Developing a Reminiscent VR Game to Enhance Cognitive Function and Well-Being for Older Individuals with Dementia

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Abstract

For this thesis, the possible ways to include reminiscent therapy and cognitive abilities into a game for older people with dementia were explored. The non-pharmacological treatment: reminiscence therapy aims to recall distant memory with conversation and other tools such as objects, art, and, music.

In recent years there has been interest in technological applications such as VR for people with dementia. However, research on this topic is novel and there is yet a lot to discover and be determined for the development of virtual reality games and applications for people with Dementia.

This research project started with a literature review of the current research on the topics: Dementia, design guidelines, technologies, games for PwD, and non-pharmacological treatments. In the second phase, expert interviews were conducted to gain additional knowledge on the current use in the field and more info about the use of virtual reality for people with dementia in the Netherlands specifically. Lastly, an evaluation with high-fi-prototype testing with proxy users was done.

The findings of the evaluation concluded that a VR game can have a positive effect on a person's well-being, stimulate cognitive abilities, and help people recall memories; however, more research is needed to understand how the act of reminiscing can be improved.

Contents

1. Introduction

In the current day and age, societies around the world struggle with the increase of elderly. As people evolve more information is gained through research, and technology is built upon. Through decades multiple diseases have been cured or eradicated by science and technology. This is one of the reasons that people nowadays live longer lives than their predecessors. One disease that is on the rise as more people reach higher ages is dementia [21]. As of now, more than 55 million people in the world have dementia [5]. People with dementia (PwD) slowly lose their cognitive abilities and experience a variety of effects. These can be categorized into three categories: cognitive impairment, functional disability, and behavioral and psychological symptoms [2, 20]. There is no cure for dementia. However, there are pharmacological and non-pharmacological treatments available. Pharmacological treatments include medication used to mitigate the effects PwD may experience [30, 18]. A review of these treatments done by Van De Glind et al. [12] shows that these medications mostly help with cognitive decline and behavioral symptoms. Although their purposes and benefits pharmacological treatments have proven to be less efficient than non-pharmacological treatments. They can have dangerous side effects such as fall risk and occurrences of strokes [27]. On the contrary, research on non-pharmacological treatments has shown positive results in improving cognitive functions and increasing quality of life [16]. These treatments aim to maintain or improve cognitive function to stimulate PwD with their daily life activities and general well-being. For non-pharmacological treatments different therapies exist such as art therapy, music therapy, and reminiscence therapy [25]. The act of recalling memories is an important aspect of reminiscence therapy. Visuals and interactives such as pictures, videos, music, or tangible objects can help with recalling personal memories. The methods of reminiscence come in many forms, visual, taste, scent, and tactile they have in common that are all based on sensory memory (Field, 2023). The purpose of reminiscence therapy (RT) is to evoke discussion and conversation to relive memories. RT has shown beneficial and positive results in reducing depressive symptoms and strengthening the cognition of PwD [31].

In recent years there has been interest in technological applications for PwD. This interest comes specifically from a research, medical, and commercial perspective [19]. Y. Bhargava and V. Baths [19] mention different areas in technology such as lifestyle management, security, autonomy, and assistance which are beneficial for PwD. In a literature analysis done by three main categories are described; connection, moneteration, and cognition. Telecom and other technologies have made human connection and interaction over distance easier. These connections are important to the psychological state of PwD. Monitoring technologies increase autonomy for as long as a person with dementia can retain this autonomy. As dementia progresses it causes people to become more and more dependent on caretakers. Lastly, interactive gaming can be used for cognitive stimulation. Both Y. Bhargava and V. Baths [19] and Pappadà et al. [23] discuss the many uses for technology made for PwD. There have also been various technological applications that encourage reminiscing. One example is a study conducted by Unbehaun et al. [32] where they used a Kinect system with a TV and a controller. The study aimed to improve cognition and physical activity for PwD with games. A different study done by Zhu et al.[35] involved a web application for phones, tablets etc. Participants could remi-

nisce about old memories and save new memories in the application. Lastly, a Virtual Reality (VR) system with the LEAF Cafe game was also tested with PwD [28]. This study indicated the possible use cases of VR for PwD.

For this research project, the aim is to analyze different technologies and reminiscence techniques that could be combined into a game. A literature review will be conducted to discover suitable technologies and reminiscence elements that a game can be based on. With the literature insights, a game will be designed with as goal a hi-fi working prototype that will be tested by proxy testers. The research question that would be introduced for this research is;

How can an immersive VR game with reminiscence therapy elements be designed and developed to assist people with dementia?

Sub-questions:

1. How can reminiscence help people with dementia with their daily activities and general well-being?
2. How can cognitive abilities be improved with technology and reminiscence therapy?
3. How do PwD and their caregivers use current VR and Mixed reality applications?
4. What type of VR game and design are suitable for PwD?
5. To what extent can a VR game for PwD be beneficial for their well-being, reminiscing, and, cognitive functions?

2. Related work

This chapter will cover and discuss relevant literature for this research project. Understanding prior research literature and projects will help with getting a better understanding of the project. This chapter aims to answer the first four sub-questions:

1. How can reminiscence help PwD with their daily activities and general well-being?
2. How can cognitive abilities be improved with technology and RT?
3. How do PwD and their caregivers use current VR and Mixed reality applications?
4. What type of VR game and design are suitable for PwD?

To answer the questions, the literature review will cover topics such as dementia, design guidelines, technologies, games for PwD, and non-pharmacological treatments, including RT. There is a lot of research on the topic of technology as an aid tool for people with dementia. However, when searching for games in combination with dementia, this proved to be more difficult.

Interviews with experts were conducted to discover and gain more insight into game technologies for PwD. The details and results of the expert interview will be further discussed in Chapter 4.

2.1 Dementia

Dementia is a collective term indicating the progressive decline of cognitive abilities. The symptoms get progressively worse. The four most common types of dementia are Alzheimer's disease, vascular dementia, Lewy body dementia, and frontotemporal dementia [8]. The most common type is Alzheimers disease, which affects 60 to 70 percent of PwD.

PwD experiences many effects due to cognitive decline and memory loss. The effects differ per person and stage. There are three stages that PwD go through, the early, middle, and late stages [29]. These stages are also considered mild, moderate, and severe. In the early stage, PwD suffer from minor brain damage. Which part of the brain will be affected first depends on the type of dementia. For example, for people with Alzheimer's, the hippocampus is affected first [6]. The hippocampus is important for learning, long-term memory, memory retrieval, and spatial memory [9]. That is the reason why people who are in the early stages of Alzheimer's tend to have memory loss. As time goes on, more brain parts will be affected, causing more symptoms. In the early stages planning and communication abilities also undergo decline. Orientation, mood changes, and visual perception which help with understanding depth are also impacted. During the middle stage of dementia, mostly the same symptoms occur; however, they are worsened. Additional symptoms are delusions and hallucinations. In this stage, PwD might need more help and could move to an assisted living environment. Due to the symptoms increasing in severity, the physical and behavioral changes will be more prominent in the moderate stage. In the last stage, dementia takes over a person's life. Eventually, they will need full-time assistance with tasks such as washing, cleaning, and eating. The characteristics of dementia are similar throughout all of the types of dementia in the severe stage.

2.2 Reminiscence therapy for people with dementia

RT is one of the therapies of non-pharmacological treatments. Other therapies include art therapy, music therapy, and animal-assisted therapy. These treatments do not only come in therapy forms other forms are household activities, Cognitive and Sensory stimulation, and social relationships management.

The purpose of RT is to evoke discussion and conversation to relive memories. Visuals and interactives such as pictures, videos, music, or tangible objects can help to recall personal memories. The methods to evoke reminiscences come in many forms, such as visual, taste, and tactile. The commonality of these methods is that they are all based on sensory memory [10]. It was found that RT improves the cognition abilities of older adults, specifically in delayed recall. In a study conducted by Gil et al. [11] RT and cognitive stimulation therapy were compared. The results showed positive findings regarding RT. Besides the cognitive improvements, there was also an improvement in well-being which was measured and analyzed with the Quality of Life Scale (QOLS). Although RT has indicated improvement in well-being and cognition, it is unsure whether it lowers the agitated behavior of PwD. In a study that was carried out by Hsiao et al. [13] agitated behavior was monitored while participants undertook art and RT. The research suggests that art therapy decreased agitated emotions, whereas no significant improvement was found for the reminiscence group. However, the researchers themselves indicated that the control group was smaller due to the drop-out rate within the group. The group consisted of eight people. A similar study comparing art therapy and reminiscence was researched by Lee et al. [15]. Regardless of the few positive results regarding cognition and AT and no significant results for RT, the study did not prove statistically meaningful enough. Lee et al. [15] also overlooked the big differences between the AT and RT group activities. The RT group would engage in discussions, listen to music, and look at videos and pictures. On the other hand, the AT group had art-making sessions and made multiple outdoor visits to museums. The previous study mentioned by Hsiao et al. [13] had a similar list of activities, enabling a fair comparison. Perhaps if the RT sessions would include outdoor activities they could prove to be more effective.

To conclude, reliving memories through RT improves cognitive abilities and the general well-being of PwD. The type of activities affects the effectiveness of the RT and should be chosen with that thought in mind.

2.3 Technologies for people with dementia

There are a variety of technologies that could be used for this research project. When considering the options the usability of the technology by the target group which are elderly with dementia should be considered. Also, the effectiveness of the addition of the technology should be considered since the goal of the application would be to encourage cognitive abilities and retain/ delay memory loss. The possible technologies found in the literature include web applications that can be used on mobile devices, tablets, and computers (IoT, such as smartwatches). Other possible technologies are VR, Augmented Reality (AR), Mixed Reality (MR), Kinect, and interactive board games. Technologies such as VR, AR, and MR are considered to be immersive or have an immersive effect. Immersive means to be surrounded, deeply involved, or absorbed by something or a situation. A state wherein the mind feels as if it is somewhere else that is real

even when it is not. Immersion in technology can have many purposes. They aim to be more interactive, and engaging, and possibly have a safer environment [24]. This could be helpful for PwD for example they could be able to wander around in a VR environment safely.

Technologies in combination with Reminiscence

For this literature review, a couple of studies with different types of technology were collected. These technologies were either used for PwD or had reminiscence elements for elderly people. When considering the options the usability of the technology by the target group should be assessed, in this case, elderly with dementia. Also, the effectiveness should be reviewed since the goal of the application would be to encourage cognitive abilities, retain/ delay memory loss, and general well-being.

The first technology is the Kinect, a system that allows users to interact with applications using their bodies through motion detection. A study conducted by Unbehaun et al. [32] used a Kinect system including a TV and a controller. The study aimed to improve cognition and physical activity for PwD with games. It was concluded that systems like the Kinect with a TV create social experiences and collaborative interaction while also providing PwD independence. The games could be played by PwD still living at home as well as those living in nursing homes. Due to the cooperative aspect, social relationships were maintained. Although the system did not focus on reminiscence, the participants did reminisce while using the application. One participant was reminded of her husband when she heard the music used in the application. This indicates that the application made the participant reminisce through music. However, it was also mentioned that one of the limitations of this system is that people with dementia have trouble to fully understand the system. Technical problems did occur during the experiment, which caused negative emotions such as frustration. Furthermore, some participants simply could not be motivated to play the games. Despite the challenges for participants using the system, the overall outcome of the experiment was positive. The key design aspects appreciated by the participants were the level system and the collaborative aspect of the games. Participants could also adjust the game to their interests; This allowed personalization which is beneficial for PwD.

Web applications are the second technology that could be suited for a game for PwD. These are written in computer languages and can operate on different devices. Zhu et al. [35] conducted a study involving a web application for phones, tablets, and other devices capable of running web applications. The web-based application was used to screen the daily activities of PwD. Participants could reminisce about old memories and save new memories in the application. One key concept they used is story sharing which generates common topics and evokes positive emotions. There were no major limitations but the possibility for accessibility improvement within the application was noted.

Another study that included a web application was conducted by Siette et al. [28] where the video game LEAF Cafe was tested. The goal of the study was to better understand the feasibility and acceptability of VR, however the application was not connected to VR hardware. Instead, the environment and design were tested on a mobile screen with a web application. This technology was primarily meant to detect dementia in people by evaluating their learning capacity and cognitive abilities. One limitation of this system is that the variability in screen sizes may have influenced the sense of immersion in the game since each participant used their own mo-

bile device. Other web applications that were also received positively by PwD and caregivers are the Memento smartwatch system [22] and the InspireD reminiscence app [3].

The third suitable technology is VR, in the last couple of years, numerous studies have come out related to VR and reminisce for PwD. Siette at al. [28] conducted more than one study with the LEAF Cafe game. In this research, a VR system was used instead of solely a web application. This experiment also provides interesting insights. In the game, participants could access memories from different VR environments. One of the main conclusions of this study is their evidence suggesting the acceptability and viability of VR platforms for PwD. Participants found the VR game easy and enjoyable. On the other hand, the researchers noted that one of the main challenges is that older adults have difficulty handling the VR equipment. One of the main reasons for this is the stiffness in the hands of older adults and trouble with vision. Siette at al. [28] claim the acceptability and viability of VR application for PwD, however, at the same time they acknowledge the common challenges such as hand motor skills and vision impairment. They do not provide possibilities in which these two conclusions would work together. For example, the VR controls could be better designed to support people who struggle with fine motor skills.

Another study that involved a VR application, conducted by Huang Yang et al. [14], used a VIVE Pro VR head-mounted display (HMD) with two controllers. Photographs, narration, and music of participants were used to help with reminiscence. No significant difference was found in the improvement of cognitive abilities, however, the depressive symptoms improved significantly after the therapy. They also noted that supervision was needed and participants could experience motion sickness when using the headsets. These results differ from a similar study done by Hsiao et al. [13] who reported positive results and found that VR combined with RT was more effective than the regular RT and encouraged cognitive abilities and well-being. Limitations were also addressed, a quarter of the participants were hesitant to use the new technology beforehand. In addition, the sessions were individual and group environments and sessions have proven effective for RT. Giving the VR game a multiplayer option and allowing a group setting can lower the cost. Compared to Huang Yang et al. [14] the study done by Hsiao et al. [13] had a control group.

In a nutshell, a variety of technologies incorporating RT have been explored that could help the elderly with dementia. Games with technology such as the Kinect bring individualism and engage PwD in maintaining social relationships through collaborating during activities. Additionally, in combination with music, it helps reminiscing. Web application platforms provide daily activity screening and memory stimulation. Generated topics that motivate people to talk help with reminiscing. The size of the screen influences the immersion. PwD can use mobile technology and no major limitations were found against the use of mobile devices and web applications. Lastly, VR environments that are recognizable trigger memories. Although PwD initially may be apprehensive about using VR games and its hardware, it is an easy and fun experience once they start using the game. It has proven to be effective and helps with maintaining and improving cognitive abilities and general well-being. For VR technology for PwD, motion sickness, and fine motor skills struggles should be considered and implemented into the design.

2.4 Conclusion

This literature review aimed to discover the current state and developments of game technologies in combination with RT for the elderly with dementia. This knowledge will later be used for designing and creating a game that encourages cognitive abilities, retains and delays memory loss, and aids toward general well-being. Furthermore, with this information, the first two sub-questions can be answered.

Firstly, sub-question one; How can reminiscence help PwD with their daily activities and general well-being?
From the papers and research analyzed, it can be concluded that combining technology with RT is effective in improving the cognitive abilities and the well-being of individuals with dementia. Furthermore added technology to RT is beneficial for PwD. The key elements of RT that have shown positive results in stimulating reminiscence include collaboration, personalization, storytelling, and sensory memory triggers such as sound, touch, movement, and visuals.

These elements of RT can be used in games and activities that can improve their mood, cognitive function, and social interaction, thereby positively affecting their general well-being. Combining reminiscent methods and technologies can have many forms that PwD could use in their daily activities. Examples include the Kinect system and the VR systems in the living area. Additionally, web applications that can operate on tablet-like devices or smartwatches, which offer more mobility.

Secondly, for sub-question two: How can cognitive abilities be improved with technology and RT?
A couple of methods for improving cognitive abilities were found when analyzing the literature. Firstly the act of reminiscencing improved cognitive abilities, particularly in delayed recall. Secondly, the movement elements provided by the Kinect system stimulated cognitive abilities. Although cognitive abilities are very broad, these two elements were identified and both can be implemented in technology.

Thirdly, for sub-question three: How do PwD and their caregivers use current VR applications?
A variety of VR systems were found in the literature. The research papers were fairly recent, being published between 2022 and 2024. The recent publication dates indicate that the topic of VR applications for PwD is currently relevant and actively researched. However, not much information was found on the current use of VR technology by PwD and their caregivers. Further research is needed to explore the current VR systems available and used by PwD. To fully answer this question, more information is required, and this will be discussed further in Chapter 4.

Lastly, for sub-question four: What type of VR game and design are suitable for PwD?
This literature review discussed technologies used by PwD or older people, as the focus of this research project is older people with dementia. From the research papers on different technologies, various design concerns were mentioned. The main concerns for the technology are visual impairment, difficulty with fine motor skills, and small screens that interrupt the sense of immersion. These can be accounted for by for example having text and graphics at a big

enough size. Including buttons that can be pressed more easily with softer and bigger shapes. These findings can be used to create design guidelines for the final high-fidelity prototype of this research project.

In a VR game, the player is surrounded by the environment and thus immersed. For other technologies such as the Kinect and web applications a bigger screen can help. The Kinect also benefits from movement and body engagement which increases the sense of immersion as well [32].

As for the game aspect, while a few of the technologies mentioned above involved a game the types of games were not the focus point of the research. Only the Kinect system compared different activities and games with each other. The Kinect system highlighted two positive game-related findings: the level system and the collaborative aspect of the games. For further understanding, more research could be done surrounding the types of games that PwD can play and reminisce with. This will be further discussed in Chapter 4.

3. Methodology

In this chapter, the methods for this research project will be discussed and displayed. The main method that was used is the creative technology design process [17]. This design process is divided into four parts. The illustrated version of this design process is displayed in 1. It includes three dominant parts; ideation, specification, and the realization phase. Evaluation is the last part which includes testing the high-fidelity prototype. The main aspect of this design process is the circular design, which allows for reflection and correction during the design.

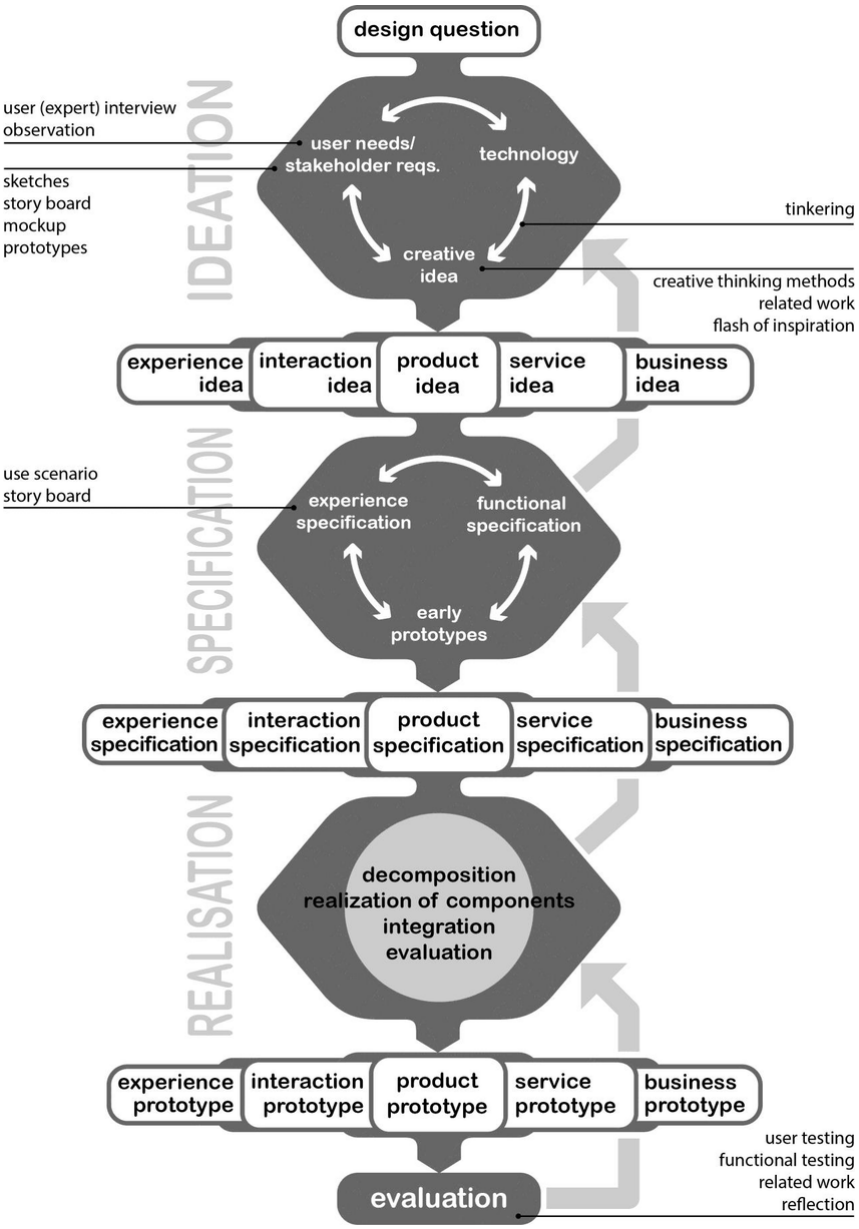

Figure 1: Creative Technology Design Process

3.1 Ideation

Observation

The ideation phase involved a problem statement, research, and creative solutions. The design process developed by Mader and Eggink [17] offers different starting points due to its spiral design. For this project, the 'Observation' section was chosen as the starting point. During the observation, background knowledge was gathered and analyzed. The main purpose of this phase is to understand the research case or problem, which can then be used to generate possible ideas and solutions. This phase included gathering the stakeholders' requirements, conducting a literature review, and assessing the state of the art.

The literature research focused on several main topics: dementia, reminiscence therapy, technologies, and games. The research began with an analysis of papers provided by the supervisor of the research project, involving a total of ten research papers. Additionally, more papers were found through sources such as Research Rabbit and Google. Information and resources on dementia in the elderly population are widely available, as the disease is well-known and extensively researched. Therefore, the literature provides sufficient insights for understanding dementia. Research literature was also available for the other topics, reminiscence therapy and technologies used by People with Dementia (PwD). However, when researching types of games for PwD, the literature was found lacking. Since background information on game types is important for this research project, which aims to develop a game, expert interviews were organized to fill these information gaps.

The expert interviews are also part of the observation phase. The aim was to conduct two expert interviews to gain insight into topics that were still unclear after the initial literature review. Possible participants for the interviews were contacted by email. After the experts agreed to the interview a date was chosen. The interviews were conducted online using Microsoft Teams, which provided options for video recording and transcription. Before the interview, experts were introduced to the research project through an information sheet and a consent form, shown in Appendix A and B. The interviews were qualitative, semi-structured interviews with a few main topics and specific questions. However, the interviews could deviate from these questions if related topics arose. The experts were asked about their experiences with dementia as an introduction. The main focus of the interview lay on what games PwD already use and enjoy playing. What games and which technologies do PwD already use? Also, what are the effects of using these types of games and technologies in their daily life?

Technology and creative solutions

After the observation phase, the gathered information was used during the consideration of technology types and creative solutions, two important concepts of the ideation spiral. This idea-generation phase included brainstorming and tinkering. Tinkering is a creative way to come up with solutions often it encourages solution crafting with the help of objectsfor example, cardboard, pens, Legos, etc. Finally, the concepts created were compared to each other to determine which one would be selected for further stages.

3.2 Specification

This was the second phase of the design process, where the final concept formed during ideation was further developed. To gather all the necessary details, this phase focused on the experience and functional specifications. The experience specification entailed the interaction between the game and its users, designed through a scenario storyboard. On the other hand, functional specifications outlined the essential elements required for the game to function properly, including the technology specifications needed for high-fidelity prototype development. To gain insights into the game experience of the user, low-fidelity prototypes could be used. Low-fidelity prototypes are early prototypes; an example is paper prototypes which include sketches that capture and display the ideas. With the results, the chosen design requirements were evaluated. Furthermore, the possible design, concept, and usability problems or missing elements were identified.

3.3 Realisation

After the specifications were clear the realization of the high-fidelity prototype could be made. The realization phase focused on the creation of the game with the specification details as fundamental building blocks. The components of the game such as software, hardware, assets, and audio were developed and integrated. The finished prototype was tested during the evaluation phase. This stage is also a part of the realization phase however for this research project the evaluation would be a separate and final stage of the design process.

3.4 Evaluation

This was the final phase of the design process. The prototype developed in the realization phase was put to the test. The testing process was divided into two parts; the functional prototype test and user testing. The functional operation of the prototype was tested first, as a malfunctioning prototype could negatively influence and disrupt the user testing phase. For user testing, proxy testers and experts were asked to evaluate the prototype. The information gained was then used to assess the prototype. User testing is essential for discovering to what extent the prototype meets the users' needs. Ultimately, the gathered information could be used for future improvements and development.

4. Ideation

In this chapter, the ideation phase is discussed. For the observation method previously mentioned in Chapter 3 a literature review and a state of the arts were conducted. These were discussed in chapter two. This chapter will focus on the other elements of the ideation such as identifying the stakeholders, establishing the requirements from the literature review, and brainstorming.

4.1 Stakeholders

The game will be played or interacted with by stakeholders such as the caretakers, the family members, and the elderly with dementia. In Table 1 the stakeholders are identified and given an importance level.

Table 1: Stakeholder Identification

Stakeholder	Role	Importance level
Person with Dementia	Users	10
Family members	Users	8
Caretakers/medical professionals	Users, Setting up and interacting with the game	8
Corporations	Commercialization	4
Project supervisor	Decision makers	6
Designer and Researcher	Decision makers	6

Person with dementia

The target group for the game is PwD. The game of the research project is made for this group, making them the most important stakeholders. They should be closely considered since their requirements are the most important. They can also be seen as the dominant stakeholders. The decisions made on the concept, design, usability, and functionality will heavily rely on their needs.

Family members

Besides the player's family members might also interact with the game and set-up. If they want they can also play the game. They can also aid the players with setting up the game and equipment if needed. Family members can play a big in whether they allow their loved ones to play the game. For example, if a person with dementia is still living on their own a family member could buy the game. Stimulating cognitive function and improving well-being can result in the person with dementia suffering less. This in turn can make the loved ones feel more at ease and make them worry less since nobody wants to see their loved ones suffer.

Caretakers and Medical Professionals

These stakeholders will interact a lot with the game as well. If the VR game is used and placed in a nursing home caretakers will have to set up the game and its equipment. Caretakers can be seen as medical professionals, however, other medical professionals could also interact with the game. For example, a medical professional could hold sessions including the game. Although this application was meant for dementia screening, not specifically game playing.

Corporations

Currently, there are already companies that sell VR experiences for the elderly with dementia. Examples are Recreo VR [1] in England and Virtuele Dromen [2] located in the Netherlands. Those companies could take inspiration from the research project and broaden the market. Their main interest is to sell and provide technology for their customer use cases. These companies also act as a state of art, showing what already exists and is used. This stakeholder does not directly influence this project which makes them the lowest contender on the stakeholder importance level.

Project Supervisor and Developer

These stakeholders will make to most important decisions in this project. Their interest is to research and design a well-functioning game that will improve the daily lives of the target group. The task of the developer relies on the research done which also influences the design. The research will be done by the developer, and after this is completed the design and product will be developed by the developer. The supervisor is the one providing this research project together with the HSI department. Their main role was to guide difficult decisions and keep track of the process.

4.2 Expert interview

In this section, the conducted expert interview will be discussed. The gathered information will be used to finalize the answers to the third and fourth research sub-questions.

Interview with expert

As mentioned in Chapter 3, Methodology, expert interviews were held to gain further insights between games and PwD. Two experts were contacted via email, both were interested and agreed to participate. Unfortunately, one of the interviews, with an expert working with VR and PwD, fell through.Thus, only one expert was interviewed, and this interview was held online.

The expert had more than five years of experience in research regarding design for PwD. Furthermore, the expert worked at the Expertise Center for Dementia and Technology [3] at the Eindhoven University of Technology. Much information was gained from the interview. The expert specified that the games PwD play depend on culture, history, and country. Applications should be designed with a very specific target group and their knowledge in mind. An example

[1] https://www.recreovr.co.uk/

[2] https://www.virtueledromen.nl/

[3] https://www.tue.nl/en/research/research-areas/humans-and-technology/mental-health-technology/expertise-center-for-dementia-technology

given during the interview was a quiz organized by caretakers, which included local historical events.

The expert also had knowledge on current played games by elderly with dementia in the Netherlands. It was mentioned that games and stimulating reminiscence are a part of the daily activities in care homes. Examples of these games are Rummikub, cards, pop quizzes, and Longfield. Another important aspect was the tangible part of games or applications. Getting to hold on to things that were made during different activities. For example, if there was an art activity the participants could hold on to the art piece. This also helps with remembering and reminiscence. The expert noted that being in nature and having animal interactions can have a positive impact on PwD. This is also used in animal therapy.

The technology used by PwD was also discussed. Technologies that came up included iPads and tablets, PwD can use these technologies independently. Although there might be a learning curve, PwD are capable of learning to use new technologies, especially in the early stages of dementia. Another technology used by PwD was the Wii, a home video game console with a variety of game options. In 2013 the Wii was discontinued, however, there are still people using it. The developers of Nintendo launched the replacement of the Wii in 2017, the Switch.

The expert highlighted the most important aspects to consider when designing for PwD. These aspects can be taken into consideration for the design requirements of the game. Simplicity is key, applications should not be overly complex as this can lead to an overwhelming experience for the user. Complex systems can be divided into simpler parts to ensure simplicity. The visual appearance of the design should not resemble something meant for children, rather, it should have a simplistic design that appeals to older adults. Lastly, the expert noted that PwD might have trouble with fine motor skills, and bigger movements such as arm movements might be easier for them.

Conclusions

The combination of the literature results and the insights from the interviews gave enough information to answer the third and four sub-questions:

3. How do PwD and their caregivers use current VR and Mixed reality applications?
4. What type of VR game and design are suitable for PwD?

VR aplications are used by PwD in the Netherlands, it is up and coming and it is not yet widely accessible. This finding aligned with what the literature review showed. The literature had been unclear whether PwD actually used VR equipment, which was confirmed after the expert interview. The expert did not have specific knowledge of design guidelines for a VR game. However, general design guidelines for application for PwD were discussed. Together with the previous VR and other technology design aspects, a list of guidelines was be formed. The list is displayed in Table 2. As for the type of games, these can vary as long as the target group is familiar with the topic, which they can reminisce about. Examples include daily activities, nature, animals, and, music.

Table 2: VR Game Design Guidelines for PwD

Design Category	Design Solution
Visual Impairment	Size adjustability in the game for text and other elements.
Difficulty with Fine Motor Skills	Buttons that can be pressed more easily with softer and bigger shapes. Bigger arm movements instead of hand movements.
Motion Sickness	Players should be seated during the game. The sensitivity of the movements should be low, with slow movements
Game Fun	A level system, with an achievements system.
Appearance	Realistic style and not based on cartoon styles.

4.3 Requirements

A few main moral values were established during the brainstorming and literature review of this project. Firstly the game must be easy to use and play. The game has to contribute to the main goals which are, contributing to the well-being of the target group, stimulating cognitive abilities, and making the player reminisce about their past. Another important value is that the game must not create hindrances in the current work of the caretakers or medical professionals. If the game is played in a nursing home, it should not cause stress for the staff. To establish the requirements the MoSCoW, a technique that helps with prioritization and managing requirements was used. The established requirements are shown in Table 3.

4.4 Concepts

The initial concepts were created by brainstorming. The first brainstorming session was a verbal and written brainstorming session. Where ideas were discussed with people and random ideas were written down. After the literature review, more ideas were developed. After this unstructured brainstorming phase, the more structured brainstorming method was used. The initial ideas were placed on a grid, this led to the combination of initial ideas and new ideas to fill up the gaps. The technology and the game concept were divided during the brainstorming process. For example for a farming game, Wii and a VR environment can be used, in both the overall theme would then be farming. However different game ideas can be made with the concept of farming.

Preliminary Concepts

For the top of the brainstorm grid, a few technologies were chosen based on the knowledge gained during the literature review. They can be categorized into Web applications, VR/ AR, MR, and Wii/ Switch technologies. They have different challenges and benefits. Web applications are accessible since they work on many devices from mobile to computers. Some people with

Table 3: Requirements Table

	Requirements
Must Have	• Game features • Cognitive stimulation • Reminiscence effect
Should Have	• Easy set up • Audio • Visual pleasing
Could Have	• More mini-games • Personalization adjustments • A multiplayer option
Wont Have	• Multiple walking options

dementia are already familiar with these devices and technology making the learning curve shorter. There are also many different software and code languages which brings a lot of possibilities. The mixed reality technologies are still novel when looking at the research available. However, the studies done so far show promising results. Of course, the challenges such as motion sickness and fine motor skills difficulties should not be forgotten. Technologies such as the Wii and Switch are accessible to the public and nursing homes. They also have controllers that put less strain on the fine motor skills that the elderly with dementia might struggle with. Additionally, they add an element of physical activity. The Wii or switch can be connected to a TV which increases the immersion.

The vertical section of the grid contained possible game settings and topics such as farming, daily activities, nature, history, art, and sports. The goal was to come up with many creative games. In Figure 4.1 all of the generated ideas are shown. From the grid, the three most promising and interesting ideas were chosen: the AR Board Game, the VR Nature Environment, and, and the Wii.

From the brainstorming session, the three most promising concepts were selected. The concepts are described below. The concepts were then compared to each other and finally, one was chosen for further development.

AR Board game

This idea was inspired by the AR photobook [26]. During the expert interview, the board games that PwD enjoy playing were discovered. It was also discovered that PwD can benefit a lot by using tangible objects this in turn stimulates sensory which is a crucial part of memory re-

taining. The idea that came about from the grid was a board game with the topic of daily life experiences or occurrences. The board game would have a similar layout as the Dutch game Ganzenbord. This is a childrens game where players move forward on a path with the throwing of dice. The winner or winners are the ones who arrive at the finish line at the end of the path first. Ganzenbord is based on goose but for this research project, the daily life activities would be more suitable since more reminiscent elements can be used with a broader topic. The board game would illustrate rooms and places where people live. At different spots, they could have to pick up a card with a question for reminiscing or a card with action on the board. A sketch of the idea can be seen in 2.

Figure 2: AR Ideation

VR

A nature-inspired environment where players can experience nature and play games, a combination of a calming yet fun environment. During the literature review, wandering and PwD were explored, concluding that PwD like to wander, and in VR they would be able to do that. Another positive aspect was the 3D aspect of VR which can stimulate the hippocampus in the brain. The environment could have a variety of mini-games such as memory games, ball/ ring throwing, cards, and Jeu de Boules. An example of a memory game could be: A game with a few memory cards, the memory card could not only have visuals but also sound. When a dog card is shown, there would also be a barking or other dog sound. This way the player has two indicators that will help them to remember the location of the cards.

Wii

The idea of a Wii or Switch game was promising, the technology is already used by PwD. Next to that, it can bring immersion without the motion sickness risk of VR. Similar to the other two technologies many different topics and concepts could be incorporated in a Wii/ Switch game. Unfortunately, the Wii technology is not supported by its company anymore. Which could eventually lead to the technology becoming older and buggier without easy solutions to counter this. The Switch is a good replacement for the Wii, however, the development tools are difficult to obtain making it unfeasible to develop a Switch game for this research project.

4.5 Final Concept

For the final concept, the VR idea was chosen. The VR game is designed on the notion of older

peoples fondness for wandering, providing them with a stimulating and engaging experience. In this virtual setting, players can explore a park, and partake in mini-games and reminiscent activities. Walking in a 3D park experience helps stimulate the hippocampus in the brain, which is crucial for functional and spatial memory. This VR setup aimed to create an enjoyable and beneficial experience for PwD, combining the joy of wandering with mini-games and activities.

5. Specification

5.1 Specification of final product

In this section, the final game will be described in detail. There will be two parts; the design and technology part. The specification will entail a description and the necessary components.

Design Specification

The design specification revolves around the environmental setting and the game setupdetails indicate how it will be displayed and function together.

The environmental design was inspired by a typical Dutch park. Dutch parks have existed for a long time and have been valuable for people of all ages. An example of an old park is the Vondelpark in Amsterdam, which opened in 1878 [33]. Dutch parks have had a positive effect on the well-being and health of park visitors [4]. The mood board and sketches for the layout of the park are shown in Figures 3 and 4. The 3D objects included in the park were benches, grass, Dutch flowers, trees, lampposts, butterflies, birds, and ducks. In addition to visual park elements, ambient sounds, and sound effects were incorporated into the design. Audio such as birds chirping, wind sounds, and music were included. A complete list of sounds can be found in Chapter 6. The background music was intended to be relaxing yet fun.

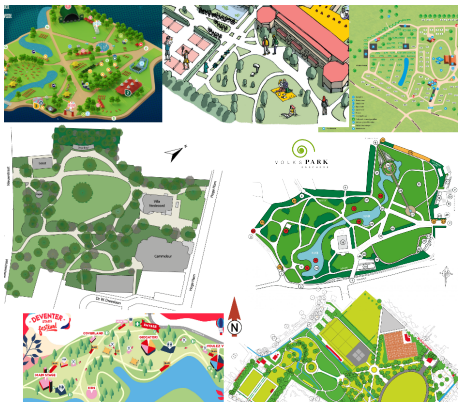

Figure 3: Park Mood Board

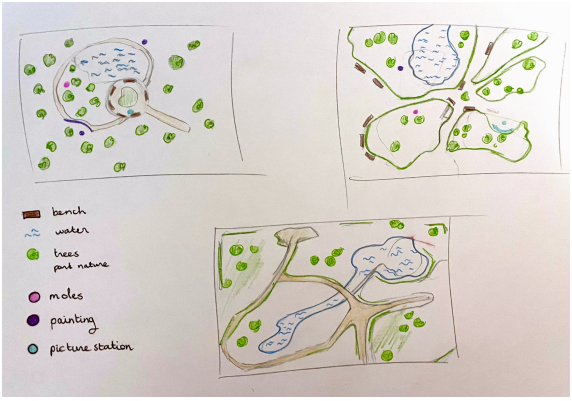

Figure 4: Park layout Sketches

The game design featured a few different games, providing the player with a sense of free-

dom and autonomy. The first game was 'Whack-a-Mole,' where players had to hit moles that appeared from holes in the ground. Other activities considered included ring throwing, memory games, and jeu de boules. However, offering too many choices could lead to confusion and undesired results, so a maximum of three game elements were selected. These games were designed to encourage hand and arm movements, aimed at stimulating cognitive abilities, a benefit supported by findings in the literature review. The second activity was painting, where players could paint on a canvas mounted on an easel. This activity offered two modes: painting with and without a reference or prompt. The final activity in the game would be a feature that specifically focuses on reminiscence. A camera that functioned like a real one, allowing players to take pictures of the environment at any time. If players did not take the initiative to use the camera, they were gently guided with traffic signs indicating scenic spots for photos. In the introduction, they can also have a tryout with the feature. After they have taken a picture they would see a preview together with a question.

Technology Specification

For the VR equipment, the Meta Quest 3 was chosen, which is the newest VR set from Meta. Figure 4 displays the Meta Quest 3 VR set. The equipment is provided by the Interaction Lab [4] at the University of Twente. They also offer other brands and types of VR gear that were considered for this project, including the HP Reverb G2, HTC Vive Pro, HTC Vive, Oculus Quest 2, Meta Quest 3, Meta Quest Pro, and the Valve Index. Ultimately, the Meta Quest 3 was selected because many games have already been developed using it. The hardware and software are the most reliable, and it has good documentation, which is beneficial for troubleshooting and debugging in development mode. Additionally, switching between VR environments and reality while wearing the headset is easy, which allows for more efficient development.

Figure 5: Meta Quest 3

Figure 6: Meta Quest Controllers

[4] Interaction Lab: https://www.utwente.nl/en/eemcs/interaction-lab/

The Meta Quest 3 comes with two controllers, one for the right hand and one for the left. For the high-fidelity prototype, seven elements of the controllers were given a function. On both controllers, the two largest buttons located beneath the thumb hold and the index finger were used for grabbing, holding, and right-click operations. The right and left joysticks were used for navigation throughout the game. Lastly, the B button was used for the camera feature.

For the game development software, the Unity Engine was chosen. The Unity Engine has been used for VR game creation before and provides templates and designated packages, which are beneficial for VR game development. Another important component is the computer or laptop. The Unity software and VR equipment must be connected to a computer to function together. The Meta Quest 3 requires a computer with a good Central Processing Unit (CPU) and Graphics Processing Unit (GPU) combination to properly run VR games.

5.2 User scenario

A user scenario helps to understand the possible usage ways of a player. It also displayed possible walkthroughs that a player can have in the game, Figure 7 shows a user scenario with the main elements of the game.

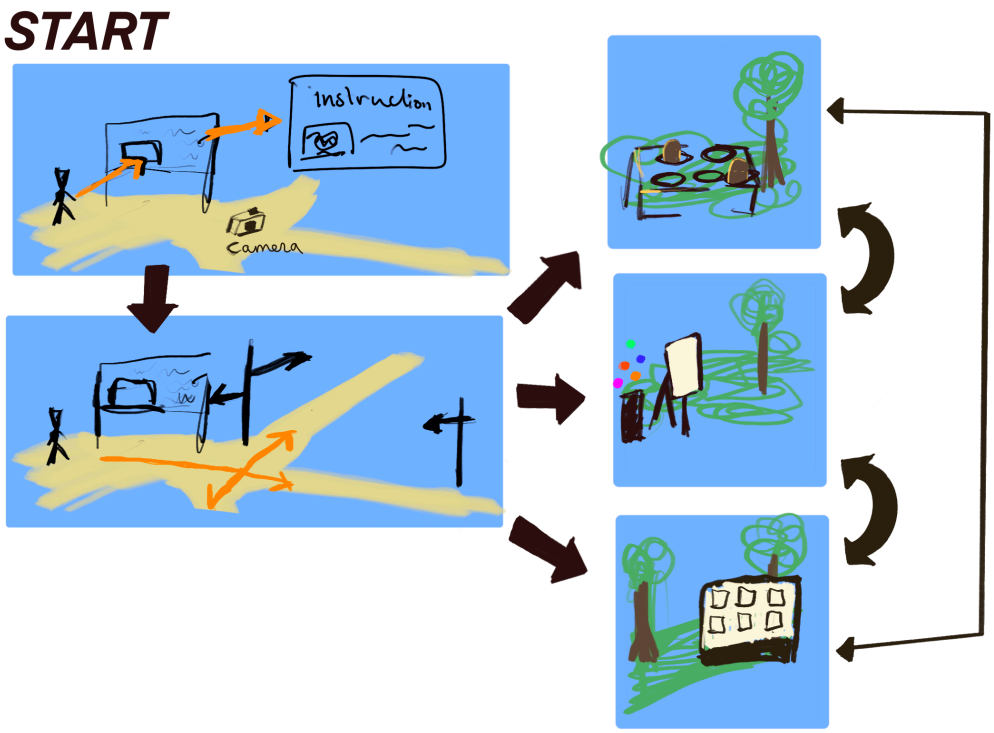

Figure 7: User Scenario

Players aged 60 and above will enter the VR environment. At the start, they will see an information board in front of them that explains which buttons on the controllers are used in the game. Players will receive instructions on how to capture their first memory by taking a picture. After taking the picture, they will see a two-dimensional (2D) preview in front of them. Additionally, a question will be asked through both text and speech.After the initial introduction, players can wander through the environment. The walking path and signs will indicate where they can walk, but deviation from the path is allowed, enabling players to walk through

the grass and nature. There are three activities they can walk towards: the Whack-a-Mole game, the painting activity, and the memory collection area. The first option is the Whack-a-Mole mini-game. Players will see a table with six mole holes and a User Interface (UI) next to the table displaying the word Start. A hammer is also visible on the right side of the table, with a 2D UI prompt above it saying, "Please pick the hammer up!". If the player presses the Start button before picking up the hammer, they will be instructed by text to pick it up first. Once the player grabs the hammer and tries to swing it, moles will start popping up from the table. Players must try to hit as many moles as possible. Different sound effects play when the player hits a mole or the table. By knocking out three moles the winning goal of the game will be achieved, and the words 'Winner' appear. Next, the option to proceed to level two will appear. In level two, players must hit four moles instead of three. Moreover, the difficulty increases with two types of moles, each having a different color. After winning the second level, players can choose to end the game or restart it.

The second option is the painting activity. When they arrive, players see a painting canvas on an easel, with brushes and a paint color palette on a table to the left. The UI text on the blank canvas allows them to choose between starting with an empty canvas painting or a painting with a reference. After making their choice, they can begin painting on the canvas. Throughout the game, players can take pictures of their environment and find vantage points in the park. Near the starting point where the information board is located, players will find the memory collection area. Here, by clicking on a picture, they will be asked a question related to the picture.

5.3 Non-functional and functional requirements

Defining the requirements can help make the game more specific and aid in determining what is important or not when dilemmas arise. The requirements can be divided into two sections: functional and non-functional. The functional requirements refer to the essential components needed for the game to operate properly. The non-functional requirements focus on the experience delivered to the player, ensuring an overall positive feeling towards the game. The requirements in this chapter are based on the MoSCoW method in Chapter 4 and the ethical analysis done regarding this research project [7].

Table 4: Function requirements

#	**Functional Requirements**
1	The rotation of the player in the VR environment should be slowed down to lessen the chance of motion sickness.
2	All of the hardware should be well charged beforehand and placed in the charger when playing the game since VR systems are heavy on batteries and power.
3	Players must be able to exit the game easily when they want to, the feeling of being stuck in an environment can result in undesired scenarios.
4	When in the VR environment safety of players, objects and others around them must be ensured.
5	Objects and other elements in the environment must be placed proportionately to not cause disorientation.

Table 5: Non-functional requirements

#	**Non-functional Requirements**
1	The game should be visually pleasing.
2	The speech voice should be kind and calm.
3	Players should have fun playing the game.
4	The system should not be difficult to interact with.
5	The system and game should be easy to set up.
6	Cognitive abilities should be stimulated.
7	Players need to be able to reminisce in the game.

6. Realization

In this chapter, the realization of the final high-fidelity prototype game is described. The main design choices were discussed, and the development process was displayed. The key parts of the Virtual Reality (VR) development were the environment and the game activities.

6.1 Design Choices

At the beginning of the development, specific design choices were made regarding the Unity project details, the VR details, and the park design setting.

Unity Project Details

The Unity VR Core template [5] with Universal Render Pipeline (URP) [6] was used. The pipeline affects the rendering options and functions. The template used is shown in Figure 8. In this template, camera setup and controller functionality were already set. Furthermore, the XR Plug-in Management [7] was used for the main functions of the VR setup and equipment. The Meta Quest controllers and headset were assigned in the XR management settings.

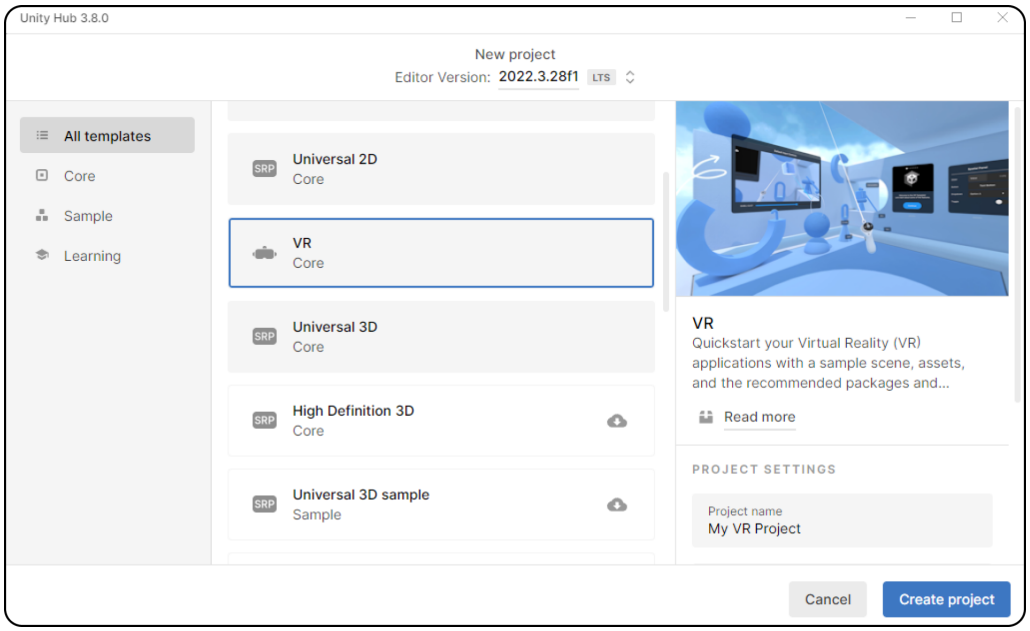

Figure 8: Unity VR Core template in Unity Hub Editor

Players stance in the VR game

In VR environments, users often see a representation of their hands and sometimes their entire body to create a sense of where their hands and body are in reality. The VR template that was used came with a representation of the controllers. This feature was kept since the players would have to press buttons on the controllers, and seeing the representation of the buttons could be beneficial. Figure 9 shows a comparison between the VR hands and the VR controllers.

[5] https://docs.unity3d.com/2022.2/Documentation/Manual/xr-template-vr.html
[6] https://docs.unity3d.com/Packages/com.unity.render-pipelines.universal@17.0/manual/index.html
[7] https://docs.unity3d.com/Manual/com.unity.xr.management.html

In the game for this project, the player was shown the Meta Quest 3 controllers, with the lines coming from the controllers displayed in white instead of red as in the example in Figure 9. From the specification was decided that participants should be seated, this affects the camera height that is needed to create a natural feeling. Another aspect from the specification chapter is the use of a maximum of six buttons and the preference for using the largest buttons to counter fine motor skills troubles.

Figure 9: Hands versus Controllers visual representation

Park Setting

For the park setting, spring and summer seasons were chosen in the early design stages. During the development stage, assets that matched these seasons were prioritized. (For example, the Netherlands is known for having bright grass due to the humidity retention and rain thus a bright green color was chosen for the grass in the game.)

6.2 Environment

The realization of the high-fidelity prototype started with the designed map created in the specification. Unity has a built-in terrain feature that can be activated, allowing designers and developers to paint on a 3D plane using 2D textures. Figure 10 shows the final sketch and the 3D-painted plane, including the two main textures used for the grass and walking path.

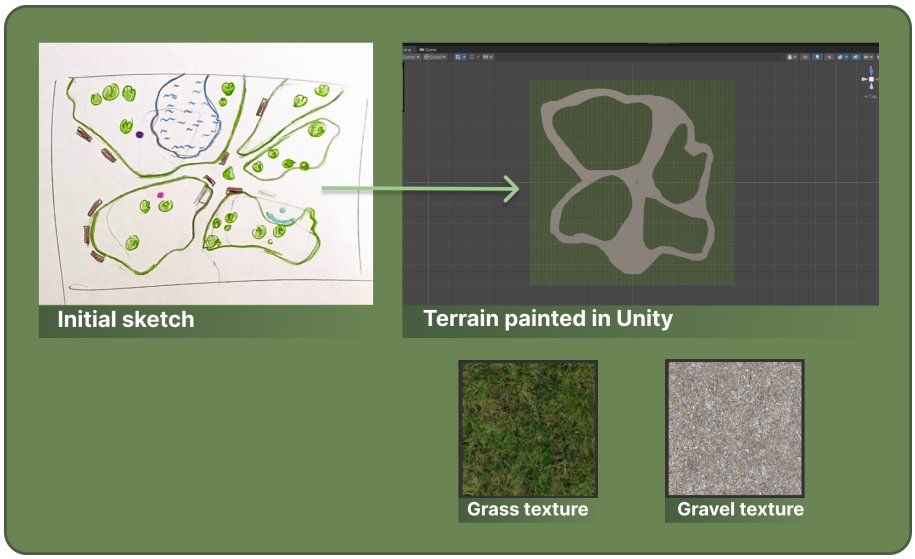

Figure 10: Terrain Realisation

The environment is one of the most important aspects of the game. Players will be in contact with their surroundings during the entire game. Creating a sense of endlessness is necessary for the player to believe that they are in a park. Additionally, falling off the park terrain can be dangerous and result in a free fall into nothingness, which can feel very real in a VR environment and cause fear and panic. To avoid this players are forced to stay within the boundaries shown in Figure 11. However, they must not feel these physical boundaries. To achieve this, the edges of the terrain were raised to create hills that block the falling-off areas. The initial terrain did not provide enough room for raising the hills, so the edges could not be fully blocked, and the path was disturbed. The best practice in this case would have been to redo the terrain and start from scratch. However, due to time constraints, this was not possible, and a second terrain was added to surround the initial terrain. This is displayed in Figure 12.

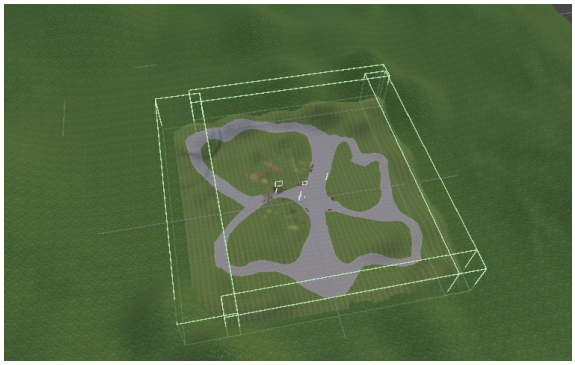

Figure 11: Blockage of Environment

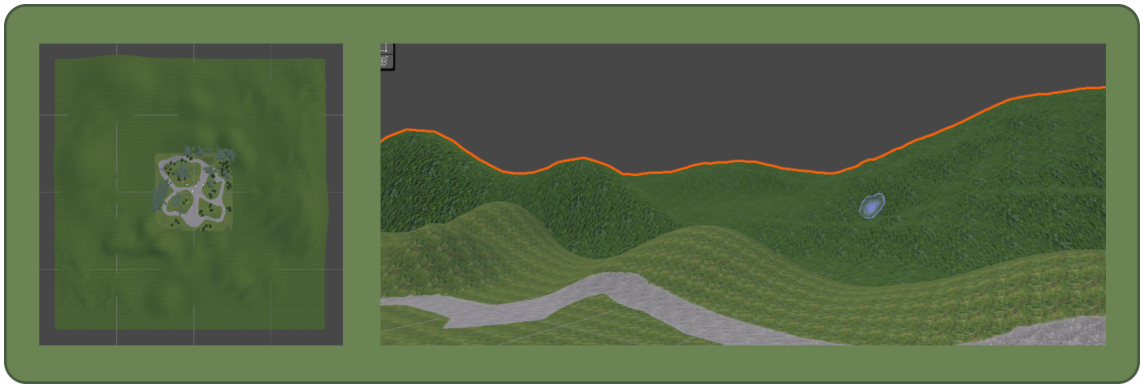

Figure 12: Second terrain surrounding the initial terain

As the terrain base was finished, other necessary elements for the park creation were added. Although many free realistic nature objects were available, the shaders in Unity were not working well together. Shaders in unity determine the look or visual appearance of all the objects in the game. According to the Unity manual: Shaders are small scripts that contain the mathematical calculations and algorithms for calculating the colour of each pixel rendered, based on the lighting input and the Material configuration.. In Figure 13 an example of an object that cannot be rendered properly by the shader is shown.

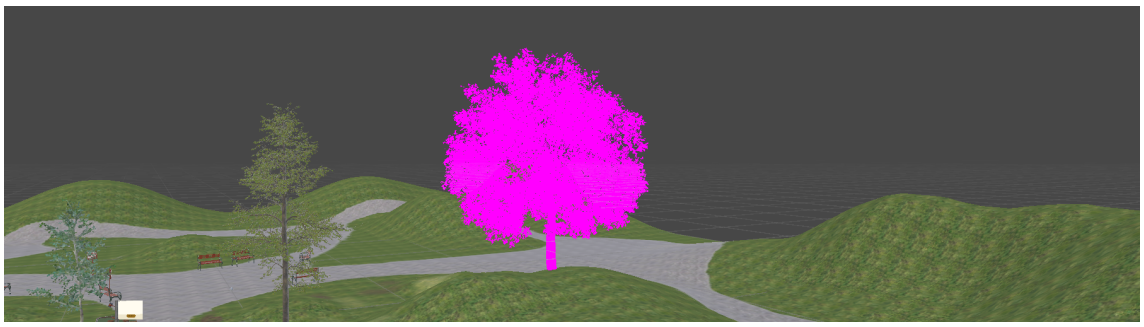

Figure 13: Tree object that can not be rendered by the sShader

After struggling with the shaders not working, the asset package Meadow Environment - Dynamic Nature was purchased from the Unity Asset Store. Since it is a paid product, it has customer support and a manual including shader troubleshooting solutions. The package contains trees, bushes, grass, flowers, rocks, fences, and nature particles. Figure 14 shows the trees and bushes used in the environment, and Figure 15 displays the vegetation. These assets were also placed using the terrain tool, which provides object brushes that place objects instead of 2D paint textures.

Lighting is another important aspect of the environment as it determines how the colors react and sets the mood of the space. Unity works with sky boxes which are essentially high-quality images from 4k to 16k in size, visible from all angles in the environment. A skybox was chosen from the AllSky Skybox Set in the Unity asset store. The chosen skybox can be seen in Figure 17. Besides the skybox, a directional light was placed in the middle of the scene, and the fog was minimized to give the player further sight into the distance. The light and fog settings are shown in Figure 16. Additionally, dust particle systems were added to create a sense of movement together with wind zones that moved the grass, flowers, and trees. Lastly, nature ambient music was added to that game to complete the nature environment. The music asset can be found the the asset list Table().

Figure 14: The tree objects placed in the final environment

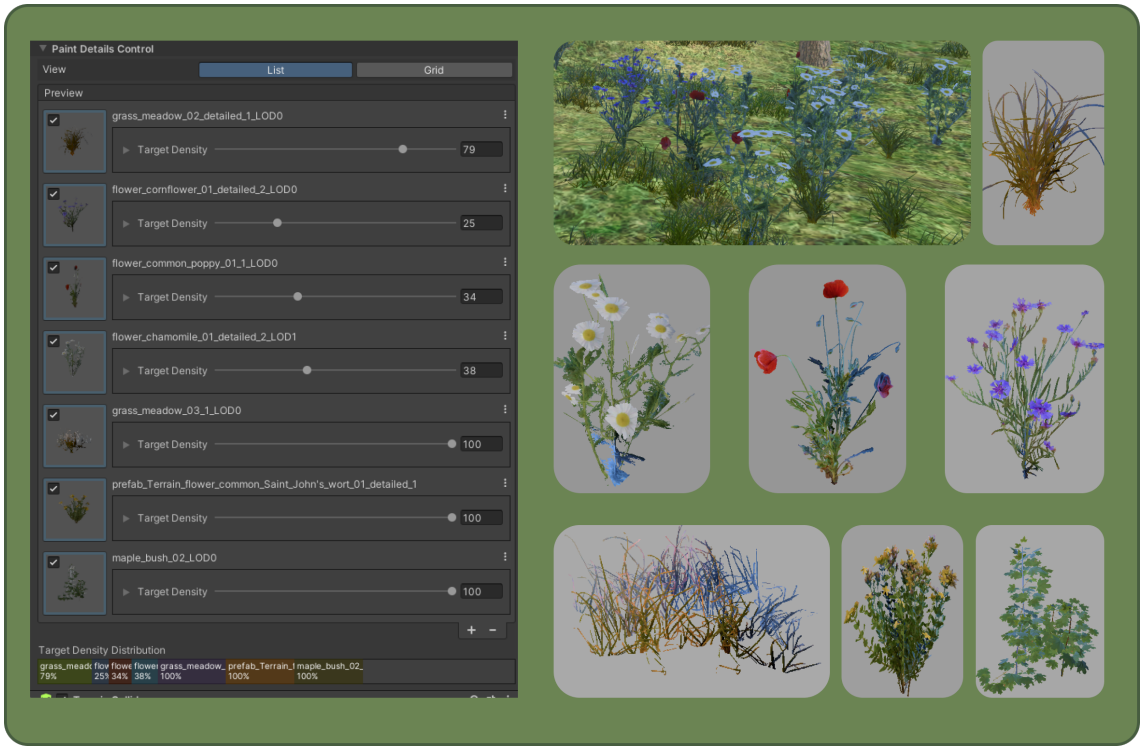

Figure 15: The grass and flower objects placed in the final environment

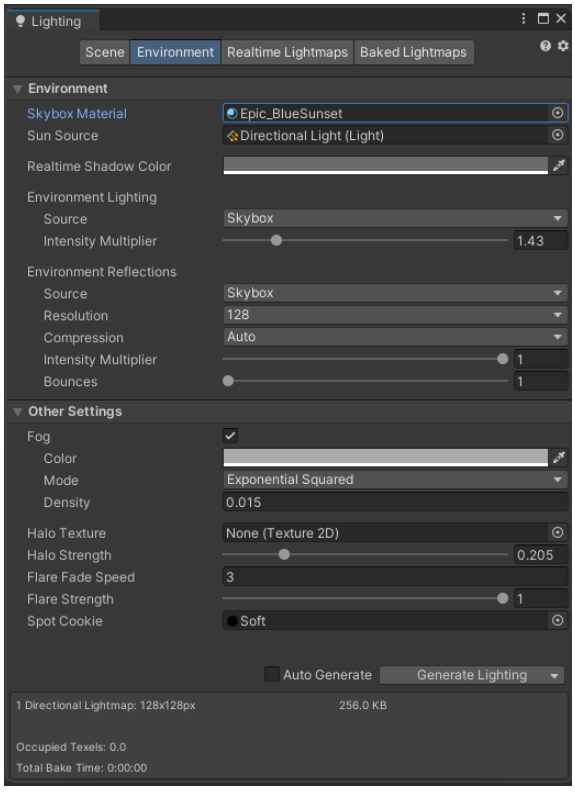

Figure 16: The light settings

Figure 17: The Skybox

6.3 Game and Activities

The game was finalized with two game elements: the Whack-a-Mole game and the picture-taking activity. In the specification, a third element, painting in the park, was discussed. Unfortunately, due to technical difficulties with the VR camera, this activity was not realized.

Mole whacking game

The mole game has three elements that players will interact with, the instruction board, the hammer, and the box with moles. Firstly, the board with instructions, tells the player to click on the start button, then instructs players to pick up the hammer and hit the moles. The start button has audio and visual feedback through color, as shown in Figure 19. Another form of feedback for the player is the moles that pop up after the start button is pressed. Initially, all of the six moles popped up, to then show up randomly one by one, in figure 20 the mole objects and the way they spawn are displayed.

Figure 18: Mole Game Instructions

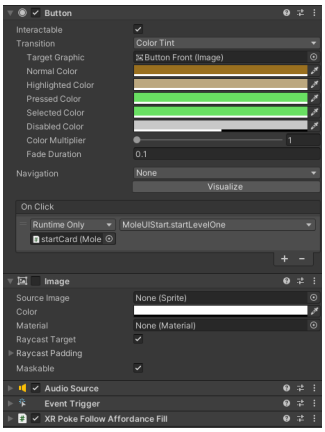

Figure 19: Start Button UI

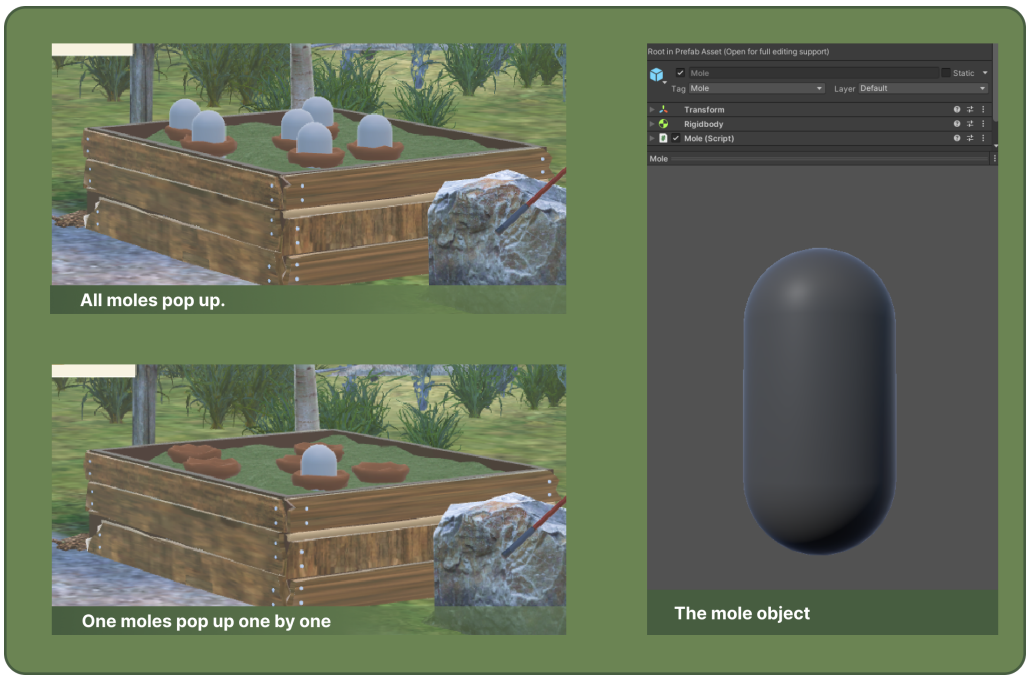

Figure 20: The mole object and how the moles spawn during the game

The hammer is another important element, functioning similarly to a real-life object such that it can be picked up and dropped. Players can pick up the hammer using the two largest buttons on the right controller, which are highlighted and shown in Figure 21. While keeping the buttons pressed they can attempt to hit the moles that pop up in different locations. Once a certain number of moles have been hit, they achieve the levels goal, and the win state is activated. The win state consists of a celebration soundbite, a winner text, and a confetti particle system, which can be seen in detail in figure 22. The win state also brings a small menu with two buttons. Players can either play again and go to level two or stop playing the game. In level two, the player had to hit more moles than in level one, increasing the difficulty level.

Figure 21: Hammer object and interaction

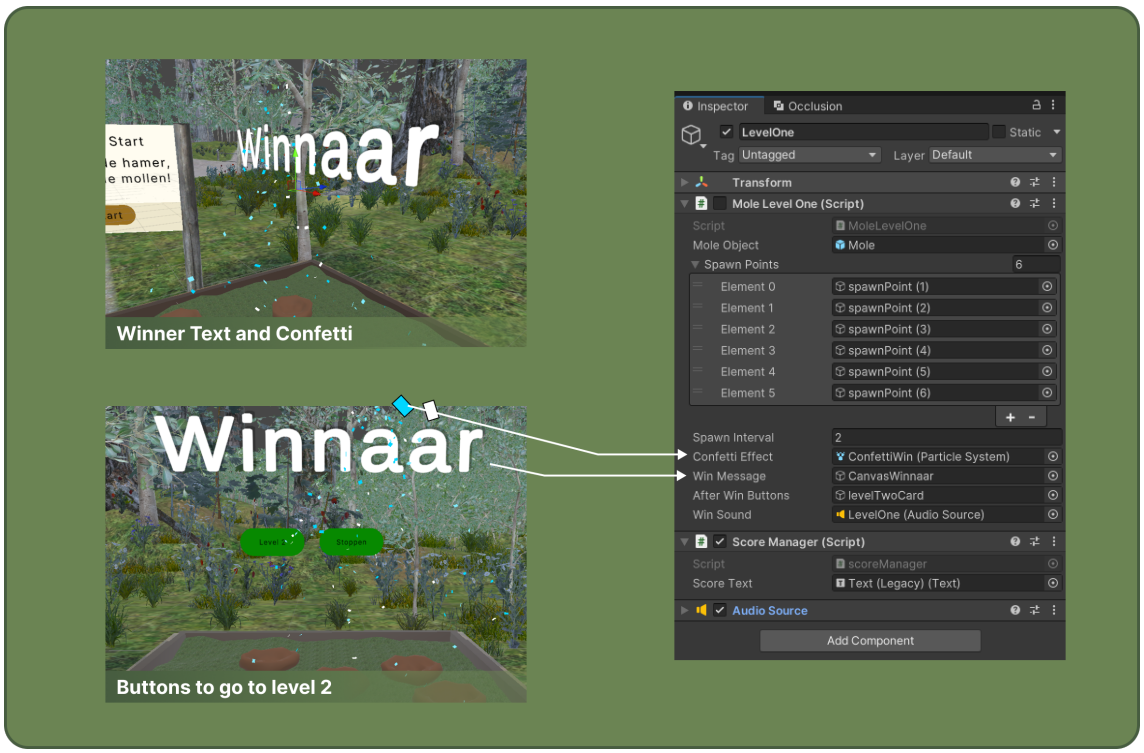

Figure 22: Win state elements and settings

Picture-taking Activity

This feature gives the player the option to take an infinite amount of pictures while walking through the park. In Figure (), the signboard points to the Whack-a-Mole game, and a sightseeing point where another sign instructs the player on how to use the camera function. The sign states: Look around you and take one or more photos by pressing the camera button. This button is the B on the left controller. When it is pressed, a screen capture of the players current view is taken. Paired with the picture, a random question from a list of fifteen questions is displayed.

Figure 23: List of assets

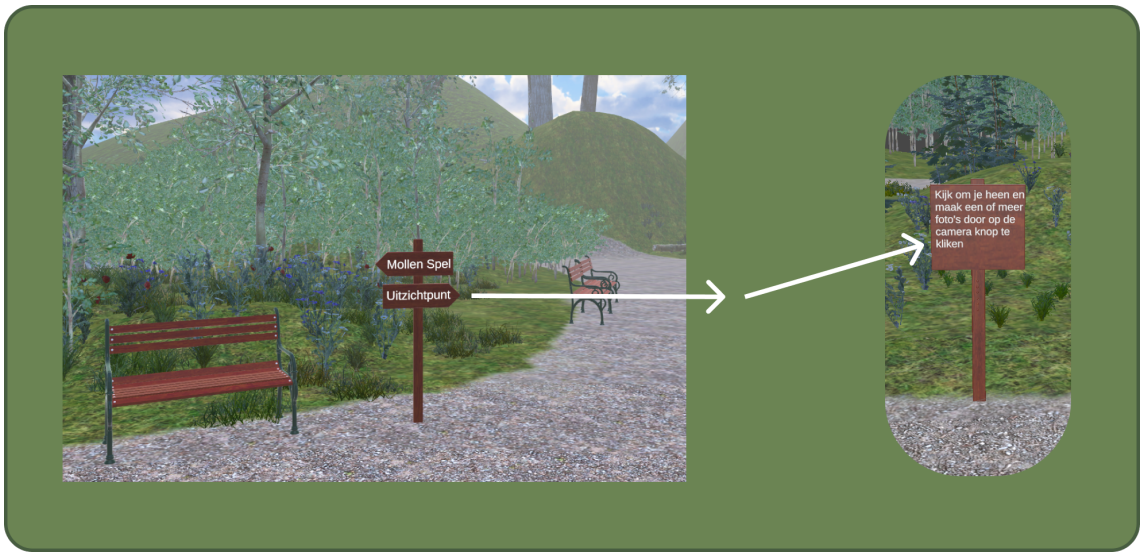

Figure 24: Instructive Signs

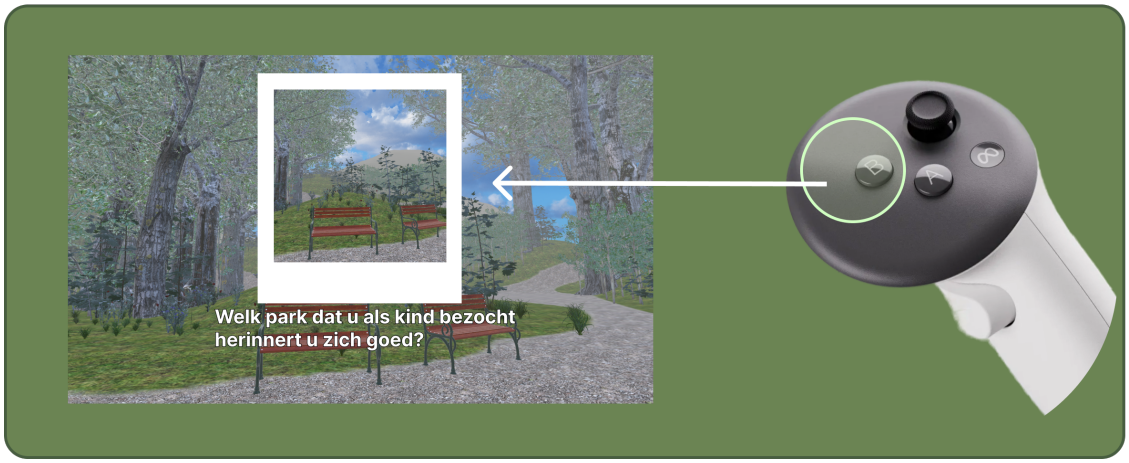

Figure 25: Taking a picture

7. Evaluation

The evaluation is the final stage of the creative technology design process, as previously mentioned in Chapter 3.4. To evaluate the high-fidelity prototype, user testing was conducted using the think-aloud method. Afterward, participants took part in semi-structured interviews with quantitative questions. The evaluation aimed to discover findings on three main aspects: the usability of VR technology, the effectiveness of recalling old memories to reminisce, and the level of cognitive function use specifically in movement. These aspects, can in turn aided in answering the fourth sub-research question: To what extent can a VR game for PwD be beneficial for their well-being and cognitive functions?

7.1 Ethics

Before the user testing could take place, the experiment had to be approved by the Computer and Information Science (CIS) department of the University of Twente Ethics Committee [ref]. The testing procedure was explained in detail, and possible ethical concerns were addressed, including solutions to mitigate them. Three main ethical concerns were identified. Firstly, participants might feel uncomfortable with the VR equipment due to the novelty and weight distribution of the headset. This was mitigated by carefully explaining and reassuring the participants on the use of the VR equipment. Secondly, motion sickness could occur, to counter this as much as possible the sensitivity was adapted to be suitable for older people. For example, ensuring that the movement throughout the game is not too fast. Lastly, for people with vision impairment, the text should be big enough and they were allowed to use the VR headset with their glasses if necessary. To safeguard participants, could withdraw at any point when feeling uncomfortable or sick.

The University of Twente Ethics Committee also provides templates for the information letter and the consent form. The English versions of the information letter and the consent form that participants received for this evaluation can be found in Appendix A and B.

7.2 Experiment Set-up

For the experiment, the location depended on the participant. The options varied from a private room at the university to public spaces or personal living homes. The researcher traveled to the participants, to make the process as easy as possible for the participants. The experiment consisted of three main segments: the introduction, the prototype testing, and the interview. The equipment was set up either before or after the introduction, depending on the scheduling with the participant and their preference. For example, the experiment located at the university allowed for set-up time before the participant arrived. However, for experiments that took place at the participant's home, this prior set-up time was not available.

Introduction

All participants received information through an information brochure before the experiment. This was given to them through mail, WhatsApp, or physically, depending on their preference. During the introduction, they were given another introduction to the topic and the experiment

again. Participants also had the opportunity to ask questions about the research during this part. Lastly, the introduction was concluded with the signing of the consent form. All in all, 10 minutes were spent on the introduction.

Prototype Testing

The prototype testing began with instructions on using the equipment. Players were asked to hold the VR controllers first and test all of the buttons one by one. Once they were comfortable with the workings of the controllers they received instructions of the headset. They were briefed on the type of head movements possible and how to put on the headset.

After the VR equipment explanation, players first placed the headset on their heads, and then were given the right and left controllers. When the players were set, the play button was pressed, and the participants entered the VR environment. Participants were given 15 to 30 minutes to experience and play the game. This timeframe was chosen to prevent participants from feeling pressured or rushed. During the game, they were asked to think out loud while playing. The researcher observed their actions and took notes. When players had completed all the games and activities, they were given the option to end the game. When they wanted to stop, the researcher took the controllers from them, allowing them to slowly take off the headset.

Interview

After the prototype testing, an interview followed to evaluate the participant's experience. The interview covered several aspects such as user demographics, digital immersion, the wack-a-mole game, and the picture-taking activity. The method used was semi-structured interviews with quantitative questions, which can be found in Appendix (). Participants were informed that the audio interview would be recorded and deleted after transcribing. The interview lasted 15 to 30 minutes, afterwards, there was an after-talk/ debriefing, and goodbyes.

7.3 Selection of Participants

This evaluation contains the first high-fidelity test. All of the game risks are not known yet, therefore, a group of proxy testers was asked to participate. In this case, 'proxy' refers to people who are as similar as possible to the target group. For this experiment, the focus was on age, since the target group was older people with dementia, specifically Alzheimer's. Thus, the proxy group consisted of healthy adults 60 years and older. Evaluating with this proxy test group is safer and more ethical. The proxy participants will be able to give an indication on how the real target group might respond. At the same time using proxy participants will ensure a robust and safe evaluation process since they are less vulnerable than the target group. Five users in total were selected, considering the Nielsen Norman Group Theory [1]. According to this theory, testing with five users is enough to discover at least 85 percent of the most important usability issues. Additionally, this method is time- and resource-efficient.

7.4 Testing and Data Gathering

In this section, the methods and questions used to gather data will be discussed. To evaluate the prototype and answer the fourth sub-question, specific questions were formulated and

used during the observation of the prototype testing and the interview. For the usability of the VR technology, participants were asked questions about their experience. To discover the effectiveness of the reminiscing effect, there was a focus on whether participants recalled old memories from at least 5 to ten years ago. Lastly, to determine if the cognitive abilities of participants were stimulated, their movements were observed.

Prototype Testing

The first section of the evaluation, where data was gathered is the high-fidelity prototype testing. The participant's interactions with the game were observed. To get a good understanding of what participants were thinking and experiencing during the game they were asked to think out loud also known as the think-aloud method. As an aid for the researcher, questions for during the observation were developed, which are shown in Table 6. These questions focused on how players behaved in the environment and interacted with the game elements.

Table 6: Questions that were used for the observation

Element of Observation	Questions
Movement in the environment	• Which head movements does the participant make? • How is the walking behavior of the player with the left and right joysticks? • How does the player move their full body during the game?
Mole game	• Does the interaction with the instructions go well? • To what extent is the player able to pick up the hammer? • How does the player move with the hammer? • How much fun does a player experience during the game? • Does the player understand the gameplay and achievements? • Is the game difficult for the participant?
Picture taking	• Does the player take pictures on their own? • Does the player take more pictures after the first one? • How does the participant react to the questions?
Environment	• Does the user take a moment to observe the environment? • Does the player wander through the environment?

Interview

An interview followed after the prototype testing. During this, the answers of the participants were collected. The answers were recorded and later transcribed using the Microsoft software Word. The questions of the interview were split into two parts. The first part included demographic questions and questions regarding the participant's connection with nature. The second part focused on the VR experience, the game elements, and the reminiscing effect. The full list of questions can be found in Appendix C.

7.5 Results

In this section, the results and insights of the high-fidelity prototype will be discussed, and the information gained will be used to answer the fifth sub-research question. For the final testing, five participants in total were recruited. The first participant that came to mind is an expert on older people. The recruited expert had six years of experience with older adults and elderly individuals, as well as with digital nature applications. The other participants would be healthy adults 60 years and older. For the recruitment, a poster was made to distribute, around areas where an older population lives. The poster can be found in Appendix D, with the personal phone number removed for privacy protection. Unfortunately, none of the participants were found through the poster distribution. The other participants were recruited by word of mouth and telling as many people as possible about the research project and the hi-fy testing. Four participants willing to contribute to the study were found, the ages ranged from 59 to 86. One participant was 59 and would celebrate their birthday in three months. Since the participant was very close to 60 and the recruitment of participants proved to be difficult the evaluation proxy group was adjusted in order to allow this participant. In total, there were two women and two men in the proxy testers group.

Expert

The expert participant spent six years researching the topic of digital nature for older people. The testing set-up for the expert was the same as for the other participants, with additional questions for the interview part. Unfortunately, during this test, not all of the features were working properly. The Mole game had a bug that caused it to loop, and the questions for the picture-taking feature were not fully working. However, still valuable information was gained.

The expert was asked about the game features and the VR functions. In the game, the hammer was seen first, which led to confusion about the instructions that required pressing the start button first. The expert felt as if standing in a park due to the flowers, light, and green surroundings. Especially after the focus was not on the mole game, the expert was able to take in the environment. According to the expert, the environment park was pretty and a comfortable place. However, animals and more movement could make the environment more lively.

As for the buttons and the VR equipment, the expert stated that there were too many buttons to remember, which might be challenging for older people. In addition, the type of buttons such as joysticks might be unknown to older people. An important note from the expert was that while older people tend to struggle with controller equipment, the expert did research the effect or the capability of older adults being able to use new buttons or controllers.

VR environment and immersion in digital nature

This section includes results regarding the use of VR equipment, technology, and the immersion effect of the digital nature environment. Participants interacted with three VR equipment pieces: the headset, and left and right controllers. The head movements were less than expected; not many participants used the full functionality of the headset when it came to looking around. Participants were given two options to turn and look around: using the headset or the joystick. Users mostly made small head turns and used the joystick as the main tool to turn around.

Between the two controllers, the right controller was assigned the most features: the grabbing of objects, the click function, and the turn option. The left controller had two features: the joystick for walking forward and backward and the camera button B. Users had trouble using the right grabbing buttons and the left joystick for walking forwards and backward at the same time. For the joystick used for turning, users needed some time to get used to the turning mechanics together with the forward and backward movements. The findings regarding the grabbing button will be discussed in the next section, Mole game.

When asked, all players said that after a short time, the button mechanics could be easily learned. After playing the game for a while, they gained a good understanding of button interactions. All players felt immersed by the surroundings, except for one player who did not feel fully immersed due to the sounds outside of the experience. The ambient sound and nature objects gave most of the participants a sense of standing in a real park. One participant noted that they barely noticed the music, while another noted that the combination of the park and the sound created a peaceful environment. When asked if they missed something in the game, all users suggested the addition of animals. One participant also suggested more buildings, activities, and games. Another note from a participant stated that nature in the environment was not Dutch enough. Only one participant noted a specific plant that they recognized.

Mole game

The mole game was the first game that players encountered when entering the game. All participants were able to locate and walk to the mole game. The start button was clear, and participants understood the starting instructions. Although they did not immediately see the moles popping up, since they had to make a small turn to the right, all of them eventually managed to see and understand that the game had started and the moles were appearing.

The hammer caused difficulties, all participants had trouble picking up the hammer. It was not always clear whether the issue was with the grabbing buttons or the hammer pick-up point. When asked, all players noted that they did not find the buttons difficult, indicating that the hammer pick-up point could have been the problem. It could also be said to be a combination of the novelty of grabbing VR objects and the hammer pick-up point being difficult to locate.

Not only was grabbing the hammer difficult, but players also lost the hammer after dropping it. Two participants lost the hammer for a significant time and needed guidance to find it back. the actual game of hitting the moles went well for all participants; they were all able to hit the mole objects and all participants managed to win the levels the game provided. There was, however, a difference in the speed of completing the game, essentially certain players finished the game faster than others. Another important observation was the cognitive movement,

three of the five users made full-length arm movements to hit the moles, while the other two participants made smaller arm movements and had little to no full-arm movements.

Reminiscing and picture-taking

With the camera feature in the game, players could take pictures of their surroundings. There was a signboard in the game pointing players to two activities: the mole game and the picture taking. Many participants did not make use of the sightseeing point that the signboard indicated, suggesting that the signboard was not efficient in directing players. Most of the participants needed help with remembering which button to press for the camera function. Regardless after using the camera feature at least once, they could easily remember and find the B button. All participants took multiple pictures after taking the initial photo. Three out of the five participants seemed to enjoy picture-taking, adjusting their angles to create pretty pictures. Other participants spend less time and effort on angles or getting the perfect picture.

Each picture taken was accompanied by a question. When the question appeared on the screen, participants either answered briefly or hesitated. One participant skipped the first question. However, after being asked further questions regarding their answers, participants provided more details, and memories of their far past did come up. During the interview, participants noted that when faced with the question alone, they would answer it for themselves. Additionally, participants were asked whether they thought of the past during the game, and all participants answered no. However, observations during the prototype testing showed that participants did think of the far past. When given the remainder of the past-related questions in the game, participants seemed to remember that they did answer questions about their past.

Conclusion

To conclude this section, the gained information and findings will be used to answer the fifth sub-research question: To what extent can a VR game for PwD be beneficial for their well-being, reminiscing, and, cognitive functions?

This question aims to determine if a VR game's reminiscent elements can positively affect the well-being of PwD, as well as assess the extent of reminiscing and cognitive abilities participants experienced. The answer to this question will be divided into three parts: well-being, reminiscing, and cognitive abilities. Complication with VR could ditrough the well-being aspect.

Firstly, for the well-being of PwD, it is important to note that the well-being of an individual is difficult to measure since it does not have one solid metric. However, in research on subjective well-being measurements such as psychological, social, and spiritual have been used [34]. For this research project, the fun factor and the prominent feelings and emotions participants experienced were used as metrics. According to Pressman et al. [] Having fun has also proven to have a positive effect on psychosocial and physical well-being.

During the prototype testing, all of the participants were intrigued, laughing, and smiling. Participants were laughing and smiling the most during the Mole game. One participant mentioned feeling calm and relaxed in the environment, this too contributes to the well-being. Some of the questions asked during the picture moments brought positive memories back, which is another positive outcome. However, more testing is needed to ensure that the fun

elements stay fun after the initial gameplay. In addition, when participants encountered difficulties, such as not being able to pick up the hammer, they stayed calm and continued to play. However, PwD might have different responses, so more research on VR equipment and older PwD is needed.

In the game, one task aimed at making participants recall their past was the picture-taking activity. Players used this feature and answered questions for which they had to recall memories. However, during the interview, participants stated that they had already forgotten the memories they recalled. This suggests that while participants recalled memories the reminiscing effect was not strong enough. A few participants also pointed out that the nature park environment did not make them reminisce.

Recalling memories was not only important for the reminiscence element but also served as one of the cognitive abilities metrics. Additionally, the movement of participants was observed as the second cognitive abilities metric. These two metrics were discussed earlier in Chapter 2. The cognitive functions of participants were stimulated and used during the game. While some participants made smaller movements and others made larger movements, they all moved; thus, it can be said that movement-related cognitive abilities were stimulated. Participants were observed moving their heads, talking, using fine motor skills, and thinking about the distant past.

8. Discussion and Future Work

In this chapter, the results and their implications will be discussed, along with the limitations and strengths of the research project, and what these findings could mean for future research.

8.1 Discussion of primary findings

The aim of this research project was to analyze different reminiscence techniques and technologies that could be used to design a game. The conclusions of the conducted literature review provided insights for the design and development of a high-fidelity prototype. Finally, the game prototype would be tested by proxy testers.

Throughout this research project, main conclusions were drawn at three different stages. The first set of conclusions was drawn after the literature review, which answered the first two research questions. Secondly, sub-questions 3 and 4 were answered using insights from the literature review combined with information gathered from the expert interview. Lastly, the evaluation of the high-fidelity prototype provided results that addressed the fifth research sub-question. All of these questions were answered in depth in Chapters 2, 4 and 7.

In this discussion section, the aim is to summarize the findings and discuss their implications for the literature.

Sub-questions one and two

1. How can reminiscence help PwD with their daily activities and general well-being?
2. How can cognitive abilities be improved with technology and RT?

Various research papers about RT aimed at sparking reminiscence were reviewed in the literature. These studies concluded that RT has positive effects on PwD, especially for their well-being. The key elements of RT, such as collaboration, personalization, storytelling, and sensory memory triggers such as sound, touch, movement, and visuals were shown to be the most effective in delivering the reminiscence effect.

Regarding the technology aspect, it was found that RT can be implemented in different technologies that PwD can use in their daily activities. These technologies included web applications, Kinect systems, and, VR systems.

Cognitive abilities people have are broad, the two cognitive abilities for PwD mentioned were movement and active memory recalling. Both of these can be implemented in technology and RT.

The literature analyzed showed that reminiscence therapy had positive results in improving the well-being of PwD. While the improvement in well-being was clear from the literature, what was missing was an analysis of how the spesific activities with RT elements affected the effectiveness of the therapy. More research can be done with a focus on activities and their relation to reminiscence therapy.

Additionally, more research was needed to compare traditional RT with RT in combination with technology. This comparison could aid in determining the positive and negative aspects of RT with and without technology. Both approaches had their own strengths and weaknesses. Regular RT, which is most commonly done in groups, stimulates social relationships. On the

other hand, RT using technology could be more accessible for PwD requiring less planning than in a group therapy setting.

Sub-questions three and four

3. How do people with dementia and their caregivers use current VR applications?
4. What type of VR game and design are suitable for PwD?

The literature found that VR applications have proven effective in maintaining and improving cognitive abilities and general well-being. Although there is a learning curve, PwD can have an easy and fun experience in VR. Although the VR applications found in the literature were aimed at PwD, all papers stated the need for further research with the designated target group. The extent to which VR applications were used by PwD in the Netherlands was unclear from the literature. In the expert interview which was discussed in Chapter 4.2, an expert confirmed that VR applications are used by PwD in the Netherlands. However, it is novel and it is not yet widely accessible. Regarding the types of VR games and their accompanying design guidelines, both the literature and the expert interview provided answers. According to the literature, the main design concerns included motion sickness and fine motor skills. Other technology design concerns were visual impairment and interruption of immersion. These issues could be addressed by using larger text and graphics and including buttons that are easy to press.

The expert also provided crucial design application guidelines for PwD. Personalization and autonomy are important. Furthermore, simple designs and gameplay are necessary, however, the appearance should still appeal to older adults. Moreover, fine motor skills should be replaced with bigger movements whenever possible.

These findings were considered when developing the set of design guidelines for the final high-fidelity prototype. The type and topics suited for VR games varied and could include daily activities, nature, animals, and, music. The most important aspect is that the target audience is somewhat familiar with the chosen topic.

According to the expert, design guidelines are very personal within the target group and vary from country to country and even local regions. VR guidelines for PwD are not well-established in the literature. However, since the guidelines for PwD fluctuate, trial and error is often necessary to discover the right guidelines. Guidelines should be global but still highly adaptable and flexible.

Sub-question five

5. To what extent can a VR game for PwD be beneficial for their well-being and cognitive functions?

It was concluded that the game provided the participants with a fun experience. Having fun contributes to improving and maintaining well-being. Thus, a VR game can contribute to the well-being of PwD. However, more testing is needed with the actual target group to ensure that the fun element will last after the initial gameplay.

Additionally, cognitive functions were stimulated in the form of movement and memory recall. Indicating that a VR game can motivate older people to use their cognitive abilities. Lastly, the reminiscing element in the game proved to be not strong enough. However, participants

were able to recall memories and share past experiences. Concluding that a VR game can have a positive effect on a persons well-being, stimulate cognitive abilities, and help people recall memories; however, more research is needed to understand how the act of reminiscing can be improved.

8.2 Limitations and Strengths

In this section, the limitations and strengths of this research will be discussed briefly.

The first limitation was the use of proxy users for the high-fidelity prototype testing. Although the proxy group gave an indication of the response of the real target group, it can not be ensured that tests with the actual target group will have equal results. When research involves a vulnerable target group an initial experiment with proxy users is necessary to eliminate as many flaws as possible, ensuring safety. In this research, testing with a proxy group showed how healthy adults in a similar age category as the real target group would respond to the VR game. Researching and designing for Dutch PwD requires highly specific literature since the effects and responses of PwD differ from person to person. The topics that were lacking in the literature included games and VR guidelines for PwD, as well as specific literature about Dutch PwD.

The second limitation was a practical one, related to the design and creation of the game. Game development can take years to complete. The game for this project was developed in 6 months, indicating that there was still room for improvement. More player tests were needed to ensure that the functional requirements were met.

The biggest strength of this research was the results regarding well-being. The importance of maintaining good well-being for PwD was noted in the literature, and the high-fidelity evaluation concluded that a VR game could positively affect the well-being of the target group. Participants had fun during the game, which was an important factor for improving and maintaining well-being. Another strength was that the VR technology was picked up relatively well, and participants stated that they did not have too much difficulty with the technology, indicating that VR was indeed a viable option. However, further research was needed for clear results on this topic.

8.3 Future Work

The goal of the developed high-fidelity prototype was to help PwD reminisce and stimulate their cognitive abilities. From the evaluation, it was concluded that the reminiscing elements of the game were not strong enough. The movements related to cognitive abilities were stimulated. However, the memory recall aspect of cognitive functions could also be improved. The possible recommendations for future work will be mentioned in this section.

For the reminiscence elements, the picture-taking activity in the game could be built upon to stimulate more memory recall. The pictures that participants take could be used in another mini-game, such as a memory card game. Giving the pictures an older look in black and white can make the pictures resemble photos from the past. Furthermore, participants pointed out that parks between now and the far past have not changed much. To bring more reminisce in the environment other elements such as buildings could be implemented. A good example would be the dementia village in the Netherlands. Increasing memory recall would also

increase the amount of cognitive function used in the game. Additionally, other types of movement could be incorporated into the game.

VR technology was used in this research. Although fine-motor skill problems were not observed during the testing, this could differ when tested with the actual target group, as PwD lose cognitive functions over time. More research could be done on ways to lower the amount of fine motor skills usage and discover whether VR controllers are user-friendly for PwD.

9. Conclusion

The goal of this research project was to analyze different reminiscence techniques and technologies that could be used to design a game. The conclusions of the conducted literature review provided insights for the design and development of a high-fidelity prototype. Finally, the game prototype would be tested by proxy testers.

In this research project, a set of reminiscence techniques and technologies were analyzed to design a VR game aimed at stimulating cognitive abilities and improving the well-being of PwD. The research drew main conclusions from a literature review, expert interviews, and the evaluation of a high-fidelity prototype, each addressed by specific research sub-questions.

The literature review highlighted the positive effects of reminiscence therapy on the well-being of PwD and identified key elements such as collaboration, personalization, storytelling, and sensory memory triggers. However, it also indicated the need for more focused research on specific activities and their effectiveness.

Expert interviews provided insights into the use of VR technology among PwD in the Netherlands. Main design concerns were identified, such as motion sickness, fine motor skills, and visual impairment. The most important notes were the personalization, simple design, and familiar topics to enhance the reminisce effect and user experience of PwD.

The evaluation of the high-fidelity prototype with proxy users showed that the game could positively impact well-being, stimulate cognitive abilities, and help recall memories. However, the reminiscing elements of the game were not strong enough, and further research is needed for possible improvements.

Appendix

A. Information Letter

Information Sheet for "Virtual reality game for stimulating cognitive abilities and the well-being of elderly with dementia"

Purpose of the study

This graduation project proposal was introduced by The Human Media Interaction (HMI) group, which researches multimodal interaction. It is a multidisciplinary group in which computer science meets social science to investigate, design, and evaluate novel forms of human-computer interaction. This project revolves around dementia and Alzheimer's disease which is one of the most common types of dementia. In the current day and age societies around the world are experiencing an increase of elderly with dementia. People with dementia slowly lose their cognitive abilities. For this project, I will propose and design an interactive game that will be used to assist individuals with Alzheimer's disease to enhance their memory and promote cognitive simulation and communication skills. During this study the created game will be tested.

Procedures for withdrawal from the study

You are free to leave this interview and this study at any moment, upon which all collected data from you will be removed from this research. This can be done by contacting the researcher via email or mentioning this to the researcher during or after the interview. There will be no repercussions for this.

Use of personal information

The audio recordings, forms, and other documents created or collected as part of this study will be stored in a secure location in the researchers' offices, on the researcher's password-protected computers, or in secured cloud databases. This data will be destroyed after the research is completed in July of 2024. Every piece of data that could identify you, such as this consent form and audio recordings, will be kept safe. Your privacy will be protected to the maximum extent allowable by law. Moreover, the audio-recordings will not be made public, only myself, my supervisor, and a few staff members of the University of Twente will have access to your responses. Potential audio transcripts will be made anonymous.

Usage of data during research

The data collected during this interview will be used in the design and ideation process of this research project. The data you provide can also be mentioned in the final report of this research. This report will be available to the supervisors, and possibly others who are interested. As previously mentioned, your identity will not be linked to the data, thus anonymous.

For any further information/questions, you can contact the researcher using the following email address: a.v.a.vanvandinter@student.utwetnte.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente by ethicscommittee-cis@utwente.nl

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B. Consent Form

Consent Form for "Virtual reality game for stimulating cognitive abilities and the well-being of elderly with dementia"

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the research information dated __/__/_____, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions. I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves an audio-recorded interview. After the research is complete, all personal information and audio recordings will be destroyed, only anonymous data and the final report will be maintained and stay public.	○	○
Use of the information in the study		
I understand that the information I provide will be used for publication of the report for this research. This report will be made public, and available for everyone. However, the data used in the report will be anonymous.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the research team.	○	○
I agree that my information can be quoted in research outputs.	○	○
I agree to the audio of this interview being recorded.	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	Signature	Date

Study contact details for further information: Anaisa van Dinter
a.v.a.vanvandinter@student.utwente.nl

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C. Interview questions

Table 7: VR Game Evaluation Questions

Category	Questions
Start vragen	Wat is uw leeftijd? Had u het gevoel dat u in een park was? En wat specifiek gaf u dat gevoel? Gaat u vaak naar een of meerdere parken?
Eerste indruk	Tot hoeverre werd u meegenomen door/ in de digitale omgeving. Had u het gevoel dat u in een park was? En wat specifiek gaf u dat gevoel? Is er iets wat u in het park zou toevoegen?
VR	Hoe vond u de interacties met de VR elementen en knoppen?
Molen Spel	Hoe heeft u het mollenspel ervaren? Wat vond u van de beweging die het spel vereiste? Hoe was de moeilijkheidsgraad van het spel?
Foto making	Wat vond u van de camera functie? Welke gedachte had u na het zien van de foto?
Omgeving	Neemt de gebruiker even de tijd om de omgeving te observeren? Dwaalt de speler door de omgeving?

D. Recruitment Poster

BEN JIJ 60+ ?

EN HEB JE ALTIJD AL EEN VR SPEL WILLEN SPELEN?

Ik ben Anaisa, student aan de Universiteit Twente. Op dit moment maak ik een spel waarin de goede tijd van vroeger terug komt. Voor mijn onderzoek heb ik hulp nodig van mensen die mogelijk het spel willen uitproberen. Als deelnermer kunt u het VR spel spelen uiteraad met volledige begeleiding en een goede uitleg. Als deelnemer helpt u met de ontwikkeling van technologie voor mensen met de dementie.

IK WIL MEEDOEN!

DE LOCATIE IS OP DE UNIVERSITEIT. VERDER KUNT U KIEZEN TUSSEN DE DAGEN VANAF 10 TOT 24 JULI. VOOR MEER INFORMATIE OF HULP KUNT U MIJ BELLEN OP 06 _____
OF EMAILEN → A.V.A. VANVANDINTER[AT]STUDENT.UTWENTE.NL

JUNI 2024

DE UNIVERSITEIT TWENTE

CONTACT:

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