction has been incorporated. The system would not make use of the Virtual Buttons anymore, but by touch input on the screen of the smartphone. By watching through the screen, the six buttons show up on the page of the book. This way of interaction also solves the second issue found in the usability test of *Iteration I*, because now you are watching through the phone and also interacting with the application on the phone itself instead of the physical book. *Figure 20* demonstrates the workings of the touchscreen input.

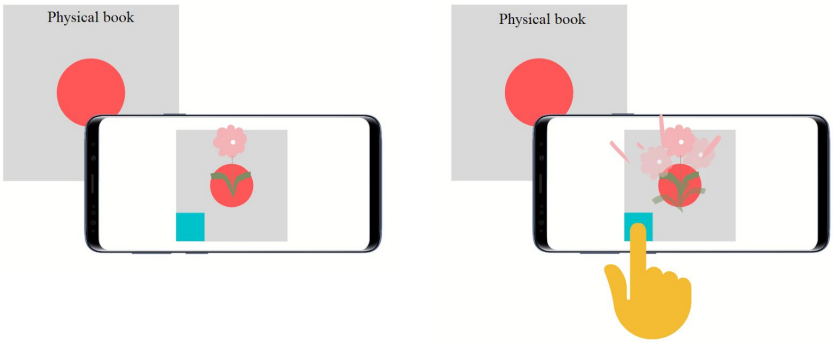


Figure 20: workings of touchscreen input in the Vuforia Engine. Left: a flower in augmented reality placed on the book. The button is also displayed in augmented reality. Right: by tapping on the button you can see on the screen, the flower starts moving.

5.4. Technical Requirements

Based on the findings from the use case scenario; development of and feedback on the lo-fi prototype and combining these results with the design guidelines and requirements for people with dementia established in *section 4.3,* a set of technical requirements was formed that is limited to this specific specified solution. This list can be used for developing the lo-fi prototype into a hi-fi prototype. In contrast with a lo-fi prototype where the basic functionality is key and visual appearance is kept at its minimum; the goal of a hi-fi prototype is to resemble, visual and functional wise, an actual product. The list of technical requirements are classified using the MoSCoW method [55], which used four categories: must have, should have, could have and won't have. The definitions of these categories can be found in *table 2* in *section 4.3.*

The following items in the tables with requirements are in no particular order of priority.

Must have	
Requirement	Source
The prototype must have multiple pages.	No specific source. Yet, otherwise, there would be a decrease in personalization; too much going on one place; not recognizable; hard to track for the AR tracking system.
The prototype must have spots where users can put their own pictures.	Functionality testing with dementia experts.
The augmented object must fit within the theme of the page.	Functionality testing with dementia experts.
The animation must be meaningful.	Functionality testing with dementia experts.
The animation must add something to the memory.	Functionality testing with dementia experts.
Interacting with the system must work flawlessly.	Usability testing with peers.
Audio played during the animation must make sense and not be obtrusive.	Functionality testing with dementia experts, and usability testing with peers.
The prototype must have interactions on how to use the system.	Functionality testing with dementia experts, usability testing with peers, use case scenario.

Table 14: Must have technical requirements for a hi-fi prototype using the MoSCoW method.

Should have	
Requirement	Source
The prototype should use the physical and augmented layer together, the main memory should remain visible.	Functionality testing with dementia experts.
Every animation should have fitting audio elements that enhance the animation	Functionality testing with dementia experts.

Table 15: Should have technical requirements for a hi-fi prototype using the MoSCoW method.

Could have	
Requirement	Source
The prototype could have multiple animations per page that can be selected.	Functionality testing with dementia experts, usability testing with peers.

Table 16: Could have technical requirements for a hi-fi prototype using the MoSCoW method.

6. Realisation

Based on the Lo-Fi prototype of *section 5.3* and the technical requirements of *section 5.4*, a Hi-Fi prototype has been realised. A Hi-Fi prototype represents the solution in such a way that it can be seen as an actual product and tested with the target users afterwards. In this section, the Hi-Fi prototype and all its components and tools used will be described.

6.1. Components of the prototype

The two main components of the prototype consists of a physical book and an Android application (.apk file[8]).

6.1.1. Book

The design of the book consists of five themes that have been established in the concept specification (*section 5.1*), which cover ten pages. Before the first theme, there is an index present with an instruction page that explains the workings of the solution. The design of every page will be shown in the upcoming sections, a more detailed version can be found in *Appendix F*.

The idea for this solution will consist of a template. There are empty slots where users can put in their pictures and write descriptions about specific memories. An example of the page can be found in *figure 21*. For this prototype, pictures will be included based on the persona of Piet (*section 5.2.1*).

Figure 21: example of a template page.

On the left side of the book, the user will find personal photographs and text in the context of the theme. On the right side, there is room for the augmented object. The image for that page needs to be detailed with clear contrast, detectable lines and no repetitive elements. The reason for this is so that the AR

[8] An APK (Android Package Kit) is Android's file format for applications and can be installed on Android devices.

system can easily track all features of the image and display the augmented 3D objects on the right place and on the right page. This image tracking will be elaborated on in *section 6.3*.

On the pages where a single animation happens and only one button suffices, the actual button will also be printed on the page itself. In the expert interviews for the lo-fi prototype, this was considered as a factor that would improve the user experience, as mentioned in *section 5.3*.

Index and instruction page

Some personal photographs can be inserted directly into the first page already, which makes it familiar to the user and the caregiver. The different themes that are present in the book will be highlighted so that the user or caregiver can decide on which page they start and to give a general overview of what is present in the book. The instruction page, which is on the right, is the first encounter with the augmented reality component. The demo page consists of a beach with an arrow pointing to the button and a text to indicate how to start the animation. When the button is pressed, a sailboat will sail on the water and sea/beach/boat sounds can be heard. See *figures 22* and *23*.

Figure 22: the two first pages of the physical book, with the index on the left and the demo page on the right.

Figure 23: screenshot of the AR application pointed at the demo page.

Pet/Animal page

During the experts interviews, it was established that cats or dogs are strong candidates to be remembered by the person with dementia. On the left side, the person can find pictures of their own pet if they had one, on the right side a cat or dog will appear in augmented form. The plan was to incorporate a setting to choose if a dog or a cat appears, this functionality did not make it into this prototype; only an augmented cat will be shown. Next to the cat that appears on the page, the button will also appear in augmented form.

By clicking on the button, the cat will start to come to live and wiggle his tail. The cat will *meow* when the animation plays. See *figures 24* and *25*.

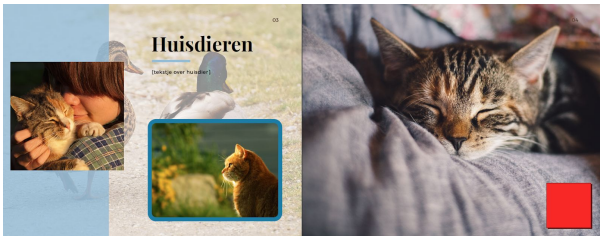


Figure 24: the two pet/animal pages.

Figure 25: screenshot of the AR application pointed at the pet page.

Home environment page

As the persona of Piet has been living and working on a farm during the largest part of his life, the design of the home environment consists of a farm. The augmented part consists of a little farm with two barns, a sheep, a chicken, a pig and a cow that start walking and moving when the animation starts. During the animation, the user can hear farm sounds. See *figures 26* and *27*.

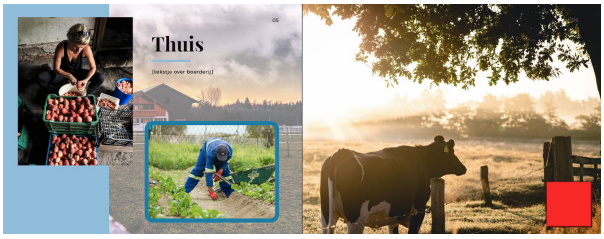


Figure 26: the two home environment pages.

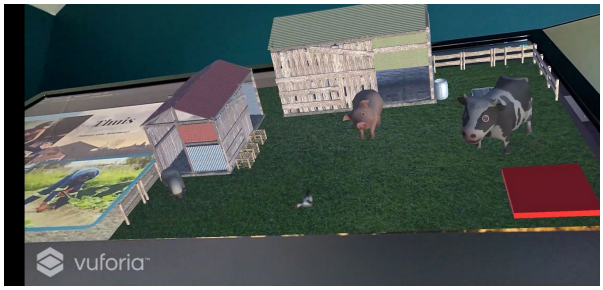


Figure 27: screenshot of the AR application pointed at the home environment page.

Travel page

As the persona of Piet enjoyed going camping, the travel page consists of a little camping. The campings consist of some tents, a caravan, trees and a motorhome. When the animation starts, the camper starts moving and is parking on a camping spot. During the animation, camping sounds of winds blowing, birds and the motor of the motorhome can be heard. See *figures 28* and *29*.

Figure 28: the two travel pages.

Figure 29: screenshot of the AR application pointed at the travel page.

Music page

This page consists of more interaction than the other pages, and is incorporated from *Iteration II* of the lo-fi prototype, in *section 5.3*. A 3D model of a piano is shown on the page, next to six keys that play different notes. See *figures 30* and *31*.

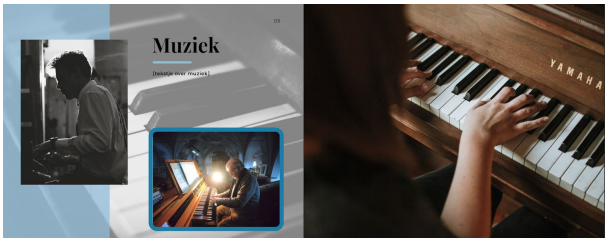


Figure 30: the two music pages.

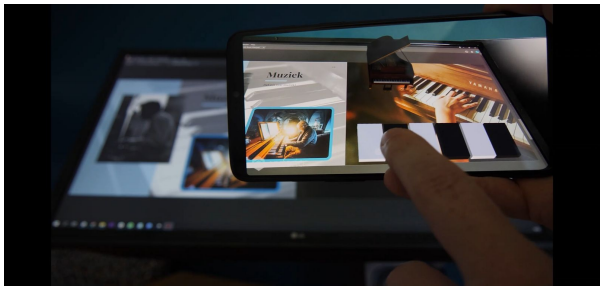


Figure 31: screenshot of the AR application pointed at the music page.

Sports page

As the persona of Piet enjoyed going to football games and playing football with his grandchildren, a football is shown. When the button is pressed, the football will shoot towards the goal and score. In the 'idle' state, when the animation is not happening, stadium sounds will play. When the button is pressed and the ball hits the net, a cheering sound will play. This theme has the potential to make it more interactive as well by sliding the ball into one of the goals for example. This functionality is not present in this prototype. See *figures 32* and *33*.

Figure 32: the two sport pages.

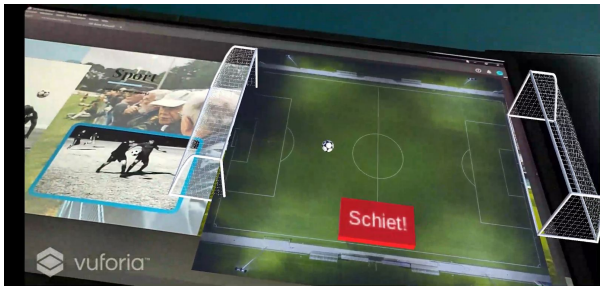


Figure 33: screenshot of the AR application pointed at the sport page.

6.1.2. Application

The mobile application is only working for Android, but could be built for iOS devices as well. The application has been deployed via an APK (Android Package Kit) (.apk) file that can be transferred or downloaded via a direct link. Depending on the Android device, the user might need to give permission to install unofficial APK files. In the Android settings this can be found by 'enable Install Unknown Apps/Sources'.

The application itself is rather simple and has no menu or buttons. When the user opens the application, they see what the camera of their device is seeing. For this to work, users with Android 6.0 and above need to give the application access to use the device's camera.

6.3. Augmented Reality implementation

In this section, the workings of the Augmented Reality component; the software and its assets will be explained.

6.3.1. Software

The core of the application is made within Unity (version 2018.4) on Windows (10). Unity is a game-engine platform to develop 2D, 3D, VR, AR games, simulations or other experiences. To develop the AR component, the Vuforia SDK (Software Development Kit) was also needed. Vuforia uses computer vision technology to recognize and track images and 3D objects in real time.

6.3.1.1. GameObjects

Within Unity, six pages are visible in the 3D editor. These are five *ImageTargets* for every page where a 3D object needs to appear. Linked to every page, there is one or multiple *GameObjects* that carry relevant information such as a 3D-object file; the button(s); the position relative to the page; animation files; etc.

The hierarchy of the Unity Scene, which contain *GameObjects,* is as follows:

- ImageTarget (6x)
    - Button
    - 3D object
    - Plane surface
- AR Camera
- Directional Light

The ImageTarget carries the most components and is a *Vuforia Engine GameObject*. This *GameObject* connects with the Vuforia Database where the different pages in image format (.PNG) are stored. Per ImageTarget, a different image is linked so that the Vuforia Engine can keep track which objects need to appear on which page. See *figure 34* for all image targets and 3D objects.

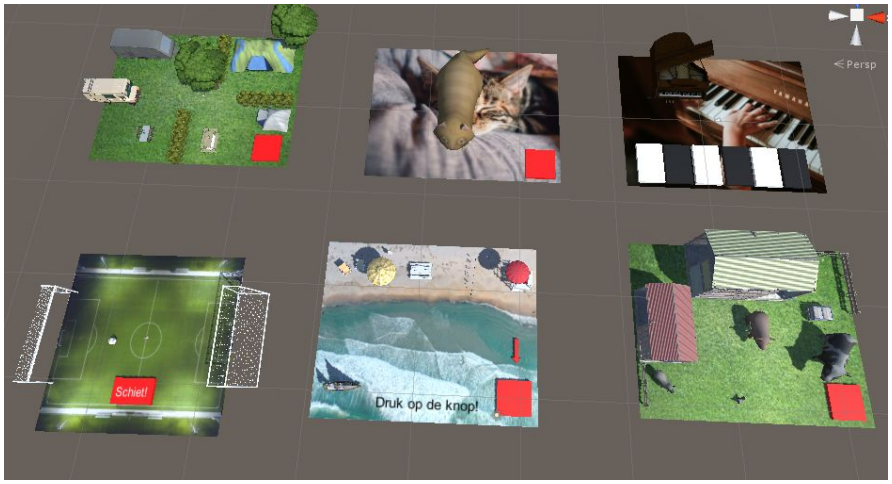


Figure 34: five image targets and 3D objects attached in the Unity 3D editor.

The *ImageTarget* also has an *Audio Source* connected to it. This component carries the audio files that are relevant to the specific page. At last, but most importantly, a script is attached to the *ImageTarget* which handles the complete interaction between all *GameObjects* attached to the *ImageTarget*. The general working of the script can be found in section *6.3.2*. The *GameObject* of the button has a collider attached to it, which means that it can collide with other objects such as a touch input. The *GameObject* of the displayed 3D model has an animator property attached to it, which can hold a range of animation (.anim) files. The AR camera in the hierarchy acts as the device tracker for the ImageTargets. This AR camera will find the camera of the Android device and follows the orientation of the physical device's camera, so that the 3D objects on the pages will be on the same spot. The directional light adds light to the objects in the scene to create depth in terms of shadow.

6.3.1.2. Assets

Vuforia Database

An image format can be uploaded to a database held by the Vuforia Engine developers portal. The images will receive a rating, which indicates if the image is a strong candidate to be 'augmentable'. See *figure 35* for an example of a good target image with features. In general, the more features, the better the system can track the image.

Figure 35: uploaded image to Vuforia database with augmented marker features.

3D objects

The 3D objects are imported in Unity as a FBX (.fbx) file format. For this prototype, some of the FBX files are made by the researcher itself in Unity or Autodesk's Maya. Maya is a 3D computer graphics application where interactive 3D objects, animations and assets can be developed. Due to the time constraints and the requirement that the objects should be as lifelike as possible, some FBX elements are imported via the Unity Assets Store with the correct licenses (educational purposes). A complete list of imported assets and its sources can be found in *Appendix F*.

Animations

Some imported assets already had animation (.anim) files attached to it, while some were made inside Unity. The motorhome and football animations are highlighted in this section. These two animations are interesting as they make use of the physics inside the Unity engine. Instead of animating all the parameters one by one, real-life physics are attached to the *GameObjects* to mimic the movement. Then, within Unity the 'game' starts and the physics are applied as it would in a real game; i.e. driving a

motorhome and shooting a football. All of the parameters like position and rotation are then recorded during this play mode and saved in an animation. The script to record the animation was obtained via a YouTube tutorial [57] and can be found in *Appendix G.*

Audio

The audio files are all royalty free and obtained via freesound.org, the list of sound files can be found in *Appendix F*.

6.3.2. Interaction

The interaction with the AR system can best be described in a diagram, see *figure 36.* All the different scripts of the *ImageTargets* have a similar structure and are written in C#. The C#-script of the *ImageTarget* for the Pets/Animals page can be found in *Appendix I.*

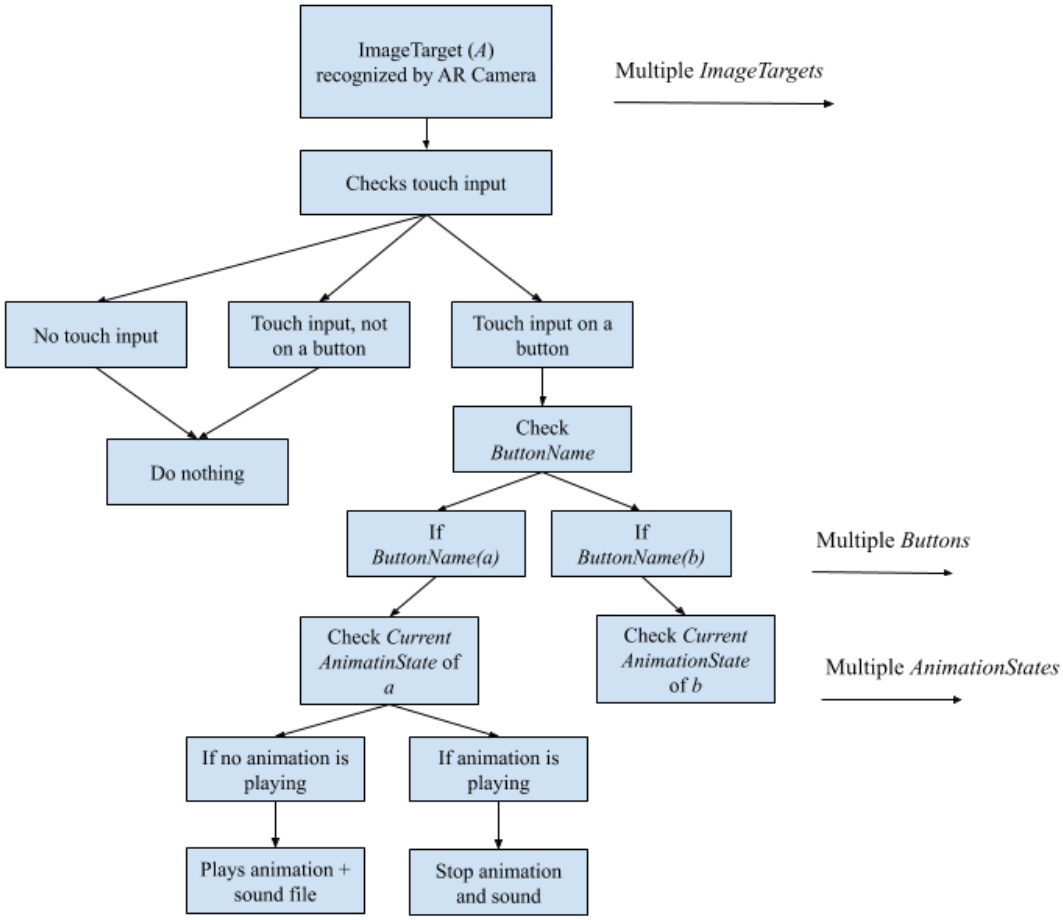


Figure 36: UML diagram of the workings of the scripts per image target (generalized).

7. Evaluation

In this section, the evaluation process of the Hi-Fi prototype developed in *section 6* will be explained and discussed.

7.1. Methods

This evaluation test was approved by the Ethics Committee of the faculty of electrical engineering, mathematics and computer science at the University of Twente. Information about the research and a consent form were available and singable via the digital survey. All participants provided consent and allowed the inclusion of quotes for this research.

Due to the COVID-19 pandemic restrictions during this research, major limitations of testing the hi-fi prototype were present. Most importantly, it was not possible to test the hi-fi prototype with people with dementia. To still be able to test the prototype, proxy testers have been used instead. Proxy testers are defined here as testers that are able to represent the actual target group by demographic and empathy. Two groups of users have been asked to give feedback on the prototype:

- Healthy elderly people (65+)
- Healthy people who are *familiar* with dementia (i.e. know someone in their direct environment such as a partner, family member or good friend)

The argument to test with elderly people is that dementia is highly more likely to develop at an older age. If a healthy elder person is not comfortable or does not understand the prototype, it is an indicator that a person of the same age with dementia will not understand it as well. Next to that, the neurologist in the project team of the HoloLens-based MRT Experiences [48] noted that Alzheimer's disease does not affect a person's functional capability of interacting with a device. In their research, they assumed that they could evaluate their prototype with subjects who are age compatible with the actual target group.

The people who are familiar with a person with dementia were asked to imagine how a person with dementia would react. As this group is the secondary type of user for this solution and is able to use the solution as a means to communicate with a person with dementia, they are eligible to answer questions about the prototype as well.

Procedure

The test consists of two parts with an active *(i)* and a passive *(ii)* component, in the form of a digital survey via Google Forms. At first, the general idea of the application will be explained.

i) The user will be asked to download the application (.apk) file. In the survey, the page of the demo page and music will appear. The tester will be asked to point their android device with the installed and opened application at the page on their screen without any instructions except for the instruction on the page itself. Next, they will see the piano buttons appear on the music page and can touch them to hear sound. After this interaction, they will be asked to answer a question if the demo page alone would be sufficient enough to demonstrate the workings of the application and if a person with dementia would understand the causal relationship of tapping on a touchscreen button and an animation/playing music.

ii) Then, four videos will follow that guide the testers through the other pages: pets, home environment, travel and sports. In the videos, the interaction with the prototype will be shown. After every video, the tester will have to answer questions on the specific video. These questions are about the richness of the animation; the details of the 3D object; the level of stimulation and if the specific animation and theme is interesting for a person with dementia. Furthermore, the participants were asked if they had other ideas about a potential interpretation of the theme.

After watching all four videos, more general questions will be asked about their opinion of the prototype in general; if they would use this solution with a person with dementia; if this solution would suffice as a facilitator for communication; if they think that AR is an interesting technology for people with dementia and how AR could be implemented in another form for people with dementia.

Because this test involves a bit of technical knowledge, installing an .apk file on a smartphone; playing videos in a survey, and all answers need to be typed into a digital survey, the researcher has made an appointment with a set of elderly people over the phone to guide them through the process. Being physically present was not an option due to the COVID-19 restrictions. The eldery people did not have to type in the answers in the survey because the researcher noted their responses and remarks in real time.

In total, three call sessions via Skype with eldery people were held, these sessions took on average 60 minutes per person. The sessions were not recorded, as responses and remarks were noted in real time.
Four respondents have filled in the digital Google Form survey. There were no personal questions involved, the survey was completely anonymous.

The answers of the survey and notes of the Skype sessions were copied into a separate document and stored on a secure hard drive. The notes and survey were deleted afterwards.

7.2. Results

The active part of the test showed that the demo page itself was clear enough to understand the working of the prototype. All participants understood what they had to do without any problem and cited that this demo page will be sufficient for people with dementia. The interaction with the six buttons on the music page alters from the rest of the page, yet the respondents noted that it was clear that they could click on the buttons except for one eldery person.

The video of the cat showed that the interaction was insufficient, the animation was too simple and could be more elaborate or some other form of interaction instead of a simple button could be present. An idea would be to be able to pet the cat by sliding on the screen or feeding him food. Using a generic cat would work, according to the participants, although it would work better if the user could choose the colour of the fur for example.

The feedback of the home environment theme showed that using a personal environment of the home would work the best. One respondent said: ‘a generic home environment, like this farm, would work if there were some personalized elements. If a room was shown, the pictures in the 3D room can be personal pictures or a specific fabric on a coach/chair. The personal the better, but that would be hard to implement, I assume.’ The responses of the level of interactivity was sufficient according to half, the other half noted that it could be more interactive. One participant responded with ‘The animations could be more extensive so there are more objects and movement that could be identified with. Adding a tractor, for example, can provoke even more topics of conversation. Other tips on elements and objects that would be interesting within the home environment theme were: a garden with plants and birds; a kitchen, car; music, more farm animals and feeding them.’ One interesting comment was ‘adding scents to the experience. I understand that that is not possible with a smartphone, but different scents will really help with evoking memories.’

The respondents were enthusiastic about the travel page, which shows the camping. The animation of the motorhome was fun to look at, but the level of interaction was too low. A proposition was given in the survey to let the user steer the motorhome with four buttons, yet all but one respondents cited that this would become too complicated. Other ideas that would work for the travel page according to the participants were: a train, boat, island, sea, forest, snow, city square, church, airport, anything related to relaxation.

The sport page was also a good idea according to the respondents, yet very specific to people who like football. One respondent noted that it would be a great idea for men, not so much for women. The idea to show a specific stadium of a favourite football club (or any other sportclub) was confirmed to be a good idea. However, the stadium displayed should be an older one and not the recent updates ones as they will not remember these.

The most interesting observation of this evaluation was that all respondents in the survey indicated that they would use it with a person with dementia to talk about things, evoking memories and having subjects to talk about. The sessions held via a Skype call with older persons resulted more in a conversation about the memories that were triggered by the prototype, than on testing the prototype and answering questions. This is a strong indication that this solution might also work for evoking memories with people with dementia and work as a facilitator for communication. In general, the respondents noted that a specific book for this application, instead of a pre-existing one like a life story book or a photo album, would be more practical. Furthermore, the themes were chosen well and the quality of the 3D objects were lifelike enough, according to the participants. Another remark was that the solution would indeed work as a medium for communication, but that the level of interactivity is simply not high enough to be used as a medium for entertainment. Overall strong points of the prototype, according to the participants were: recognizable themes and objects; recognizable sounds; clear 3D objects and design; quality of audio.

About the general applicability of AR for people with dementia, the participants indicated that it is an interesting technology to work with and could possibly also be implemented as a guide for their daily rhythm. Future improvements could be ‘the use of old songs from their childhood; more interactive and more older objects.

8. Conclusion

In this section, the research questions will be answered.

RQ1: How can Augmented Reality engage people with dementia to participate in stimulating activities?

Interactive stimulating activities in the form of AR content, i.e. 3D objects, animations, sound effects, music, are relevant when they are used as a facilitator for communication between the person with dementia and their caregiver, family member or friend. A way to do this is by implementing AR content in RT sessions, where the AR content directly complements certain memories by providing more details and triggers and by stimulating more senses, visual and auditory. An important factor here is that the AR content must add something to the memory and not replace it; the main memory or main content should be visible at all times.

RQ2: Which interactive stimulating activities are relevant and appropriate with AR?

What has been shown to be relevant and appropriate interactive stimulating activities with AR in this research is categorizing memories by themes and displaying AR content based on these themes. By pressing a button, the AR objects start moving and outputting sound or music. If the quality of the 3D objects, the animation and the sound was rich enough, it was perceived as stimulating. If this was the case, the activity of pressing a single button was sufficient. However, if the 3D objects, animations or sound were not very stimulating - as concluded on the *pet page* (*section 6.1.1*) - the evaluation (*section 7.2*) shows that pressing a single button is not stimulating enough and more interaction, like petting or feeding the pet, should be involved instead of tapping a single button.

RQ3: Which design guidelines are important for enhancing the user experience by making use of AR for people with dementia?

A set of design guidelines and requirements has been established together with four dementia experts, these can be found in *tables 3, 4* and *5*. This list provides some fundamentals, but is far from comprehensive. Designing for people with dementia is complicated: it is experienced in a multitude of ways, it affects people differently and there are multiple graduations from mild to severe. The prototype in this research has been developed for people with a mild to medium case of dementia, therefore, this list is only able to represent a small set of design guidelines to enhance the user experience for people with dementia.

9. Future Work

In this section, improvements on the Hi-Fi prototype and the evaluation method will be given.

9.1. Improvement of the prototype

As the time frame of the development of this prototype was not enough to realize and design enough 3D objects and animations specifically for this project, it would be recommended to do so. By doing this, an overall more consistent design would be present. The same notion applies for the design of the photo book, which is minimal and could be more stimulating by using more graphics and slots for photos.

For this prototype, only five themes were chosen and realized. Other themes might yield interesting results and provide more personalization options. If this prototype would be developed into an actual product, the recommendation would be to design for more templates so the user can choose which one is the most relevant for them.

The interaction of tapping on a single button was not always adequate, according to the evaluation (*section 7.2).* The *music* and *travel page* were perceived as the most stimulating ones, due to more interaction possibilities of the six buttons in the *music page* and the level of detail, animation and sound effects on the *travel page.* An improved prototype could render different levels of interactivity, where some pages are more about passively watching what is happening and other pages have an increased level of interactivity by implementing more game-like elements for example.

Besides the level of stimulation by the interaction, more multi-sensory stimulation could be involved as well. In the developed prototype, only visual and auditory elements are present. In an improved prototype, textures in the book could be implemented, i.e. the texture of hay or grass. Furthermore, as one of the participants in the evaluation (*section 7.2*) mentioned, a device that could output different scents could improve the experience as well. By outputting the scent of grass, with the texture of grass in the book and displaying augmented objects on this grass might be an interesting experience for people with dementia.

Furthermore, more AR elements can be added instead. In very recent AR systems, it has become possible to let real life objects interact with the AR elements. For example: a bowling alley could be shown in AR with digital 3D bowling cones. An actual little bowling ball could be ‘thrown’ on the page and collide with the digital cones. This would improve the amount of interactions that is possible with the book and also contributes to the multi-sensory stimulation by holding a physical item.

9.2. Improvement of the evaluation

To gain more insight on the possibilities of AR for people with dementia, it is highly recommended to evaluate this improved prototype with people with dementia instead of using only proxy testers. Now, the prototype has only been tested on functionality and usability. It would be interesting to research if this prototype is able to revoke memories for people with dementia and what effect this prototype has on communication between a person with dementia and their caregiver.

Next to an actual evaluation with people with dementia, a test to research the effectiveness of this prototype in comparison with a life story book, or other RT techniques would be recommended. In particular, it would be compelling to review if this prototype with AR elements evokes more richness to a certain memory compared to the same photograph or text without AR content in a life story book.

10. Ethical Implications

10.1. Ethical Risk Sweeping

As described in the sections above, this project consists of a mobile application. Because of this, data handling and authorization for specific technology on the device that the application is working on, is an important topic. This is critical for every mobile application, but within this project there is even more at hand:

- The application will use the on-board camera to display and capture very personal information.
- The application only works if it recognizes the personal memories and photos of a specific person, which it retrieves from a database that is coupled to said person.
- The application is made for people with dementia, which means that in some (or even many) cases they don't completely understand what is happening and if something is violating their privacy.

Because of these factors, it is important to set some principles in place that will make sure that ethical implications are being minimised. This can be done by making a clear overview of the stakeholders involved and understanding every party's involvement and how ethical issues are present in all of the communication and processes. This overview should not be a "one-time made document" but a document that is alive and well, constantly updated by all the stakeholders that encounter implications - made by themselves or made by other stakeholders.

In regards to an application that is to be used in the healthcare sector for people that are not fully present all of the time, other people involved in the project are responsible to carry this responsibility. Ethical sweeps are therefore critical.

10.2. Pre-mortems & Post-mortems

Nowadays, projects are getting bigger and bigger and a lot of people are involved: from software engineers, to designers, to testers and to end-users. There are many communication channels between these people to develop a product or idea, with many ethical implications involved. What is important to keep into account, is that these implications should not only be reviewed within their own 'bubble', but addressed in a broad sense of the complete project. One team could see something as a solution, the other one sees it as a technical problem and yet another sees it as an ethical implication. Without clear communication, this can cause major failures in the system overall and a *cascade effect* is in place. Clear communication from all parties involved about issues, solutions, problems and work-arounds should be involved in every step of the design process. Next to this, all of them need to be prioritized before something is to be implemented. It is up to the people with the most overview of the project, call them managers, project-starters or leaders, to keep clear on the vision and goals of the project and how decisions contribute to this vision.

By making use of the ethical toolkit, the project can be reviewed by utilizing pre-mortems and post-mortems in combination with an ethical sweeping protocol as mentioned above. A pre-mortem protocol can be described as another protocol that is not relying on a system to fail and *getting caught* by the risk sweeping process, but is used as a means to find risks beforehand. The goal here is to get creative and find possible ethical risks that might be present. A post-mortem protocol works in a similar way, yet on the other side of the project timeline. If something fails within the system, a post-mortem protocol can be used to review if any ethical implications have caused this failure and how it could have been prevented. Such reflection on failing outcomes enables the project to be better.

10.2.1. Pre-mortems

Software is a big part of developing an application, and as Augmented Reality is a relatively new technology, not many tools are available to develop such an application. That means the system is reliable on this specific system, which may form a problem if that system is not working properly or not reliable anymore.

The application will make use of a database with personal data that needs to be coupled with just mentioned, if compatibility issues will form a problem or that system has privacy issues, the application also faces an ethical problem.

If there is a bug present in the software that results in a fault of the application, the user can get confused. This might normally not be the biggest issue, but this application is made for people with dementia. If something is not working, they might get confused and their emotions might take over because they think they are doing something wrong.

If all systems within the development phase are not constantly checked, issues might pop up that might be prevented before the testing phase.

Clear communication between designers, developers and experts of the field of dementia are critical for the success of the application, if this part does not give enough attention, it might result in wrong usage of the application.

The end users of the application, the people with dementia, might not be able to clearly communicate if the application works, what can be improved and what is not appropriate. Constant checks need to be in place to make sure the application fits and suits for these people that are mentally more vulnerable.

The application is developed to work on multiple devices, but the hardware of the smartphone/tablet might not be enough to handle the 3D rendering and animations. If this happens, the application becomes confusing and results in unwanted negative emotions. A safety check needs to be in place to see if the hardware is adequate to work with the application.

10.2.2. Post-mortems

As this project is only in its development stage, no post-mortems are applicable to reflect on at this time of writing.

10.3. The ethical circle

As mentioned in chapters 1 and 2, a thorough analysis of all stakeholders involved is part of the ethical implications analysis. In the process of developing an application for people with dementia, multiple professionals from different disciplines are able to help and improve the project. The involvement of all these people should be somewhat present in all stages of development, to make sure that ethical implications made in earlier stages are not overlooked and are now prevented. This can be done by setting up review sessions during multiple stages, the responsibility lies with the designer to act on the feedback and potential requirements and risks provided.

The application is meant to aid people with dementia, but these people are not necessarily the person who is interacting with the application. The caregiver, that can be a nurse, family member or friend, is using the application together with the person with dementia. In an ideal case, the person with dementia will interact with the application and talk with their caregiver about what is happening. But sometimes, he/she does not see the causal relationship of their actions, especially in regards with new technology. Therefore, the application should also be designed such that the caregiver can interact with the system, without confronting the person with dementia that he/she failed to interact with it. This example is a small user-case scenario that needs involvement from interaction designers, healthcare professionals and caregivers (people who are familiar with people with dementia).

10.4. User case

Next to the protocols that can be set in place and utilizing a broad ethical circle, an user case is another useful tool that can give insight on any ethical implications. It is especially worthwhile to look into similar projects and their actual user cases. By analyzing them, similar problems that might be present in this project can be found. Four topics of interest are discussed below.

10.4.1. Identifying similar or paradigm cases that mirror the present case

Other similar cases can be described as cases where new technology is used as a medium to facilitate communication for people with dementia. An example would be the user of Virtual Reality goggles to actively engage people with dementia in a virtual experience.

10.4.2. Identifying relevant parallels between/differences among all cases

In regards to the Virtual Reality application, the project is very similar to this one in terms of its goals and type of technology used. The same stakeholders are involved in the process. The difference lies in the use of personal data that is coupled to this application. Where the Virtual Reality application uses predetermined virtual experiences that can be engaged with by every user, this current application provides the stimulation by triggering animation based on markers of personal photographs and memories.

10.4.3. Evaluating choices made and outcomes of the paradigm cases

The choices made in the Virtual Reality project is by using Virtual Reality goggles that are not linked to a specific person. That is harder to achieve for this project, as it makes use of a smartphone/tablet device

that is able to store the personalized marker / photo information. It might be a better idea to use a specific device instead of a personal device for this project, to reduce risk of privacy concerns.

10.4.4. Analogical Reasoning to Risk Mitigation Strategies

To fully grasp what the best decision would be of a user either 1) a personal device that stores data locally or 2) a dedicated device that stores personal data in the cloud (protected and all), an experiment would be the wise choice. What is easier to implement with the Virtual Reality project, although very similar, is not so clear to solve for this project. This experiment or requirement should be discussed with stakeholders and privacy experts.

10.5. Remembering the ethical benefits creative work

With all ethical protocols in place, one should be careful not to lose themselves in all ethical work. While it is important, it is not the goal of the project. By constantly facing new issues, problems, solutions and ethical implications, the purpose of the project should always be a key dominator in the equation of the decision. If all we do is prevent risks the best we can without keeping a clear eye on the vision of the designer, the best decision would be to not do anything at all with the result: all risks are mitigated (hooray!). But then, on other hand, if by doing nothing at all, the project that could have been a solution for a problem forms a risk at all because the solution is not solved. Then, new and other (ethical) risks are involved yet again. Therefore, keeping clear of the why should be the key factor and let the ethical protocols be the decisive of the how.

An application such as this one is important to introduce new technology to the care sector. As of this day, dementia is an incurable disease and the only thing we can do is improve the quality of life of these people, not preventing or curing the disease itself. How much does the person with dementia care about his/hers privacy, if his/hers quality of life is improved in such a way? Where is the line? These boundaries should be clear, and the ongoing search for ethical implications are a great medium to do so, but the goal of the project should be in plain sight all of the time.

10.6. Think about the terrible people

Ideally, we would live in a perfect world and no terrible people would exist that would be able to abuse, steal or do any harm to this project. Unfortunately, this is not the case. This application is developed with all the best intentions with different people involved, but harm can be done by being who are not so

willingly. Personalized data of people that are not fully present anymore is on the line, an easy target, some would say. This data is coupled with deep and profound memories that really define who these people are at this point in their lives. Preventing that these personal information is altered is important and regular checks on all systems need to be sure of this.

Unintentionally, this information might be shared with outsiders by the people with dementia themselves, caregivers, or other people involved. Keeping clear on why this should be private information is critical, and providing and informing everyone involved of the risks of privacy/data leaks should happen constantly.

10.7. Closing the loop

An iterative design process is in most cases a great concept to use. By doing so, all stakeholders are contributing to the complete process every step of the way and this consequently results in multiple feedback loops. This also provides a perfect opportunity to discuss problems and solutions between different teams. Because this happens on many occasions, potential risks that are harder to deal with later on the process are discussed much earlier.

Appendix A: Consent form for dementia experts

Consent Form

Title of project: An Augmented Reality application for people with dementia

I invite you to participate in a research on the application of Augmented Reality (AR) for people with dementia. This research is being conducted from the bachelor programme Creative Technology at the University of Twente. Augmented Reality is a computer system where visual elements are added live to the real world. AR might be helpful for people with dementia because multiple senses are getting stimulated and a multitude of animations and stimulating activities can be made possible because of the system. Because of this new form of technology, it is important to research in which way AR is useful for people with dementia. Next to that, it is important to gain insight in which way AR is applicable and within which boundaries the system will work best.

'I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the aforementioned information brochure 'An Augmented Reality application for people with dementia'. My questions have been answered to my satisfaction. I agree with my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission. If I request further information about the research, now or in the future, I may contact Jonne Schoneveld.

If you have any questions about the research, feel free to contact me:

Mail: j.schoneveld@student.utwente.nl
Skype: j.schoneveld@student.utwente.nl
Phone: +31 6 29435159

If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, P.O. Box 217, 7500 AE Enschede (NL), email: ethics-comm-ewi@utwente.nl'.

Please tick the box if the following applies to you:

- I had the opportunity to ask questions and these were answered to my satisfaction.
- I understand that my participation is voluntary and that I can decide to cancel my participation at any moment without any given reason
- I agree that everything I said during this interview can be used for research (anonymized).
- I give permission for this interview to be recorded (audio).
- I agree to participate in this study.

Note: optional

- I allow the researcher to include quotes from this interview in presentations and articles (anonymized).

Name participant	Date	Signature

Name interviewer	Date	Signature

Appendix B: Information brochure for dementia experts

Principal Researcher: Khiet Truong
Researcher: Jonne Schoneveld

Information brochure
This brochure is meant for experts in the field of dementia, who are willing to provide insight on applicable ways to implement Augmented Reality (AR) for people with dementia.

Description
This research will consist of a (semi-)constructed interview where the researcher will ask questions to gain insight and explore ways to use AR for people with dementia. The interview will take 30 to 60 minutes and will be conducted via phone / Skype. The interview will be recorded (anonymized), only if the participant gives permission via the accompanying *consent form.* The raw audio data will be transcribed, and deleted. The transcribed data will be securely stored.

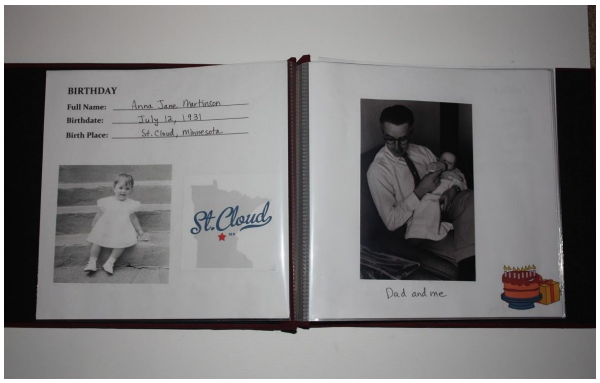
Augmented Reality
AR is a view of the real, physical world in which users find elements enhanced by computer-generated input. These elements can be seen as layers that are added to the real world, complementing the existing world with sounds, videos and graphics.

AR and dementia

Existing solutions with AR for people with dementia already exist and have been shown to be effective. AR opens up the possibility of over-laying 3D information onto the real world, which could improve how well prompting works for people living with dementia.

Using multimedia technology in the form of an Augmented Reality application to evoke personal memories seems to be promising, but I have yet to find applicable ways to design such a system for people with dementia and how to provide a stimulating experience with this AR application.

The initial idea for this project is inspired by the *life story book,* implemented in an Augmented format. With help of a life story book, people with dementia are able to preserve their memories. The book is filled with photos from the past and is an incredible way for friends, caregivers and family members to connect with people with dementia.



Example of life story book

Source: MindStart

Example of AR with a book

Source: medium.com

In this interview, questions will be asked on ways to use AR as assistive technology for people with dementia. During the interview, a very immature demo video will be shown to provide insight in the possibilities and workings of the project.

Risks and benefits

There are no risks connected to this research. Nonetheless, the participant has the opportunity to withdraw himself / herself from this research without any reason.
The benefit from participating in this research is that the participant contributes to academic research that may help develop techniques and applications to aid people with dementia.

Contact

If you have any further questions, feel free to contact me:

Mail: j.schoneveld@student.utwente.nl
Skype: j.schoneveld@student.utwente.nl
Phone: +31 6 29435159

Appendix C: Additional information on AR brochure for dementia experts

Principal Researcher: Khiet Truong
Researcher: Jonne Schoneveld

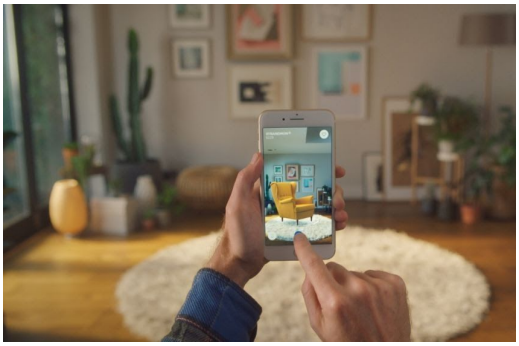
Extra Information brochure

This brochure is an additional document, complementing the original brochure for '*An Augmented Reality application for people with dementia*', to provide better insight in the working of Augmented Reality (AR) and some State-of-the-Art examples of this technology with dementia. This document is meant for experts in the field of dementia, who are willing to provide insight on applicable ways to implement AR for people with dementia.

Augmented Reality

AR is a view of the real, physical world in which users find elements enhanced by computer-generated input. These elements can be seen as layers that are added to the real world, complementing the existing world with sounds, videos and graphics. These layers, in the form of a digital animation, appear in the real environment with the help of 'markers'. The power of AR lies in its ability to create an immersive experience, as it blends into the person's perception of the real world.

Examples of these technologies are the IKEA app, where you can place an IKEA item directly in your own living room. Another great example is the popular game *Pokemon Go,* where you can chase Pokemons in real life.

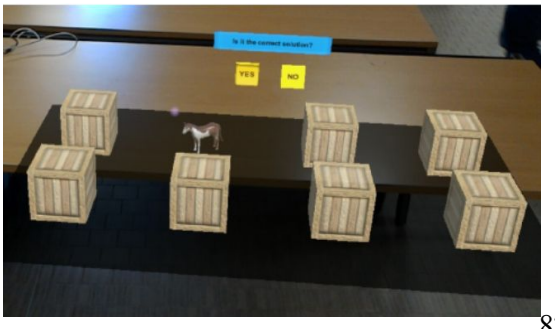


AR and dementia

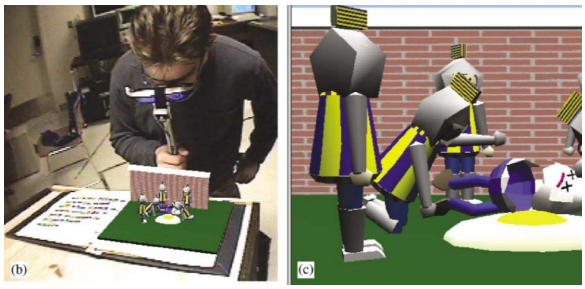
Existing solutions with AR for people with dementia already exist and have been shown to be effective [34], [47], [49], [58], [59]. AR opens up the possibility of over-laying 3D information onto the real world, which could improve how well prompting works for people living with dementia. Other findings were that users engaged in augmented visual-audio interactions evoked by nostalgic elements were very effective as a form of reminiscence therapy. Reminiscence therapy involves the discussion of past activities, events and experiences from the past and aims to evoke memories, stimulate mental activity and improve well-being and is usually done with the aid of tangible prompts such as photographs, household and other familiar items from the past [16], [60].

A strong example of the use of AR for people with dementia is *cARe* [47], where users were able to receive real time cooking instructions without having to read them.

Another interesting use of AR for people with dementia is an application by (Aruanno et al., 2017). This application provides three simple memory games to train



the short-term memory. The application was tested by people with dementia and they had positive feelings about its workings.



A similar project to this one was already made nearly twenty years ago, called *The MagicBook [58]*. It involves a real book with turnable pages. By using AR goggles, the users were able to see the images come to life in 3D space on the page itself. This project showed promising results, but graphic card performance and immersion levels were lacking. Since then, the practicality of AR and graphic card performance has come a long way, which makes it interesting to see how this project can be improved.

Contact

If you have any further questions, feel free to contact me:

Mail: j.schoneveld@student.utwente.nl
Skype: j.schoneveld@student.utwente.nl
Phone: +31 6 29435159

Appendix D: Expert interview questions

Personal

- What is your background? Career / education / history with dementia?
- What gets you excited about this subject?
- Do you have any experience with Augmented Reality?

Explanation of the idea

- Design an Augmented Reality application to engage people with dementia
    - What is Augmented Reality?
    - Augmented Reality can be used in multiple ways, phone or holo lens.
    - Camera or holo lens?
    - To engage people means to spark stimulation and conversation material between people with dementia and family members / friends / caregiver.
    - *Facilitator for communication or entertainment?*
- In combination with 'stimulating activities'
  Example: life story book as inspiration with objects
    - Stimulating activities: *Activities wherein cognitive stimulation is targeted on the individual's mental and social functioning and the individual is engaged with an activity that is meaningful to them.*
- Per page an image of an object that comes to life in 3D with AR, that can be played as / mini game / form of interaction / animation
    - How much interaction? One button? Multiple?
- Adding audio

- What do you think of the idea of using AR?
- What do you think of the idea of the book?
    - How personal? Specific book? Life story book?
- How do you see the practicality of AR for people with dementia?
    - Leaving it lying around?
- Do you think this might work?
    - Why? Why not?
- How do you think that people with dementia are responding to this application?
    - Instructions by caregiver or demo page?
- In what setting might this work best? With who? With caregivers/family members or with themselves?
- Will this application spark conversations or will it lead to more engagement? What do you think?

Constraints

- What are constraints for designing for people with dementia?
- Constraints for using Augmented Reality / a mobile device?
- What is important to keep into account when designing for people with dementia?
    - Lots of color?
    - Big buttons etc?

Functionality

- What should the application look like?
- Should the dementia patients use the application or the caregiver/family member?
- How to navigate and use the application? Use a touch screen? Gestures? Phone sensors?
- How long should one animation / object take?
- How detailed should the objects be?
- How to personalize?
- How can audio really help in this project?
- Divided in themes how can themes be incorporated in the design?)

Design of the book / application

- Should it be a big book? Old book? Other media?
- How much imagery and information on one page?

Brainstorm

- What animations / mini games are interesting?
    - Pouring tea
    - Wandeling door een park
    - Schoonmaak taakje
    - Memory game
    - Play music (piano)

General dementia questions (Task analysis)

- How to use a life story book?
- What are the problems here?
- What is in a life story book?

Is there anything I didn't ask you that you think should be included?

Appendix E: design of the physical photo album book

Inhoud

PIET'S AR BOEK

PAK DE AR APPLICATIE ERBIJ!


03
Huisdieren
[tekstje over huisdier]


04


05
Thuis
[tekstje over boerderij]


06

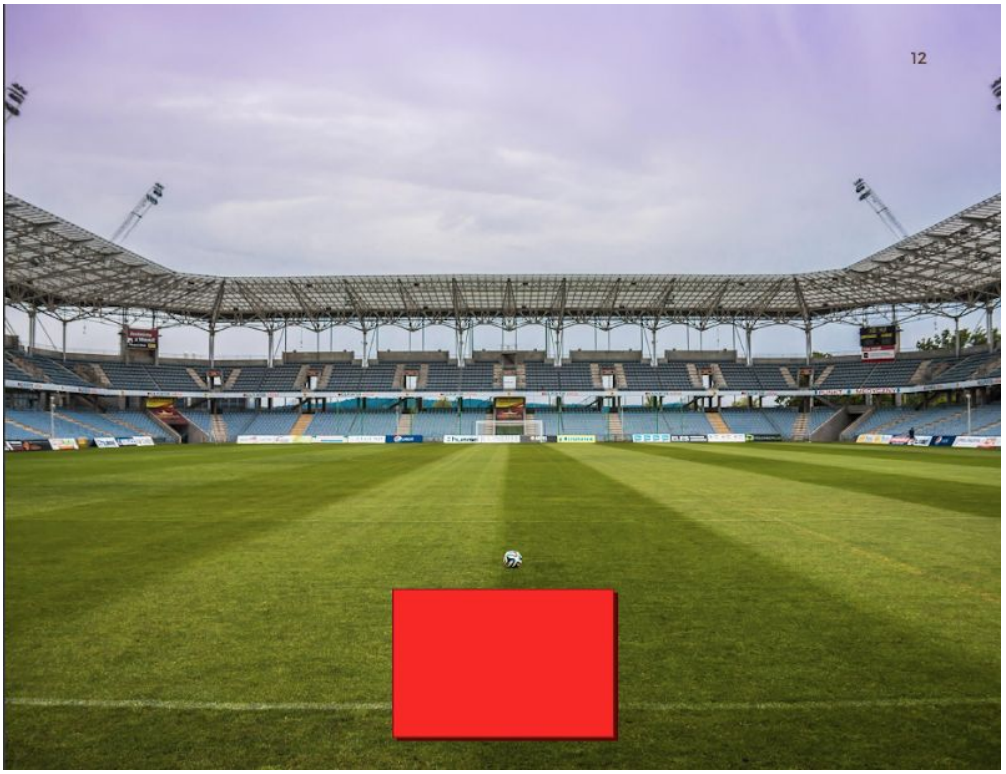

07
Reizen
[tekstje over vakantie]


08


09
Muziek
[tekstje over muziek]


10
YAMAHA


11
Sport
[tekstje over sport]


12

Appendix F: Imported assets for the prototype

3D objects (.FBX files)

FREE Beach Essentials Asset Pack

https://assetstore.unity.com/packages/3d/props/free-beach-essentials-asset-pack-131149

14 Arrow Animations

https://assetstore.unity.com/packages/3d/props/14-arrow-animations-95037

Piano

https://assetstore.unity.com/packages/3d/props/interior/piano-154

Folding Table and Chair PBR

https://assetstore.unity.com/packages/3d/props/furniture/folding-table-and-chair-pbr-111726

Yughues Free Bushes

https://assetstore.unity.com/packages/3d/vegetation/plants/yughues-free-bushes-13168

Sunny Village LITE

https://assetstore.unity.com/packages/3d/environments/fantasy/sunny-village-lite-85199

Tents

https://assetstore.unity.com/packages/3d/props/exterior/tents-21461

3d Soccer Football

https://assetstore.unity.com/packages/templates/packs/3d-soccer-football-137041

The Barns Free

https://assetstore.unity.com/packages/3d/environments/the-barns-free-155403

Low Poly Motorhome 01

https://assetstore.unity.com/packages/3d/vehicles/land/low-poly-motorhome-01-158702

Caravan with Car

https://assetstore.unity.com/packages/3d/vehicles/land/caravan-with-car-99113

Old Samovar

https://assetstore.unity.com/packages/3d/props/electronics/old-samovar-59782

Outdoor Meubels 02

https://free3d.com/nl/3d-model/outdoor-furnitures-02-99510.html

Images (.png or .jpg)

Orange outdoor tent

https://unsplash.com/photos/wTVr4HR4SBI

Man grabbing a green grass

https://unsplash.com/photos/CXKk4zU7anE

Man playing on hammond organ

https://unsplash.com/photos/4yZGWYCul-w

Men playing soccer

https://unsplash.com/photos/4JDaCTFyUfM

Group of men standing on railings

https://unsplash.com/photos/KGvLHzpOiaQ

Sea and shore at daytime beach

https://www.wallpaperflare.com/sea-and-shore-at-daytime-beach-coast-topdown-wave-water-wallpaper-azpyy

Sound effects and music (.mp3, .wav, .aiff or .m4a)

camping spot 07-25.wav
https://freesound.org/people/Kyster/sounds/125877/#

Diesel V8 Engine Start.wav
https://freesound.org/people/vanishing_points/sounds/276477/

catGrowls.wav
https://freesound.org/people/Zabuhailo/sounds/146968/

Cat Meowing
https://freesound.org/people/theshaggyfreak/sounds/274989/

Piano Intro
https://freesound.org/people/HojnyTomasz/sounds/188640/

At the farm.aiff
https://freesound.org/people/ChristiKuhn/sounds/91255/

Benfica - stadium.m4a
https://freesound.org/people/Rosachoque/sounds/463918/

on a wooden ship at sea.wav
https://freesound.org/people/LXX.70/sounds/91071/

oceanwavescrushing.wav
https://freesound.org/people/Luftrum/sounds/48412/

Seagull on beach
https://freesound.org/people/squashy555/sounds/353416/

Football-crowd-GOAL.wav

https://freesound.org/people/paulw2k/sounds/196461/

Appendix G: C# script to record animations in Unity

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEditor;
using UnityEditor.Animations;

public class record : MonoBehaviour
{
    public AnimationClip clip;

    private GameObjectRecorder m_Recorder;

    void Start()
    {
        // Create recorder and record the script GameObject.
        m_Recorder = new GameObjectRecorder(gameObject);

        // Bind all the Transforms on the GameObject and all its children.
        m_Recorder.BindComponentsOfType<Transform>(gameObject, true);
    }

    void LateUpdate()
    {
        if (clip == null)
            return;

        // Take a snapshot and record all the bindings values for this frame.
        m_Recorder.TakeSnapshot(Time.deltaTime);
    }

    void OnDisable()
    {
        if (clip == null)
```

```
            return;

        if (m_Recorder.isRecording)
        {
            // Save the recorded session to the clip.
            m_Recorder.SaveToClip(clip);
        }
    }
}
```

Appendix H: C# script of the Pet ImageTarget

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Vuforia;

public class farm : MonoBehaviour
{

    public Animator catAni, dogAni;
    public AudioClip [] audioClips;
    public AudioSource myAudioSource;
    string buttonName;

    void Start()
    {
        myAudioSource = GetComponent<AudioSource>();
    }

    void Update()
    {

        for (int i = 0; i < Input.touchCount; ++i)
        {
            if ((Input.GetKeyDown("1") || (Input.touchCount > 0 &&
Input.touches[i].phase == TouchPhase.Began)))
            {
                Ray ray =
Camera.main.ScreenPointToRay(Input.GetTouch(i).position);
                RaycastHit Hit;
                if (Physics.Raycast(ray, out Hit))
                {
                    buttonName = Hit.transform.name;
                    switch (buttonName)
```

```
                    {
                        case "catbutton":

                            if
(catAni.GetCurrentAnimatorStateInfo(0).IsName("tailwiggle"))
                            {
                                myAudioSource.clip = audioClips[0];
                                myAudioSource.Play();
                                catAni.Play("cat_idle_3");
                            }
                            else if
(catAni.GetCurrentAnimatorStateInfo(0).IsName("cat_idle_3"))
                            {
                                myAudioSource.clip = audioClips[1];
                                myAudioSource.Play();
                                catAni.Play("tailwiggle");
                            }
                            break;
                        case "dogbutton":

                            if
(dogAni.GetCurrentAnimatorStateInfo(0).IsName("tailwiggle"))
                            {
                                myAudioSource.clip = audioClips[2];
                                myAudioSource.Play();
                                dogAni.Play("walk");
                            }
                            else if
(dogAni.GetCurrentAnimatorStateInfo(0).IsName("walk"))
                            {
                                myAudioSource.clip = audioClips[3];
                                myAudioSource.Play();
                                dogAni.Play("tailwiggle");
                            }
                            break;
```

```
                        }
                    }
                }
            }
        }
    }
```

References

[1] World Health Organization, *Dementia: A Public Health Priority*. 2012.

[2] "Factsheet cijfers en feiten over dementie | Alzheimer Nederland," *Alzheimer Nederland*. [Online]. Available: https://www.alzheimer-nederland.nl/factsheet-cijfers-en-feiten-over-dementie. [Accessed: 03-Apr-2020]

[3] "Symptoms of dementia," *Alzheimer's Society*. [Online]. Available: https://www.alzheimers.org.uk/about-dementia/types-dementia/symptoms-dementia#content-start. [Accessed: 03-Apr-2020]

[4] D. Seitz, N. Purandare, and D. Conn, "Prevalence of psychiatric disorders among older adults in long-term care homes: a systematic review," *Int. Psychogeriatr.*, vol. 22, no. 7, pp. 1025–1039, Nov. 2010.

[5] M. F. Lou, "The use of music to decrease agitated behaviour of the demented elderly: the state of the science," *Scand. J. Caring Sci.*, vol. 15, no. 2, pp. 165–173, 2001.

[6] N. Alm, A. Astell, G. Gowans, R. Dye, M. Ellis, P. Vaughan & A. F. Newell, "An Interactive Entertainment System Usable by Elderly People with Dementia," presented at the Universal Access in Human-Computer Interaction, Beijing, China, 2007, doi: 10.1007/978-3-540-73281-5_65 [Online]. Available: http://dx.doi.org/10.1007/978-3-540-73281-5_65

[7] A. Trzinski and J. Higgins, "Therapeutic Play Activities," *Activities, Adaptation & Aging*, vol. 25, no. 3–4. pp. 121–135, 2001 [Online]. Available: http://dx.doi.org/10.1300/j016v25n03_09

[8] G. Gori, S. Pientini, and A. Vespa, "The selection of meaningful activities as a treatment for day-care in dementia," *Arch. Gerontol. Geriatr. Suppl.*, vol. 7, pp. 207–212, 2001.

[9] L. Clare, J. Rowlands, E. Bruce, C. Surr, and M. Downs, "The Experience of Living With Dementia in Residential Care: An Interpretative Phenomenological Analysis," *The Gerontologist*, vol. 48, no. 6. pp. 711–720, 2008 [Online]. Available: http://dx.doi.org/10.1093/geront/48.6.711

[10] S. J. Czaja, "The impact of aging on access to technology," *ACM SIGACCESS Accessibility and Computing*, no. 83. pp. 7–11, 2005 [Online]. Available: http://dx.doi.org/10.1145/1102187.1102189

[11] Statista, "Statista dossier about Augmented Reality (AR)." 2020 [Online]. Available: https://www.statista.com/study/38227/augmented-reality-ar-statista-dossier/. [Accessed: 23-Jun-2020]

[12] K. Ornstein and J. E. Gaugler, "The problem with 'problem behaviors': a systematic review of the association between individual patient behavioral and psychological symptoms and caregiver depression and burden within the dementia patient-caregiver dyad," *Int. Psychogeriatr.*, vol. 24, no. 10, pp. 1536–1552, Oct. 2012.

[13] H. C. Kales, "Common Sense: Addressed to Geriatric Psychiatrists on the Subject of Behavioral and Psychological Symptoms of Dementia," *Am. J. Geriatr. Psychiatry*, vol. 23, no. 12, pp. 1209–1213, Dec. 2015.

[14] H. C. Kales, L. N. Gitlin, and C. G. Lyketsos, "Assessment and management of behavioral and psychological symptoms of dementia," *BMJ*, vol. 350, p. h369, Mar. 2015.

[15] J. Cerejeira, L. Lagarto, and E. B. Mukaetova-Ladinska, "Behavioral and psychological symptoms of dementia," *Front. Neurol.*, vol. 3, p. 73, May 2012.

[16] pubmeddev and E. al Woods B, "Reminiscence therapy for dementia. - PubMed - NCBI." [Online]. Available: https://www.ncbi.nlm.nih.gov/pubmed/15846613. [Accessed: 10-Apr-2020]

[17] "Reminiscence therapy for dementia." [Online]. Available: http://dx.doi.org/10.1002/14651858.CD001120.pub3. [Accessed: 10-Apr-2020]

[18] P. Subramaniam and B. Woods, "The impact of individual reminiscence therapy for people with dementia: systematic review," *Expert Rev. Neurother.*, vol. 12, no. 5, pp. 545–555, May 2012.

[19] Vardit Sarne-Fleischmann &, "Development and evaluation of a personalised multimedia system for reminiscence therapy in Alzheimer's patients," *International Journal of Social and Humanistic Computing*, Sep. 2008, doi: 10.1504/IJSHC.2008.020482. [Online]. Available: https://www.inderscienceonline.com/doi/abs/10.1504/IJSHC.2008.020482
[20] I. Testad *et al.*, "The value of personalized psychosocial interventions to address behavioral and psychological symptoms in people with dementia living in care home settings: a systematic review," *Int. Psychogeriatr.*, vol. 26, no. 7, pp. 1083–1098, Jul. 2014.
[21] A. Hashim, R. M. Rias, M. F. Kamaruzaman, "The Use of Personalized Digital Memory Book as a Reminiscence Therapy for Alzheimer's Disease (AD) Patients," in *International Visual Informatics Conference*, 2013.
[22] A. V. J. Hulsegge, *Snoezelen: another world: a practical book of sensory experience environments for the mentally handicapped*. [Chesterfield] : Rompa, 1987.
[23] K. Hope, "Using multi-sensory environments with older people with dementia," . *Journal of Advanced Nursing 25*, 1997.
[24] R. Baker *et al.*, "Effects of multi-sensory stimulation for people with dementia," *J. Adv. Nurs.*, vol. 43, no. 5, pp. 465–477, Sep. 2003.
[25] R. Baker *et al.*, "A randomized controlled trial of the effects of multi-sensory stimulation (MSS) for people with dementia," *Br. J. Clin. Psychol.*, vol. 40, no. 1, pp. 81–96, Mar. 2001.
[26] C. L. A. Jakob, "How to make a sensory room for people living with dementia: a guide book," Faculty of Art, Design & Architecture, 2015 [Online]. Available: https://eprints.kingston.ac.uk/30132/
[27] A. Sánchez, J. C. Millán-Calenti, L. Lorenzo-López, and A. Maseda, "Multisensory stimulation for people with dementia: a review of the literature," *Am. J. Alzheimers. Dis. Other Demen.*, vol. 28, no. 1, pp. 7–14, Feb. 2013.
[28] A. Maseda, A. Sánchez, M. P. Marante, I. González-Abraldes, A. Buján, and J. C. Millán-Calenti, "Effects of Multisensory Stimulation on a Sample of Institutionalized Elderly People With Dementia Diagnosis: A Controlled Longitudinal Trial," *Am. J. Alzheimers. Dis. Other Demen.*, vol. 29, no. 5, pp. 463–473, Aug. 2014.
[29] P. Marti, H. H. Lund, M. Bacigalupo, L. Giusti, and C. Mennecozzi, "A multi-sensory environment for the treatment of dementia affected subjects," *Gerontechnology*, vol. 6, no. 1. 2007 [Online]. Available: http://dx.doi.org/10.4017/gt.2007.06.01.004.00
[30] C. K. Riley-Doucet, "Use of multisensory environments in the home for people with dementia," *J. Gerontol. Nurs.*, vol. 35, no. 5, pp. 42–52, May 2009.
[31] T. A. Cleary, C. Clamon, M. Price, and G. Shullaw, "A Reduced Stimulation Unit: Effects on Patients With Alzheimer's Disease and Related Disorders," *The Gerontologist*, vol. 28, no. 4. pp. 511–514, 1988 [Online]. Available: http://dx.doi.org/10.1093/geront/28.4.511
[32] W. D. Hairston, W. David Hairston, P. J. Laurienti, G. Mishra, J. H. Burdette, and M. T. Wallace, "Multisensory enhancement of localization under conditions of induced myopia," *Experimental Brain Research*, vol. 152, no. 3. pp. 404–408, 2003 [Online]. Available: http://dx.doi.org/10.1007/s00221-003-1646-7
[33] "What is Augmented Reality?," *The Interaction Design Foundation*. [Online]. Available: https://www.interaction-design.org/literature/topics/augmented-reality. [Accessed: 12-Apr-2020]
[34] Tsao, Tsao, Shu, and Lan, "Development of a Reminiscence Therapy System for the Elderly Using the Integration of Virtual Reality and Augmented Reality," *Sustainability*, vol. 11, no. 17. p. 4792, 2019 [Online]. Available: http://dx.doi.org/10.3390/su11174792
[35] "Augmented Reality vs Virtual Reality: What's the Difference?" [Online]. Available: https://www.primitivesocial.com/blog/augmented-reality-vs-virtual-reality-whats-the-difference.

[Accessed: 12-Apr-2020]
[36] "Exploring how augmented reality could help people with dementia to carry out tasks - Designability," *Designability*. [Online]. Available: https://designability.org.uk/projects/research-projects/exploring-how-augmented-reality-could-help-people-with-dementia-to-carry-out-tasks/. [Accessed: 12-Apr-2020]
[37] L.D. A. Ferreira, S. Cavaco, S. Bermúdez, "Feasibility Study of an Augmented Reality System for People with Dementia," presented at the International Conference on Artificial Reality and Telexistence, Eurographics Symposium on Virtual Environments.
[38] P. H. Robert *et al.*, "Recommendations for the use of Serious Games in people with Alzheimer's Disease, related disorders and frailty," *Front. Aging Neurosci.*, vol. 6, p. 54, Mar. 2014.
[39] A. Astell, M. P. Ellis, N. Alm, R. Dye, J. Campbell, G. Gowans, "Facilitating communication in dementia with multimedia technology," *Brain Lang.*, vol. 91, pp. 80–81.
[40] N. Alm, A. Astell, M. Ellis, R. Dye, G. Gowans & J. Campbell, "A cognitive prosthesis and communication support for people with dementia," *Neuropsychological Rehabilation*, vol. 14, no. 1–2: Techlogy in Cognitive Rehabilation, pp. 117–134, Jan. 2008.
[41] J. McKeown, A. Clarke, and J. Repper, "Life story work in health and social care: systematic literature review," *J. Adv. Nurs.*, vol. 55, no. 2, pp. 237–247, Jul. 2006.
[42] S Morgan &, "Life review with people with dementia in care homes: A preliminary randomized controlled trial," Mar. 2012.
[43] T. R. Elfrink, S. U. Zuidema, M. Kunz, and G. J. Westerhof, "Life story books for people with dementia: a systematic review," *Int. Psychogeriatr.*, vol. 30, no. 12, pp. 1797–1811, Dec. 2018.
[44] A. Huldtgren, F. Mertl, A. Vormann, C. Geiger, "Reminiscence of People with Dementia Mediated by a Tangible Multimedia Book," presented at the 2nd International Conference on Information and Communication Technologies for Ageing Well and e-Health, 2016, doi: 10.5220/0005758801910201 [Online]. Available: http://dx.doi.org/10.5220/0005758801910201
[45] L. Ferraz, "Augmented Paper in dementia care," University of Surrey.
[46] "Website." [Online]. Available: https://www.surrey.ac.uk/digital-world-research-centre/funded-projects/augmented-paper-dementia-care. [Accessed: 13-Apr-2020]
[47] D. Wolf, D. Besserer, K. Sejunaite, M. Riepe, and E. Rukzio, "cARe: An Augmented Reality Support System for Dementia Patients," *The 31st Annual ACM Symposium on User Interface Software and Technology Adjunct Proceedings - UIST '18 Adjunct*. 2018 [Online]. Available: http://dx.doi.org/10.1145/3266037.3266095
[48] A. A. S. Desai, "Exploring interactions of people with dementia through Mixed Reality technologies: an Observational Study," in *Feasibility of Mixed Reality Technologies for people with dementia*, Vancouver, Canada, 2018.
[49] B. Aruanno, F. Garzotto, M. C. Rodriguez, "HoloLens-based Mixed Reality Experiences forSubjects with Alzheimer's Disease," *Proceedings of CHItaly '17*, September 18-20, 2017, doi: 10.1145/3125571.3125589. [Online]. Available: http://dx.doi.org/10.1145/3125571.3125589
[50] H. Ro, Y. J. Park, T. Han, "A Projection-based Augmented Reality for Elderly People with Dementia," 16 August, 2019.
[51] M Billinghurst H Kato, "The MagicBook: a transitional AR interface," *Comput. Graph.*, vol. 25, 2001.
[52] W. E. A. Mader, "A design process for creative technology," in *Project: Creative Technology*, Enschede, The Netherlands.
[53] N. B. M. Maguire, "User Requirements Analysis," in *A Review of Supporting Methods*, 2002, p. 16.
[54] A. L. Mendelow, "Environmental Scanning," in *The Impact of the Stakeholder Concept*, p. 13.

[55] D. Clegg and R. Barker, *CASE Method Fast-track: A RAD Approach*. Addison Wesley Longman, 1994.
[56] Kootenay Boundary Dementia Core Working Group, "A Guide to Creating a Life Story for Care-giving," 2010 [Online]. Available: https://www.interiorhealth.ca/YourCare/ChronicConditionDisease/Dementia/Documents/GuideLifeStoryTools.pdf
[57] S. Tail, "How To Record Animations While In Play-Mode Unity_(Record Physics Animations)," 23-Jun-2019. [Online]. Available: https://www.youtube.com/watch?v=x9XBdFuzCv8
[58] M. Billinghurst, H. Kato, and I. Poupyrev, "The MagicBook: a transitional AR interface," *Computers & Graphics*, vol. 25, no. 5. pp. 745–753, 2001 [Online]. Available: http://dx.doi.org/10.1016/s0097-8493(01)00117-0
[59] A. Huldtgren, F. Mertl, A. Vormann, and C. Geiger, "Reminiscence of People with Dementia Mediated by a Tangible Multimedia Book," *Proceedings of the International Conference on Information and Communication Technologies for Ageing Well and e-Health*. 2016 [Online]. Available: http://dx.doi.org/10.5220/0005758801910201
[60] A. Spector, M. Orrell, S. Davies, and R. T. Woods, "Reminiscence therapy for dementia," *Cochrane Database of Systematic Reviews*. 2000 [Online]. Available: http://dx.doi.org/10.1002/14651858.cd001120