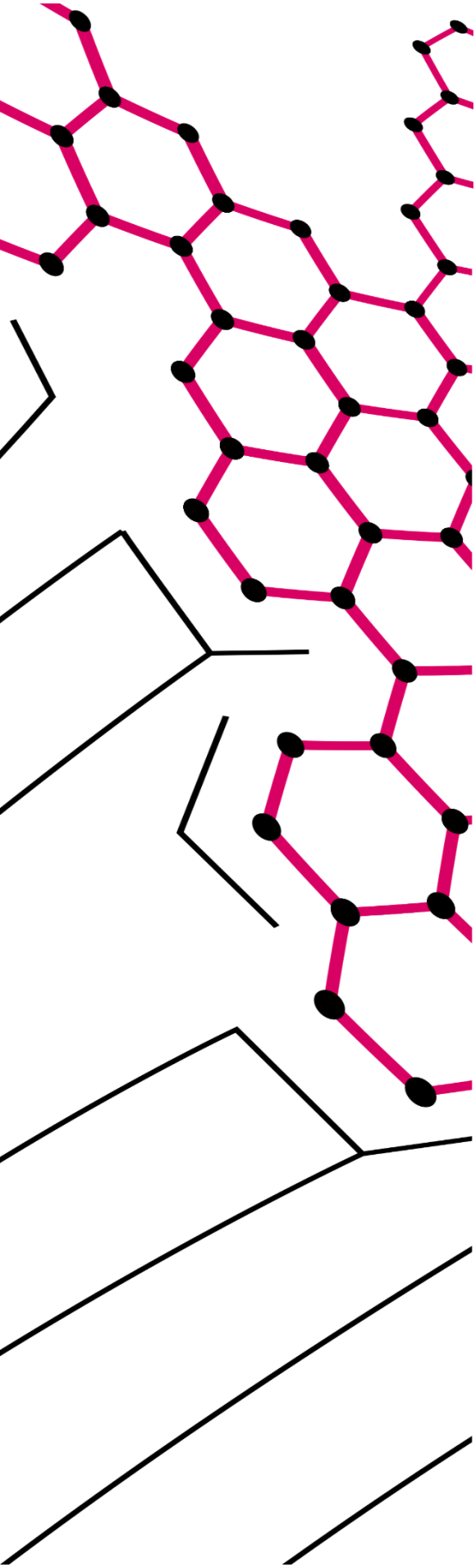

BSc Thesis Creative Technology

Developing a Tangible Interactive Game to Improve Reminiscence among People with Alzheimer's Disease

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Abstract

Millions of people around the world are currently suffering from Alzheimer's disease, an incurable neurodegenerative disease that causes cognitive impairment. As a result, numerous symptoms arise such as memory and thinking issues. Both pharmacological and non-pharmacological treatments exist to tackle the cognitive issues people with Alzheimer's face. Games are one of the approaches currently used to treat cognitive impairment among people with Alzheimer's. However, a need for games specifically aimed to tackle cognitive issues among people with Alzheimer's has been identified. A game that stimulates and aims to improve reminiscence seemed promising as reminiscence improves cognitive functioning. The inclusion of sensory stimulation techniques such as tactile stimulation via tangibles and textures was decided upon to stimulate reminiscence. Thus, the goal of this thesis is to develop a tangible interactive game that aims to improve reminiscence among people with Alzheimer's disease. By improving their reminiscence while providing an enjoyable experience, it is hoped to benefit their overall quality of life. A literature review was conducted which resulted in discovering a few effective existing methods that would be implemented into the game. Apart from this, existing technological solutions were explored, from which useful insights were gained. Additionally, two sets of existing guidelines were used as a basis for the design guidelines for the game. The Creative Technology Design Process was used for the development of the game and consists of four phases: the ideation phase, the specification phase, the realization phase, and the evaluation phase. The ideation phase consisted of an expert interview and a brainstorming session which resulted in the initial creative idea. This idea was used to create two iterations of the game in the form of low-fidelity prototypes, of which the second iteration was evaluated by an expert. The final idea was developed at the end of this phase, which was used to realize the final prototype of the game. The tangible interactive game is a puzzle game in which a user has to match five tangibles to every prompt shown on the screen. Once correct, a video of the location in the prompt is seen and a question is asked which prompts the user to reminisce. An evaluation with five proxy users took place, consisting of a playtest and a semi-structured interview. The main result was that the proxy users enjoyed playing the game and reminiscence was successfully stimulated among all the users. However, future research is necessary to discover whether the game improves reminiscence among people with Alzheimer's disease.

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1. Introduction

Alzheimer's disease is a brain disease that an estimated 32.3 million people around the world have to live with [1]. Currently, no cure has been found for Alzheimer's [2]. With so many having to cope with this uncurable disease, improving their quality of life in any way is of grave importance.

Alzheimer's disease causes dementia issues [3]. This form of dementia is called Alzheimer's dementia. Dementia issues are characterized as issues concerning memory, thinking, language, and problem-solving. A way to combat these issues is with the use of reminiscence. Reminiscing improves the cognitive ability and enhances the overall mood of a person with Alzheimer's disease (PwAD) [4], [5]. A well-known treatment in which reminiscence is used is reminiscence therapy (RT). In this treatment, a therapist facilitates an intervention in which past memories are actively retrieved. Another way to combat cognitive impairment is via games [6]. Games such as jigsaw puzzles, Angry Birds, and Wii Sports are examples of games played by PwADs.

Whilst reminiscence therapy and games have been proven to be effective in enhancing reminiscence and improving cognitive abilities, certain issues need to be addressed. Firstly, reminiscence therapy requires the need for a therapist to carry out the treatment. These treatments need to be planned out and thus are harder to implement at a very high frequency. An issue can also be seen in the use of games. The games played by PwADs, such as the aforementioned games, are not developed for people with forms of dementia. Games created for people with dementia (PwDs), such as Alzheimer's dementia, would be able to treat symptoms more meticulously and thus could be more effective. Moreover, the needs of PwADs can also be taken into consideration to make it an enjoyable game for them. This is the reason why there is a need for games made for people with Alzheimer's dementia.

The use of technology provides an opportunity to be beneficial for both the PwADs and the caretakers of the PwADs. The PwADs can improve their technological skills while having fun and enhancing their reminiscence, thus improving their cognitive abilities. The caretakers will also enjoy more free time as the technology provides guidance throughout the game. This means that the caretaker does not have to direct the experience for the PwAD. A game can also be played at any time of the day and does not require a session to be planned as seen in RT.

This study aims to develop an interactive game that helps people with Alzheimer's disease improve reminiscence. The interactive game will pair technology with tangible objects, as people with forms of dementia, such as Alzheimer's dementia, feel the urge to physically interact with objects [7]. Tangible objects have also been shown to aid in reminiscence [8]. Furthermore, elements of RT and sensory stimulation are implemented, as they have been proven to stimulate reminiscence [8], [9], [10], [11], [12], [13]. The interactive aspect of the game instigates the PwAD to actively think to progress in the game. Interactivity in the context of games implies that "the game requires a constant exchange of messages between the game and its player" [14].

By applying existing recommended guidelines for interactive games for PwADs and building upon them with the help of experts, an interactive game will be made that will positively affect the day-to-day lives of PwADs and specifically their reminiscence capabilities.

As previously stated, there is a need for games that are designed for PwADs and aim to treat their issues. Thus, by building upon existing research, the goal is to create a tangible interactive game for PwADs that aims to improve reminiscence. The main research question for this research project therefore is: *"How can we design an interactive game for people with Alzheimer's that incorporates tangible objects and aims to improve reminiscence?".*

In the first half of this report, the conducted literature review in which the background knowledge for the research was obtained is described. This research has 5 sub-research questions (SRQs), namely:

1. How does Alzheimer's disease impact the cognitive functioning of people?
2. What improves the reminiscence of people with Alzheimer's disease?
3. How can technology assist in enhancing reminiscence in people with Alzheimer's disease?
4. What are the design guidelines for developing interactive tangible games for people with AD?
5. How effective is the tangible interactive game in stimulating reminiscence?

These sub-questions together help to get closer to the answer to the main research question. In the second part of the report, the design of the tangible interactive game will be presented together with which guidelines were eventually used and how effective the tangible interactive game is in stimulating reminiscence will be discussed. Finally, the game will also be evaluated at the end of the report and the findings will be examined.

2. Literature review

To develop a tangible interactive game that effectively enhances the reminiscence of people with Alzheimer's disease, existing literature will be explored first. We will look at what Alzheimer's disease is and what its symptoms are, what the existing treatments are for the disease and which have been proven to be effective, the current technological solutions to enhance reminiscence, and the existing guidelines for a game catered towards PwADs.
By doing so, this chapter aims to answer the following sub-research questions:

1. How does Alzheimer's disease impact the cognitive functioning of people?
2. What improves the reminiscence of people with Alzheimer's disease?
3. How can technology assist in enhancing reminiscence in people with Alzheimer's disease?
4. What are the design guidelines for developing interactive tangible games for people with AD?

2.1 Alzheimer's Disease

Alzheimer's is a brain disease that occurs due to damage to neurons in the brain, which causes the structure of people's brains to change [3], [15]. The parts of the brain used for memory, thinking, and language are affected first [3]. This leads to numerous issues such as memory loss and the decline of cognitive functions [15]. These issues are typical symptoms of dementia [3]. Dementia is an umbrella term for memory, language, thinking, and problem-solving issues. Alzheimer's disease therefore causes dementia and in this case, is called *Alzheimer's dementia*. However, dementia is not necessarily caused by Alzheimer's disease. Other diseases such as Parkinson's disease and cerebrovascular disease can also cause dementia to occur. Furthermore, Alzheimer's also has an impact on the behavior of people [9]. Extreme emotions such as aggression, agitation, and mood swings are common symptoms of the disease. The personalities of PwADs can also experience change.

Dementia caused by Alzheimer's disease has multiple stages, namely the mild, moderate, and severe stages [3]. The stage a person is in depends on the severity of their symptoms. In the mild stage, most people can still perform many daily activities. However, assistance might be needed on certain occasions. In the moderate stage, the previously mentioned issues related to Alzheimer's dementia become more prevalent. Tasks that require multiple steps, such as getting ready in the morning, become more difficult. Furthermore, the PwAD may also have difficulty recognizing people close to them. The moderate stage is usually the stage that takes the longest. The final stage of Alzheimer's dementia is the severe stage. Physical movement and verbal communication become exceptionally difficult to the point where PwADs cannot leave their beds. This causes serious health complications such as skin infections and blood clots. These complications can lead to organ failure. The risk of death is the highest in this stage of Alzheimer's dementia [16]. Although the stages all have their previously mentioned characteristics, dementia issues do not have a standard stage of the disease in which they develop [15]. Instead, their emergence differs from person to person.

2.2 Existing Treatments for Alzheimer's

Unfortunately, a cure for Alzheimer's disease has not been found yet [2]. However, methods exist to treat the symptoms caused by Alzheimer's disease. These methods can either fall under pharmacological treatment or non-pharmacological treatment.

2.2.1 Pharmacological and Non-Pharmacological Treatments

When treated pharmacologically, the PwAD will be treated with medication. Currently, there are several medications available that target Alzheimer's dementia symptoms, namely galantamine, rivastigmine, donepezil, brexpiprazole, and memantine [17]. Galantamine, rivastigmine, and donepezil are all cholinesterase inhibitors. Cholinesterase inhibitors are medications used in every stage of Alzheimer's dementia that counteract the breakdown of acetylcholine. Acetylcholine is a chemical in the brain that is involved with various functions in the brain as well as in other organs [18]. The production of the neurochemical decreases as Alzheimer's worsens [17]. This contributes to thinking and memory issues as acetylcholine is involved in thinking and memory. Although cholinesterase inhibitors may improve the PwAD's symptoms, the effectiveness of this group of medicines lessens over time. The two other medications apart from the cholinesterase inhibitors are brexpiprazole and memantine. Brexpiprazole is a drug used to treat agitation caused by Alzheimer's and memantine decreases overall Alzheimer's dementia symptoms. Memantine is only used in the moderate to severe stage of Alzheimer's dementia. Lastly, a medication called lecanemab is used that aims to treat Alzheimer's itself, instead of its symptoms. Lecanemab specifically treats Alzheimer's in its mild to moderate stages. One of its benefits is that it reduces the speed of cognitive decline. In conclusion, a handful of medications exist that help to improve the quality of life for PwADs. However, these medications cannot cure the PwAD and a cure for Alzheimer's is still to be found.

Non-pharmacological treatments, in contrast to pharmacological treatments, do not use medications. Non-pharmacological treatments aim to tackle behavioral psychological symptoms of Alzheimer's dementia, as well as the cognition and mood [19]. Examples of non-pharmacological treatments to treat PwADs are reminiscence therapy, cognitive stimulation therapy, and sensory stimulation therapy. Research has shown that non-pharmacological activities that stimulate PwADs physically and mentally both improve the cognitive functioning of PwADs [19]. Experts advise that non-pharmacological methods should be tried first before considering medication to treat behavioral symptoms [17].

Several non-pharmacological treatments will be explored more extensively in the next sections because these treatments do not involve medications and are thus more relevant to the game.

2.2.2 Reminiscence Therapy

Enhancing the reminiscence is done non-pharmacologically. One method that enhances reminiscence is reminiscence therapy (RT) [9]. In this form of therapy, PwADs are stimulated to recall memories of the past. Reminiscence therapy is often repeatedly done in the form of a planned intervention. The frequency in which the intervention takes place differs from person to person.

However, RT is not solely used to improve reminiscence, but also to positively affect mental health and improve the overall quality of life for people with Alzheimer's disease. Depression is one of the mental health issues that are prevalent among people with Alzheimer's disease and can be tackled with the use of RT [4]. Within an RT intervention, the PwAD can be encouraged to re-evaluate past experiences and conflicts. This gives the PwAD a different outlook on the past, stimulates them to find peace with past conflicts, and increases their self-perception. These positive developments can all aid in decreasing depression for PwADs.

2.2.3 Cognitive Stimulation Therapy

Another method that enhances the reminiscence of people with Alzheimer's disease is cognitive stimulation therapy (CST). CST improves reminiscence by letting PwADs participate in various group activities that stimulate PwADs both cognitively and socially [20]. Cognitive stimulation therapy can combat the effects of forms of dementia, such as Alzheimer's, and aging in general. An example of how a CST intervention can be structured is by starting together with a song, then doing a group workout, and subsequently focusing on a subject that varies per week [21]. In the realm of non-pharmacological interventions that target the cognitive functioning of people with forms of dementia, CST has proven to be the intervention that has the most substantial evidence [20].

2.2.4 Sensory Stimulation Therapy

Sensory stimulation therapy is a type of therapy that plays into the senses of a person by exposing them to various stimuli [22]. Senses such as sight, smell, touch, hearing, and taste can be stimulated. Sensory stimulation is beneficial to the memory of PwADs [10]. It can initiate reminiscence, causing emotional memories to resurface. Remembering positive past experiences can give the feeling of pleasure to the PwAD. When multiple senses are stimulated simultaneously, it is called multisensory stimulation [23]. A few types of sensory stimulation are explored further as they are interesting to explore within the context of the interactive game.

Tactile stimulation

One of the forms of stimulation that plays into one's senses is tactile stimulation. In tactile stimulation, the nerves beneath the surface of the skin are triggered [24]. Various sensations can be felt, such as temperature, textures, and vibrations. Three types of tactile stimulation applied to PwADs are further explored in the following paragraphs.

Tactile massage is a stimulation technique in which the receptors beneath the skin are activated by softly touching the skin [25]. This method can be applied to all parts of the body, except the private parts of the person. The intervention starts with assuring the person is at ease. Subsequently, the parts of the body that will not receive the tactile massage are covered. There is no fixed structure within tactile massage apart from that it is started and concluded with slow stroking motions over the skin. After the tactile massage is concluded, the person is fully covered, assuring the person is warm. This technique creates a way to communicate with a PwAD non-verbally and to provide care and attention. However, no scientific sources can be found on tactile massage being beneficial for reminiscence.

Nonetheless, tactile stimulation via tangible objects has been proven to prompt a PwAD to reminisce. According to Pöllänen et. al [8], a tangible object can cause a PwAD to recall memories due to its intrinsic qualities, such as its look, feel, texture, and weight. If the PwAD makes movements related to the object, this can also aid in reminiscing. Familiar objects and objects that have meaning to a person can also help retrieve past memories better and trigger a more emotional response to the particular object. For example, objects culturally relevant to people can trigger reminiscence to take place.

Another method is tactile stimulation via textures. A wide range of materials, such as different textiles and fabrics, all with various qualities can be applied via this tactile stimulation

technique [10]. Other senses can also be stimulated via the use of materials. They can stimulate visually with their colors but also serve as forms of auditory and olfactory stimulation via the sound a material can make upon interaction and its scent. By implementing textures into experiences, new levels of interactivity and playful engagement can be unlocked. The benefits of stimulation via textures are that they can positively affect personal relationships by being triggers for conversations, improve emotional well-being, and cause reminiscence to take place [8], [10], [11], [12]. In a study by Tan et. al [12], an example of reminiscence caused by textiles can be seen. A person with dementia (PwD) interacted with a tactile material on the sensory wall developed in this study. The green feathers on the wall prompted them to reminisce about a broom they used at home.

Auditory stimulation

The second form of sensory stimulation explored is auditory stimulation. Auditory stimulation implies stimulation via hearing [22]. The most commonly seen type of auditory stimulation for PwADs in literature is stimulation via music. A lack of literature was noticed on other types of auditory stimulation for PwADs that were not used in multisensory settings. In a study by Foster et. al [13], results indicate that auditory stimulation aids in recalling personal memories among PwDs. Questions about the PwD's personal history were asked. The PwD would receive points if they were correct. The questions were asked under four different circumstances: silence, cafeteria noise, novel music, and familiar music. Results show that with auditory stimulation, the PwDs performed significantly better with familiar music and novel music being the most effective. In another study by Haj et. al [26], the recalled personal memories among PwADs were also more specific and emotional while music was playing compared to when it was silent. Furthermore, an effect was seen on the PwAD's mood and quicker memory retrieval.

Snoezelen rooms

An example of a concept that offers multisensory stimulation through visual, auditory, olfactory, and tactile stimulation is the Snoezelen room [27]. The Snoezelen room is a non-pharmacological treatment in which the person with Alzheimer's dementia is stimulated with tangible objects, visuals, sound and music, and scents in a room. The room is often solely purposed for this treatment [28]. The main objectives of the Snoezelen room are enhancing cognitive functioning, communication abilities, and overall well-being of the person. Snoezelen rooms are not only used for people with Alzheimer's dementia. The rooms are also used for people with other forms of dementia, behavioral issues, mental health problems, and autism among others [29]. However, the rooms are catered towards people who do not suffer from an illness as well. Research on Snoezelen rooms is limited and the results in existing research are divided [27], [28]. A study by Solé et al., [28] tested the effects of Snoezelen rooms and reminiscence therapy on people with dementia. Each person with dementia was assigned to either biweekly sessions of Snoezelen or reminiscence therapy. The sessions were held for 12 weeks. The results showed that the Snoezelen group experienced less depression and anxiety after the 12 weeks of treatment. On top of that, the Snoezelen group was more relaxed post-treatment. On the other hand, the reminiscence group experienced less improvement than the Snoezelen group. Another study by Todder et al., [30] showed that the Snoezelen room has short-term benefits on the quality of sleep of people with Alzheimer's. However, in other studies such as a study by Goto et al., [31] the effects of the Snoezelen room on people with dementia were negative. The PwDs did not want to interact with most of the objects in the room and became bored with the stimuli in the room. The only stimulus in the room that captured the attention of the PwDs for longer periods of time was a rotating

nature scene. Lastly, Snoezelen rooms are not a financially viable option for most PwADs as costs usually range from at least $10.000 to $30.000 to set up a Snoezelen room [32].

2.3 Current Technological Solutions to Enhance Reminiscence

Before developing an interactive game that improves the reminiscence of PwADs, it is useful to look at previous technological solutions and games that aim to improve the reminiscence of PwADs. Reviewing past technological solutions shows which elements improved reminiscence in PwADs, aiding the development of the interactive game.

2.3.1 Personalized digital interactive games

In a recent study done by Abu Hashim et. al [33], two personalized interactive games for a mobile app were developed for PwADs. A jigsaw puzzle and a memory card game were created which aimed to enhance reminiscence. In the jigsaw puzzle, a picture related to the user was used as the image that would be formed when the puzzle had been completed. The memory card game also used images related to the user, which needed to be paired with each other. The two games had multiple levels, each with a different level of difficulty. The PwAD, however, could choose which level to play. Furthermore, the app contains various pages with content that train the cognition of the PwAD. Examples of pages are a reminder page, a daily activities page, and a page that displays pictures of loved ones.

One participant with mild Alzheimer's tested the game over multiple sessions. The participant did not know how to operate the technology at first but after multiple sessions, she could play the game without help. This shows that PwADs can learn how to use technology. The main result of this study was that the participant's memory and cognitive function were enhanced. Furthermore, some useful suggestions can be taken from this research. The experts interviewed for this study suggested improvements such as the implementation of cultural language, the usage of symbols and pictures, and the ability to customize the game so that the experience can be more personalized and relevant to a bigger number of people.

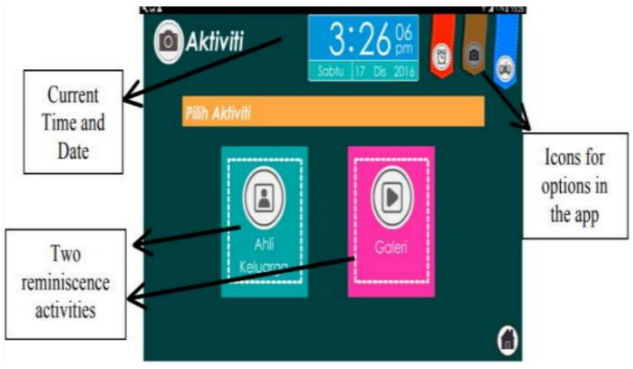


Figure 1 The game activities screen of the digital interactive game with additional information on the contents

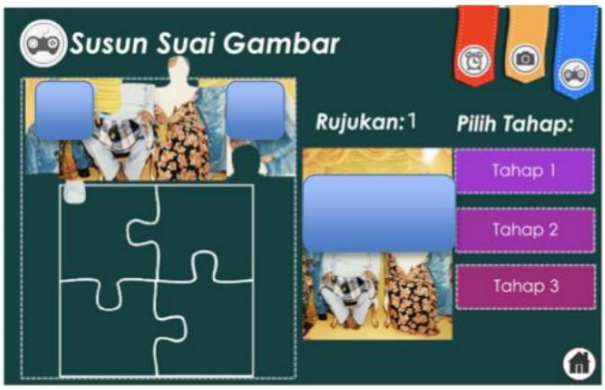


Figure 2 The jigsaw puzzle game

2.3.2 Tangible interactive drawers

Another study by Huber et. al [7] incorporated tangibles into three different interactive systems created for people with dementia (PwDs). These systems consisted of an interactive pyramid that showed pictures and played sounds related to the pictures shown, drawers with screens

on them that displayed pictures and contained tangible objects, and a jukebox with buttons that each played a playlist with a certain genre when pressed on. The goal of the systems was to facilitate reminiscence. The main result of this research was that the pyramid was the most successful in causing reminiscence to take place and also triggered emotional responses in the PwDs. The tangible drawers were not as successful because PwDs did not initiate opening the drawers themself while this was aimed for by the researchers and did not show interest in them in general. The jukebox was successful as the music activated the PwDs to sing and move to the music. The music also caused reminiscence to take place as songs made past memories resurface.

A notable finding of this research is that even non-personalized content was able to trigger the PwD to reminisce and start discussions between multiple PwDs. This shows that general content not necessarily directly related to the person with dementia (PwD) can still evoke memories and is a way to promote interaction between PwDs.

Figure 3 (From left to right) The interactive pyramid, the tangible drawers, and the jukebox

2.3.3 Memorology

Memorology is one of the few tangible interactive games in existence for people with dementia that makes use of tangibles, sensory stimulation, and technology while at the same time aims reminiscence to take place [34]. Apart from stimulating reminiscence, the game also aims to enhance the emotional well-being of the PwADs by making social interactions a part of the game. Memorology is meant to be played by PwADs together with loved ones or other PwADs. The game includes a game board and tangible balls named ‘TangiBalls’. Both the game board and the tangibles have matching themes, namely the themes ‘community’, ‘nature’, and ‘celebration’. The TangiBalls make use of various forms of sensory stimulation, namely visual, tactile, auditory, tactile, and olfactory stimulation. Examples of technology used are sensors, LEDs, and an Arduino. One TangiBall for example would play recorded audio when a PwAD would press the TangiBall and another would emit light depending on if the PwAD is shaking it or not.

The premise of the game is to first shuffle the nine tiles of the game board around and thereafter put them in a 3 x 3 arrangement. One user needs to then choose a TangiBall and can interact with it and voice their thoughts about the TangiBall or reminisce about a memory retrieved because of the TangiBall. The TangiBall gets passed on and the same actions of interacting and voicing thoughts or stories are done by every person. Afterwards, a group decision will be made as to which theme the TangiBall belongs. The previous parts of the game are repeated until three TangiBalls are lined up next to each other either vertically, horizontally, or diagonally.

Figure 4 The puzzle board and tangibles of Memorology

2.4 Design Guidelines for the Development of Games for People with Alzheimer's Disease

A set of rules based on existing recommendations and guidelines for the development of games for people with dementia/Alzheimer's disease will be made before creating the tangible interactive game. This is necessary because the game needs to be adjusted to the capabilities and needs of PwADs and to be effective in enhancing reminiscence. However, there is a limited amount of guidelines on games for people with Alzheimer's disease in existence and these guidelines are not specifically for games that aim to improve reminiscence. It is therefore essential to create custom guidelines for the game that make use of multiple sources. Nevertheless, two existing sets of guidelines have been explored.

2.4.1 Lazar et. al

Lazar et al. [35] created an extensive set of recommended guidelines for recreational systems targeted towards older PwDs. Since an interactive game is a type of recreational activity, the recommendations heavily apply to games. The guidelines are spread across five categories: hardware, content, navigation, applications, and lastly specific applications. The hardware category encompasses what features the system's components have. Aspects such as mobility and durability are advised. Keeping possible mobility issues among PwADs in mind is also recommended. Furthermore, the usage of a touch screen for its intuitiveness and a wireless keyboard above a wired keyboard is advised. The content category highlights the importance of a variety of content. Consistency in interests when designing for a single person is also stressed. Finally, the use of various types of media, such as video, audio, pictures, and text, is encouraged. In addition, a well-designed game requires navigation to be effortless. A few recommendations relevant to games are given. Firstly, the imagery in icons should be representative of their meaning. Additionally, clearly indicating which elements are interactive

and which are not is vital. Adequate spacing and sizing of interactive elements should be integrated. In the applications section, the main focus is language and accessibility. The usage of clear language and instructions is necessary to avoid confusion among PwADs. Moreover, due to the likelihood of low vision among people with forms of dementia, visual objects should have a significant size.

The specific applications section describes recommendations for games and media. A lot of valuable guidelines for the interactive game can be taken out of these two sections. The 'games' recommendations mainly focus on feedback, level of difficulty, scaffolding, and game features that can be added. The most important guidelines are to avoid the distress of the PwAD by exclusively giving neutral to positive feedback. Another piece of advice is to provide a challenge to the PwAD. Without a challenge, the PwAD's interest in the game will decline. Moreover, scaffolding is also an important game element as it can provide guidance to the PwAD while playing the game. Forms of scaffolding include demonstrating how the game needs to be played, employing additional cues and clues, minimizing the need to remember previous actions, and providing a recap of what they just achieved with their actions. Lastly, a few useful suggestions include: keep the game similar to real life, do not highlight the hardships involved with dementia, keep the amount steps involved in a game as low as possible, and encourage the involvement of others.

To finish, a few recommendations from the media section could be of use in an interactive game that aims to improve reminiscence. The first suggestion is to stimulate conversations when questions are deployed to prompt reminiscence. Questions that have a right or wrong answer or which can be answered with yes or no are discouraged as they do not promote conversations. To conclude, a reminder is given of the fact that negative memories can always arise when triggering reminiscence. Therefore it is advised to avoid generally negative topics and to have someone nearby that can provide comfort to the PwAD.

2.4.2 Ben-Sadoun et. al

The recommended guidelines of Ben-Sadoun et. al [36] focus on the design of serious games for people with neurogenerative diseases, the umbrella which Alzheimer's disease falls under. The guidelines are divided into nine criteria: compatibility, guidance, workload, adaptability, consistency, significance of codes, explicit control, error management, and game rules. For 'consistency', 'explicit control', and 'error management' criteria, a direct referral is made to the ergonomic criteria proposed by Bastien et. al [37]. Consistency within the game's interface prevents confusion and errors on behalf of the user. This can be achieved by maintaining the same structure throughout the game in terms of formatting and locations of interface objects. Explicit control means the amount of control the user has over the game. It is recommended that the user should always be in control and that only the actions of the user are replied to by, in this case, the game. Error management entails that the game should be able to avoid errors and recover from them when they take place.

Similar to Lazar et. al [35], Ben-Sadoun et. al [36] recommend presenting a challenge to the user while also guiding the user. In general, the player should be guided more than usually done in a game not specifically catered to PwADs due to the memory impairment the PwAD has to cope with. Furthermore, both recommendation sets include parallel advice on the usage of feedback. Another overlapping guideline is to not display redundant information and instead only show necessary information. Apart from using familiar language like Lazar et. al [35] recommended, images and game scenarios should be recognizable as well according to Ben-

Sadoun et. al [36]. Furthermore, navigating through the game should not be complicated for the player. Keeping the controls simple and low in quantity (a maximum of 6 controls) is advised.

2.5 Conclusion

By conducting this literature review, a good basis has been created of literature that can be built upon. The first four sub-research questions have also been answered in this chapter.

SRQ1: *How does Alzheimer's disease impact the cognitive functioning of people?*

We have discovered that Alzheimer's causes numerous issues cognitively due to neurons in the brain that get damaged due to the disease. This results in dementia, which consists of memory, thinking, language, and problem-solving issues. Dementia caused by the effects of Alzheimer's disease is called Alzheimer's dementia. Besides, Alzheimer's causes behavioral issues. Mood swings, aggression, and agitation are examples of the behavioral issues faced. The gravity of the dementia issues experienced by PwADs differs from the stage of the disease they are in.

SRQ2: *What improves the reminiscence of people with Alzheimer's disease?*

To answer the second sub-research question, various treatments were explored. The existing treatments for Alzheimer's are divided into pharmacological and non-pharmacological treatments. The non-pharmacological treatments were explored more in-depth due to their relevance to games. It was discovered that various treatments, such as reminiscence therapy, tactile stimulation, and auditory stimulation have been proven to improve reminiscence among PwADs. Elements of these particularly successful treatments will be considered for implementation in the game in the next phase of the thesis.

SRQ3: *How can technology assist in enhancing reminiscence in people with Alzheimer's disease?*

Three existing technological solutions were explored which all aimed to prompt and improve reminiscence. Different types of technologies were implemented across the three solutions, such as games inside a mobile application and a tangible interactive game. Technology has been seen to be a very promising tool, especially for games, and can assist in the following ways.

Firstly, technology can unlock multiple levels of added stimulation to a game or experience. Technology facilitates the implementation of various media, such as audio, images, and video, either standalone or consecutively. These types of media can all aid in stimulating reminiscence. Memorology, a game that can be perfectly played without technology, implemented technology to unlock more interactions and reminiscence triggers.

Furthermore, technology can also reduce the need to be dependent on another person to play a reminiscent game or experience. It might take some time for the PwAD to understand and learn how to work with the technology. However, once the PwAD learns how to do so, increased independence is reached and reminiscence can take place more often without the need for a facilitator. This also benefits caregivers as it gives them more free time in which they can aid the PwAD in different ways.

Moreover, technology also makes it easier to personalize and update content provided to a PwAD, which can cause more person-specific memories to emerge. It also makes a product more useful to a wider audience without needing to create a new custom instance for every person.

SRQ4: *What are the design guidelines for developing interactive tangible games for people with AD?*

Existing recommended guidelines for the development of games for PwADs were explored to answer this SRQ. It was observed that there was a scarcity of extensive sets of guidelines. Guidelines specifically made for interactive games that aim to improve PwADs' reminiscence could not be found. This is why the decision was made to create custom guidelines for the development of the game. However, two sets of guidelines were studied, namely the guidelines of Lazar et. al and Ben-Sadoun et. al. These will form the basis of the guidelines for the game.

3. Methods and Techniques

For this research paper, the Creative Technology design process [38] (see *Figure 5*) will be utilized. The reasoning behind this choice is firstly that this design method is designed for the bachelor Creative Technology at the University of Twente. This research was assigned by the Human-Media Interaction (HMI) group but is done as a thesis for Creative Technology. The HMI group is mainly involved with and relates heavily to Creative Technology, making the Creative Technology design process almost tailor-made for this research. This is why this design method is more fitting to this research than other design methods.

To give further argumentation, another aspect that is important for this research is the focus on human interaction as people with Alzheimer's disease will interact with a tangible game. The Creative Technology design process specifically takes design methods from the field of Human-Media Interaction among others and implements them into the Creative Technology design process.

Lastly, this design method also implements technology into its process. This makes it even more relevant to this research because implementing technology is necessary to make the interactive game. Choosing the technology that is the most effective in improving the reminiscence of PwADs and fitting both the user and the idea in general, is critical to the experience.

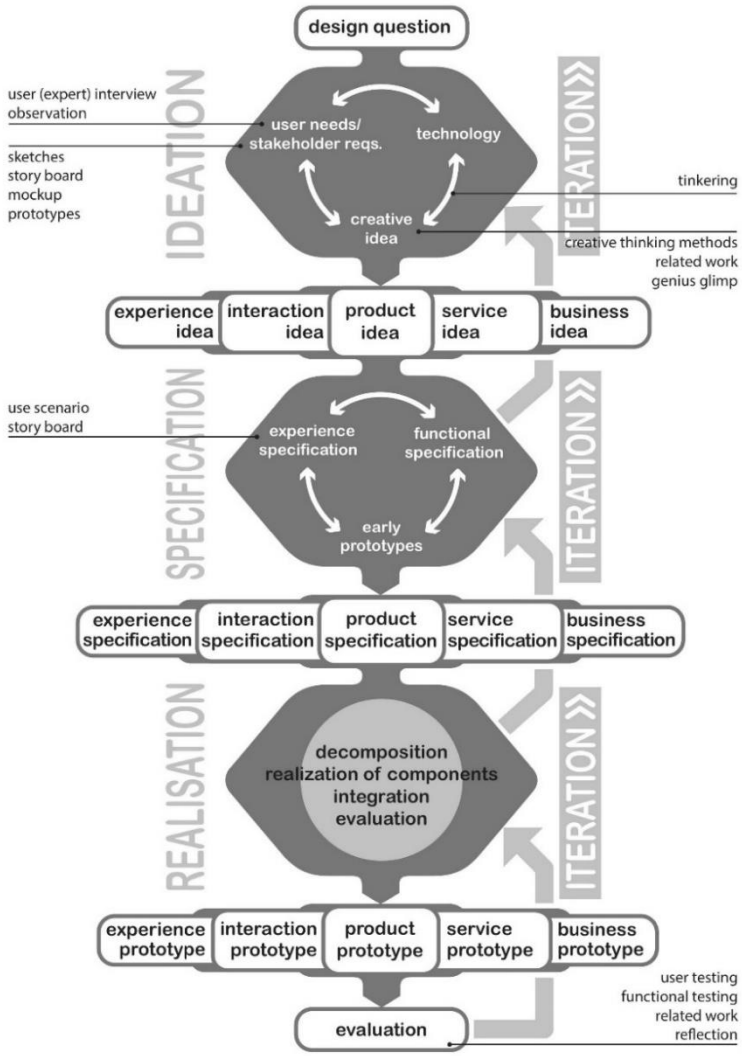


Figure 5 The Creative Technology Design Process (Mader et. al)

3.1 Ideation

The ideation phase is the first phase of the Creative Technology design process. The first task in this phase is to think of a design question that initiates the ideation process. This phase also includes the 'creative idea,' 'user needs' and 'stakeholder requirements'. These together with the element 'technology' form a cycle that is meant to generate ideas that could answer the design question. Each element in the cycle can be used as a starting point for the ideation phase.

Various methods were used in the ideation phase. Firstly, to gain further insight into various topics such as tangibles, design, and technology, an expert interview was conducted. A center for dementia and technology, the Expertise Center for Dementia & Technology (ECDT) was contacted for advice of an expert. The center was created in collaboration with the Eindhoven University of Technology and Alzheimer Nederland. The latter is an organization that supports people with Alzheimer's and other forms of dementia, their families, and their caregivers. One of the founders of the ECDT was contacted via email and he assigned an expert who he thought to be fitting for the topic. An online semi-structured expert interview was agreed upon

and conducted via Microsoft Teams. Before the expert interview was conducted, the setup of the expert interview was checked and approved by the Ethics Committee for Computer and Information Science (EC-CIS) at the University of Twente under application number 240204.

The interview was held together with a peer who has a similar thesis topic. However, the interview questions were thought of separately and were prepared before the interview. The interview questions can be found in *Appendix 3*. Before the start of the interview, an email was sent with the information sheet (*Appendix 1*) and the consent form (*Appendix 2*). The consent form had to be signed before the interview. A recording of the interview was made to transcribe the content of the interview. The transcription style that was chosen is the edited transcription. An edited transcription is a transcription in which the recorded data is edited to improve the readability and clarity of the data [39]. Furthermore, the privacy of the expert is also guaranteed as sensitive information is excluded from the transcription. The main takeaways from the interview can be found in *Chapter 4.2.2*.

3.2 Specification

In the specification phase, which is the second phase of the design process, the first early prototypes are made of the design. The early prototypes facilitate the chance to evaluate the design and receive feedback which leads to revision of the design. This process is often repeated several times until the designer finalizes the design.

Two lo-fi prototypes were made during the specification phase: a non-physical prototype and a physical prototype. The non-physical prototype was created in Adobe Illustrator and visualized the initial product idea from the ideation phase. This prototype was presented in a meeting with the supervisor to obtain validation for the concept.

The physical lo-fi prototype was developed as an iteration that could be used to gain validation in terms of design and sizing before continuing to the realization phase in which the final iteration would be made. Additionally, a physical prototype was deemed to be useful for the development of the technicalities. The recognition of the tangibles by the Arduino Uno microcontroller was fully developed on this prototype.

For the evaluation of the second lo-fi prototype, a second expert interview was held in the specification phase of the design process. The expert was from the Human-Media Interaction group at the University of Twente and was found via the supervisor of this thesis. The evaluation took place at the expert's office at the University of Twente. The expert was given an information sheet about the research and a consent form before the start of the interview. After the consent form was signed, the interview could be initiated. The prototype was placed in front of the expert and the expert was allowed to explore the features of the prototype. Consecutively, the expert was asked questions about the design, tangibles, interactivity, and general idea of the tangible interactive game. The setup of the expert interview was checked and approved by the Ethics Committee for Computer and Information Science (EC-CIS) at the University of Twente under application number 240204.

3.3 Realization

The realization phase is the third phase of the Creative Technology design process. In this phase, the final product is realized. The realization phase consists of four parts: the decomposition, the realization of components, the integration, and the evaluation. The first

three parts encompass the assembly of the final prototype. The evaluation is described separately in more detail as it is a significant part of the design process.

For the realization of the final prototype of the game, a wooden hi-fi prototype of the puzzle board was lasercut. Inside the box of the puzzle board, the wiring was organized and the Arduino Uno microcontroller was placed. Furthermore, the part of the game Unity game engine was mostly developed in this phase. A description of the entire realization process can be found in *Chapter 6*.

3.4 Evaluation

In the evaluation, the final prototype is assessed. In this thesis, the aim of the evaluation was to evaluate the usability of the game and if it evokes reminiscence. A qualitative usability study was decided upon based on the aim of the evaluation. The qualitative usability study consisted of user evaluations in which proxy users tested the game and a semi-structured interview. The evaluation was conducted with proxy users instead of PwADs to discover the initial usability issues first without having to bother the PwADs.

For this evaluation, a total of five participants were recruited, following the 5-user rule by Nielsen Norman Group [40]. This rule states that at least 85% of the usability issues will be found when testing with five users. The participants were recruited in the Dutch neighborhood of the researcher.

Before the user evaluations were conducted, an information sheet and a consent form were given to every participant. The information sheet consists of information about the purpose of the study, the procedures for withdrawal from the study, the use of personal information, the usage of data during the research, and contact information. The consent form was used as a way for the proxy users to formally consent to their participation in the research. The information sheet and consent form can be found in *Appendix 1 and 2*.

During the playtest, the participants played the game from start to finish. A video was made of the playtest and semi-structured interview to process after the evaluations had been concluded. The semi-structured interview consisted of a variety of questions. Each question belonged to one of the following categories: ‘general questions’, ‘content’, ‘tangibles’, ‘pros and cons’, and ‘closure’. The questions were asked in Dutch because not all of the participants spoke English and to avoid confusion in general. The list of questions in Dutch can be found in *Appendix 8*. The questions translated into English can be found in *Chapter 7.3*. The setup of the expert interview was checked and approved by the Ethics Committee for Computer and Information Science (EC-CIS) at the University of Twente under application number 240425.

4. Ideation

Based on the literature that has been explored, the decision to develop an interactive game that uses tangible objects was made. Research stated that PwADs have the tendency to physically interact with tangible objects and most importantly prompt a PwAD to reminisce [7], [8]. The usage of tangible objects would also create the possibility to implement tactile stimulation via textures by giving the tangibles texture. Textures have various benefits for PwADs, such as positively affecting the emotional well-being of a PwAD, as well as causing reminiscence to take place [8], [10], [11], [12]. In the ideation phase, an idea for the tangible interactive game will be developed.

4.1 Design question

The first phase of the chosen design method, namely the Creative Technology design process, is the ideation phase. Before starting the ideation phase, a concrete design question is needed to ideate upon. The use of the design question is to act as a starting point for the design process. The design question is: *"How can we combine physical objects and technology to enhance reminiscence among people with Alzheimer's?".* This design question was decided upon to put the main focus of the design process on thinking of a concept in which an interplay between tangible objects and technology eventually can be realized.

4.2 Expert interview

The second step made in the ideation phase was conducting an expert interview. The expert interview was conducted with an expert from the Expertise Center for Dementia & Technology of the Eindhoven University of Technology. The expert has been active as a researcher at the expertise center for a year but has been developing solutions for people with dementia for over five years. The method of the expert interview can be found in *Chapter 3.1*. The aim of the expert interview was to gain first-person insights on questions from the perspective of someone who has designed technological solutions for people with dementia. An expert's experiences and knowledge were assumed to be beneficial for this thesis as there was a high chance new information would be gained.

4.2.1 Topics of the expert interview

The interview started with a few introductory questions to find out about the expert's background and expertise. Then the main interview questions were asked, which were divided into a few categories. The categories of the questions were:

- People with (Alzheimer's) dementia
- Games for people with (Alzheimer's) dementia
- Tangibles
- Technology
- Design

Follow-up questions and other questions that were not on the list of questions were also asked throughout the conversation. The list of questions can be found in *Appendix 3.*

4.2.2 Main takeaways

The recording of the interview was listened to, to make an edited transcription in which the main takeaways were written down. Additionally, certain recorded data was quoted to clarify the takeaway. The main takeaways per topic with their respective elaborations can be found in *Table 1*.

The takeaways most useful to this thesis are that cultural relevancy is an important factor in creating activities such as games for PwADs. Moreover, the suggestions of things to avoid in games for PwADs can assist in the choices made in the development of the game. Another interesting point the expert made is that a group setting for games has multiple benefits for PwADs. This is why a multiplayer feature is highly considered for the tangible interactive game. The newfound information on tangibles is that weight and size can have an impact on the accessibility of the tangibles. Additionally, if the number of tangibles is too high the PwAD can visually be overstimulated. The ideal characteristics of the tangibles can be figured out via trial and error. Some pieces of advice on design have also been deemed useful for the game. The manual dexterity issues PwADs have will be catered for by keeping hand movements necessary to play the game simple. On top of that, the list of things that can make or break the game experience will be kept in mind during the development.

Table 1 Takeaways from the expert interview

Topic	Main takeaways	Elaboration
People with (Alzheimer's) dementia	The general knowledge of the world of people with dementia differs from person to person	The stage of the disease and the surroundings of the PwAD can impact their knowledge, despite being in the same age range
	Activities focused on things that solely relate to people from the same area might not be as impactful for people who aren't from that area or originally from a different country and culture	The expert noticed that the organization of day facility activities is very localized and tends to relate very well to a person's personal history or where they're from
	Probes, such as personal objects and conversations, can be used to stimulate reminiscent experiences	To stimulate reminiscent experiences, the expert has used personal objects and related objects based on the person's past work history and is currently trying to do so by inspiring conversations about leisure in their youth in workshops
	Nature and animals, as well as relationships with animals, are very valuable to people with dementia	An example of the usage of animals with people with dementia is animal therapy, which some daycare facilities for people with dementia make use of

Games for people with (Alzheimer's) dementia	Games play a significant role in the daycare environment of people with dementia	Examples of games played: • Rolling balls on a table into holes • *Sjoelen* (A Dutch traditional shuffleboard game) • Card games • Rummikub • Jenga • Pub quizzes • Crossword puzzles • Mind active/brain training games that aim to improve memory and motor skills

	Some elements in games for people with dementia should be avoided	Elements that should be avoided:
		• Too physically intensive
		• Anything that challenges their understanding of reality
		  ○ Pub quizzes are good but also perhaps harmful because if someone doesn't remember, they might feel bad, disoriented, or hurt by not knowing a certain event
		• Too difficult
		  ○ Instead, make the person ease in first and gradually make the game more complex
		• The ability to be wrong
		  ○ Can cause distress and agitation and can make the diagnosis worse
		• Giving too many instructions in the beginning and having too many steps to learn something can cause the person to be overwhelmed and confused
		  ○ Bringing the point of the game across without using too many words and go step by step

	Games that use technology are also used by people with dementia	Examples of games that use technology: • The Wii console by Nintendo • Tovertafel (although not an accessible product due to the time and energy it takes for daycare facilities to operate and it being expensive) • Dancing robots that inspire people to dance • Dance classes given by an animated character that people can do from their chairs
	A group setting for games is good for people with dementia	Positives of a group setting: • People can watch each other and learn from what they are doing • Gives confidence about doing something • Feeling of camaraderie • Prevents people from becoming isolated A possible downside of a group setting could be that some people take more control, which causes a power dynamic to commence. However, people can also take an observation role and find pleasure in that
Tangibles	Tangible objects are important due to the physical quality of the interaction	Muscle memory engages in physical interactions, which increases appreciation for the smaller tactile qualities which may not happen if you are receiving experiences in, for example, a virtual reality setting
	A tangible object can be generated more easily than a non-tangible object and can be latched onto and appreciated after the experience as well	An example of this is a clay sculpting activity in which new tangible objects can quickly be made and appreciated afterward
	Multiple textures cause various sensations to take place and allow for more opportunities to discover and notice	Additionally, the textures can trigger thoughts and feelings. The usage of textures inspired by personal history/familiar materials can also trigger more thoughts and feelings

	The size and thickness of a tangible has an impact on the experience	The size and thickness can make the tangible either more or less accessible
	The weight being too heavy or too light has an impact on the experience	Weight can cause someone to make an association with something. For example, a certain weight can allude to something being a precious object
	The number of objects given to a person with dementia can be too visually stimulating when there are too many	Visual noise should be limited by creating some structure. Finding the ideal number of objects is often a trial and error process
Technology	There is a learning curve with technology for people with dementia but this can be overcome	This depends on the stage and their personal history with technology in general. Some people in the daycare spaces have phones and iPads. They have the capacity to use them until a certain point in the disease. In general, people with dementia can learn new things and become familiar with new things. It is trial and error to find out which technologies are too difficult for people with dementia
Design	There are some difficulties when designing for people with dementia	The difficulties: • There is a tendency to have your assumptions, but it is important to enter the design process with zero assumptions • It is hard to anticipate what reactions people with dementia will have to your product
	Learning how to start a conversation for feedback on your product (design) with a person with dementia takes time	Strategy is needed when asking for feedback from people with dementia on a game or product because a conversation can quickly deviate from what you want to talk about. Additionally, when getting feedback on a game or product from people with dementia, the same opinion can be expressed multiple times because they cannot remember

		they already expressed that opinion • One strategy is making a general topic the starting point of the conversation and using it to lead up to the actual question
	Take manual dexterity issues into consideration when designing for people with Alzheimer's dementia	Manual dexterity issues increase significantly due to Alzheimer's disease compared to healthy older counterparts [41] Recommendations: • Find out what hand movements people are able to do via trial and error • Arm movements might be easier than hand movements
	The expert uses guidelines when designing objects for people with dementia	Guidelines: 1) Start with observations to see the general ability level of people when engaging in playful activities and how they direct a conversation 2) Then engage in these things with people with dementia as a researcher 3) Create a connection between you as the researcher and participant by being present in daily activities and routines 4) Make prototypes based on the observations 5) Place the prototypes into the space of the people with dementia 6) Ask questions that help with thinking of an iteration 7) Make video and audio recordings of the playtime and then use them to reflect on the engagement on multiple levels, both individual engagement, as well as engagement with others
	Some aspects of a design can make or break the experience for people with dementia	• The way you visually present something to a person determines whether they will be interested in interacting with your object

		• If an object looks childish it can make the person with dementia not want to play with it • The design looking too complex • The design having visual noise

4.3 Technology

The design question and expert interview led to thinking about which technologies could be used that are the most fitting to implement into a game that uses tangibles. Firstly, a technology is needed that can control multiple components since the tangibles need to be programmed to function together. It should also be able to communicate with a laptop screen for example that aids as a visual. An Arduino microcontroller could be used to carry out this task. Arduino microcontrollers are powerful and multifaceted and thus suit this project [42]. Furthermore, if there were a screen that displays part of the game, a game engine would be useful to run the game on. The idea of the screen was inspired by the recommendation by Lazar et. al [35] of using multiple forms of media to engage the user more. All listed media forms can be implemented via a screen. Additionally, a game engine such as Unity is, again, versatile and powerful, just like Arduino microcontrollers. Communication between the Unity game engine and an Arduino microcontroller can be facilitated with the use of serial communication, which in turn can connect the tangibles to the game experience on the screen to create both a physical and a visual experience for the PwAD.

4.4 Design requirements

The design requirements are a set of rules the design of the tangible interactive game should adhere to. These requirements aim to meet the needs of people with Alzheimer's. Existing recommendations in the scientific literature were explored in *Chapter 2*. However, only a handful of cohesive papers providing recommendations exist in scientific literature. Additionally, these recommendations were focused on fairly broad concepts, such as serious games and recreational systems for PwADs. Thus, these recommendations do not specifically cater to the development of a tangible interactive game that improves reminiscence among PwADs. This is why the decision was made to create custom requirements based on additional existing literature and findings from the expert interview.

The design requirements were created by going back and forth between the ideation and specification phases, as the final idea for the tangible interactive game was developed in the latter phase. The design requirements are divided into six categories: hardware, layout, content, gameplay, navigation, and tangibles. These categories are based on the categories of Lazar et. al but with an added category for the tangibles. All the categories, except the tangibles category, are inspired by the categorization seen in recommendations in scientific literature. The design requirements were chosen based on their relevancy to the creative idea e.g. recommendations on touchscreens were not used.

Table 2 Design requirements for the development of the tangible interactive game

Category	Design requirements
Hardware	• Make the system approachable [35]

	• Consider simple alternate forms of input [35] • Simplify the process of connecting the system to monitor [35] • Make the system mobile [35] • Avoid a large and bulky system [35] • Accommodate seated users [35] • Accommodate reaching issues [35]
Layout	• Use large sizes due to the likeliness of vision impairment [35] • Consistency in the localization of items in the user interface [36]
Content	• Make different forms of media congruent [35] • Make the content diverse [35] • Include short clips of 30-60 seconds [35] • Consider repetition [35] • Include images [35] • Use images and game scenarios that are familiar enough to the user [36] • Use language that provides context [35]
Gameplay	• Prompt user to reminisce • Involve challenge [35], [36] • Avoid interruptions [35] • Provide constant feedback [36] • Keep feedback neutral to positive [35] • User cannot be wrong as this can agitate and distress them (according to the expert)
Navigation	• Make interactive elements obvious, large, and far apart [35] • Clarify what is interactive [35] • Make it clear when an action is completed or not [35] • A maximum of six game commands should be used [36] • Provide constant navigation guidance [36]
Tangibles	• The size and thickness of the tangibles should not be too big or too small • The tangibles should not be too heavy

	• Limit the amount of tangibles to create structure and avoid visual noise • The tangibles have to stimulate the touch via textures • The tangibles should be easily recognizable

4.5 Brainstorm

To generate ideas for the game, a brainstorming session was conducted. The session's goal was to write down as many ideas as possible in a short time. The ideas were written down in the Apple Notes app. The brainstorming session led the project in a good direction. Once the brainstorming was concluded, the ideas were weighed against each other. Many ideas were eliminated based on personal opinion and other considerations such as the scope of time of this thesis and access to resources. A few ideas that were considered are the following:

- A memory lane game: A game centered around significant historical events, popular trends, and cultural icons from the past. The game includes various media such as physical objects, sound, music, and video footage from the past to stimulate reminiscence. This idea was more an experience than an actual game.
- A life simulation game: A game in which the PwAD can carry out tasks they used to do in the past to enhance reminiscence. The issue with this idea was that it was difficult to think of a way to implement tangibles.
- An interactive storytelling book about the PwAD: A game in which stories related to the PwAD's past are told with supporting imagery, sound, and music based on the choices made by the PwAD along the way to revisit memories and reminisce about them.

Ultimately, these ideas were not picked. The final creative idea was decided upon by the researcher because it was multifaceted, interactive, and had great potential to improve reminiscence.

4.6 Creative idea

The brainstorming session led to a concrete idea for the tangible interactive game. The idea is a puzzle game in which the user has to match the tangibles to the prompt shown on a laptop screen. The prompts are daily life situations such as a day at the market and a walk in the forest. In total, there are five prompts. The user gets a board with holes shaped like the base of the tangibles in which the tangibles have to be put. The user has to pick a combination of five tangibles to put into the board for every prompt. There is only one correct combination because it would be difficult to implement multiple correct combinations. If the user is right, a video of the daily life situation from the prompt is shown on the screen with a "Well done!". After the "Well done!" it will ask the PwAD "Why do these objects make you think of this situation?". If the user is wrong, "Not quite there" will be shown on the screen. When they are wrong a second time, the user will be asked "Why do these objects make you think of this situation?" The game does not say the user is incorrect as this could distress or agitate them due to it being negative feedback [35].

Furthermore, various forms of sensory stimulation will be implemented into the game since it was discovered in the literature research that these helped with stimulating reminiscence. Firstly, stimulation via textures will be implemented into the tangibles. The tangibles will have textures similar to the textures they have in real life. The tangibles already provide tactile stimulation, but the textures enhance the stimulation. Additionally, auditory stimulation will be implemented via the videos the user will get to see. The audio will be the original audio of the videos as these are representative of what the real-life situation sounds like. Lastly, visual stimulation is offered via the videos shown, which aims to stimulate reminiscence and promote engagement.

The last aspect of the game is that it will be in Dutch because familiar language and cultural language are important according to the explored literature and the expert [33], [35], [36].

5. Specification

After finalizing the idea for the tangible interactive game, the specification phase of the design process could be initiated. Ideas for a possible design were thought of during the ideation process of the creative idea but were not yet put on paper. Thus, a storyboard was made that portrayed the initial idea of the design of the game and the interactions. The storyboard serves as the experience specification.

5.1 Storyboard

A storyboard was made to create a better idea of what interactions could take place with the tangible interactive game. The storyboard can be found in *Figure 6*.

Figure 6 The storyboard of a possible interaction

5.2 Functional requirements

The necessary implementations to make the tangible interactive game functional are listed in the functional specification. In *Table 3*, the functional requirements are listed, as well as the reasoning behind it being a requirement.

Table 3 The functional requirements of the game

Requirement	Elaboration
The electronics of the puzzle board should be hidden and hard to access for the user	To ensure the safety of the user and to prevent them from breaking the game
The game is mobile	It is important for the convenience of the user that the game can easily be plugged out and stored away
The puzzle board and tangibles are robust	Lost pieces will cause the game to be unplayable
Every tangible should be uniquely identifiable	The technology needs to know which combination of tangibles the user puts in the puzzle holes
The input from the puzzle board needs to go to the laptop	For the laptop to play the videos in Unity, it needs to get input from the puzzle board with its respective tangibles via the Arduino
The laptop needs to be able to play audio	Without the audio, the auditory stimulation via the videos cannot take place
The laptop needs to have the Arduino Integrated Development Environment (IDE) and Unity game engine installed	The game cannot be played without the two computer programs being on the laptop

5.3 The first lo-fi prototype

The first prototype was a digital visualization of the game in Adobe Illustrator (see *Figures 7-11*). This helped get a clear visual of the game, instead of only having a written version of the concept. It also aided in explaining the concept to others such as the research supervisor. The visualization shows the setup of the game, a short explanation of the premise of the game, information on the characteristics of the tangibles, and the technicalities of the game.

The setup visualization gives a simplified overview of what the PwAD sees in front of them while playing the game. The board with the holes with a few of the tangibles and a laptop is shown on a brown rectangle that represents the table they are placed on. However, in reality, there should be 15 different tangibles and a wire that connects the Arduino to the laptop. The puzzle board is in the shape of a box because it was envisioned to hide the hardware in there. This not only ensures a cleaner design but also prevents the PwAD from accidentally breaking the hardware equipment.

The second visualization shows the premise of the game. The premise slightly changed after the validation from the supervisor. The PwAD will namely also be asked why the objects they chose made them think of the situation in the prompt when they get it right. This choice was made to stimulate them to reminisce more even if they are correct.

The third visualization shows in-depth information about the characteristics of the tangibles and their role in the game. The tangibles are objects related to daily life because the prompts are daily life situations. Daily life was chosen as a theme to make the game accessible to a wider range of PwADs. The prompts do not require a high level of expertise about a certain topic, making them recognizable to most people.

Furthermore, the visualization of the technicalities of the tangibles shows how they are recognized by the puzzle board. It is shown that there will be six aluminum strips under every tangible. Both the number of strips per tangible and the approach of the tangible recognition change slightly during the specification phase. The last visualization displays the connection between the puzzle board, Arduino, and Unity.

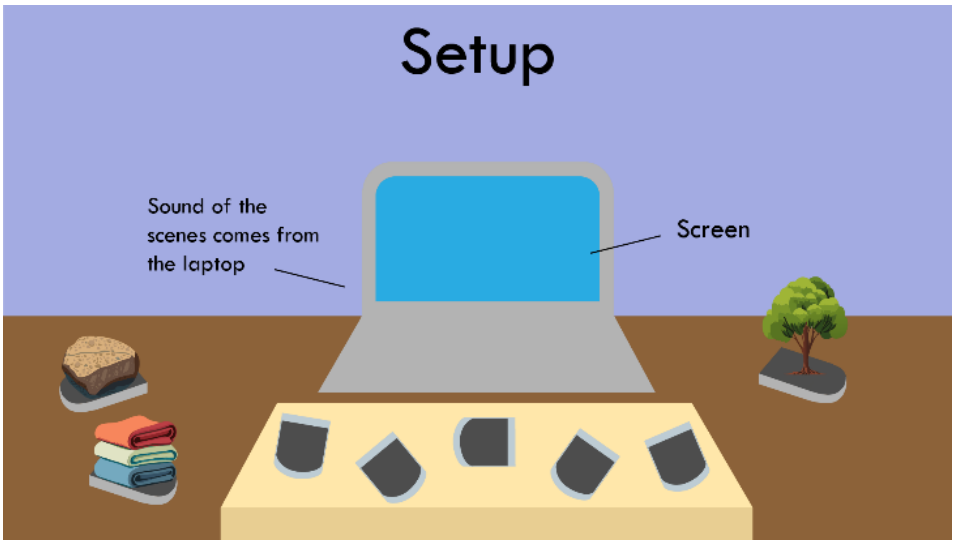


Figure 7 The visualization of the setup

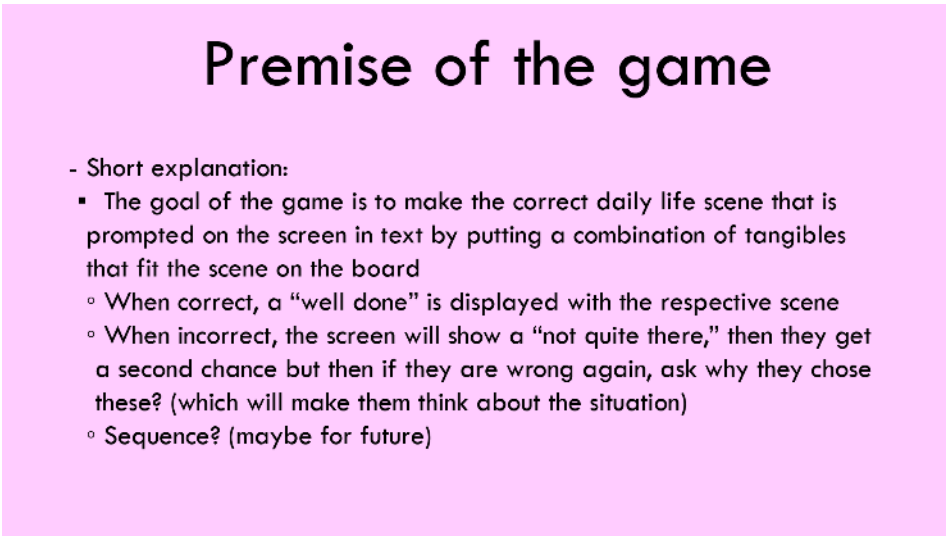


Figure 8 The premise of the game

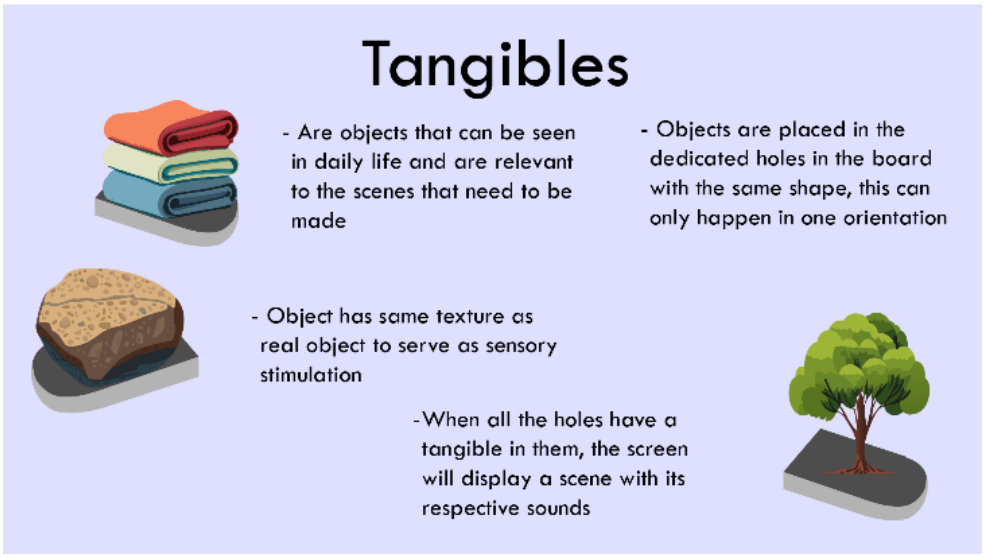


Figure 9 The tangibles and their characteristics

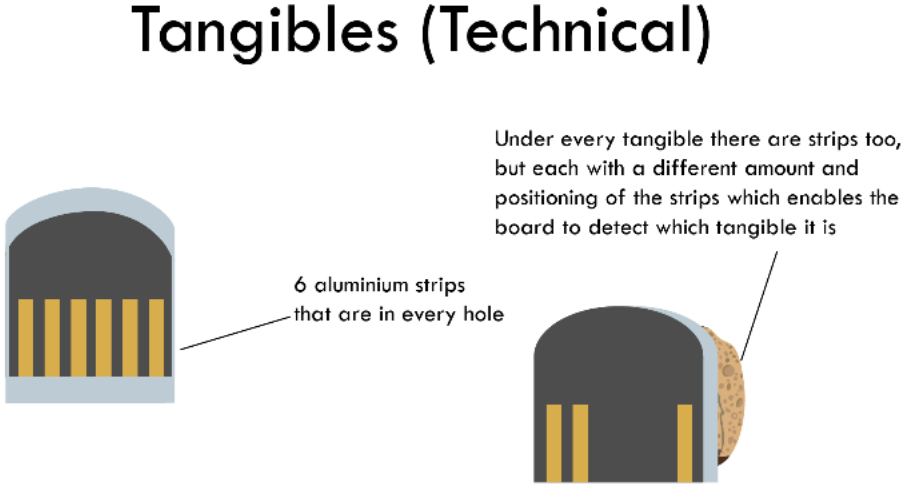


Figure 10 The technicalities of the tangibles

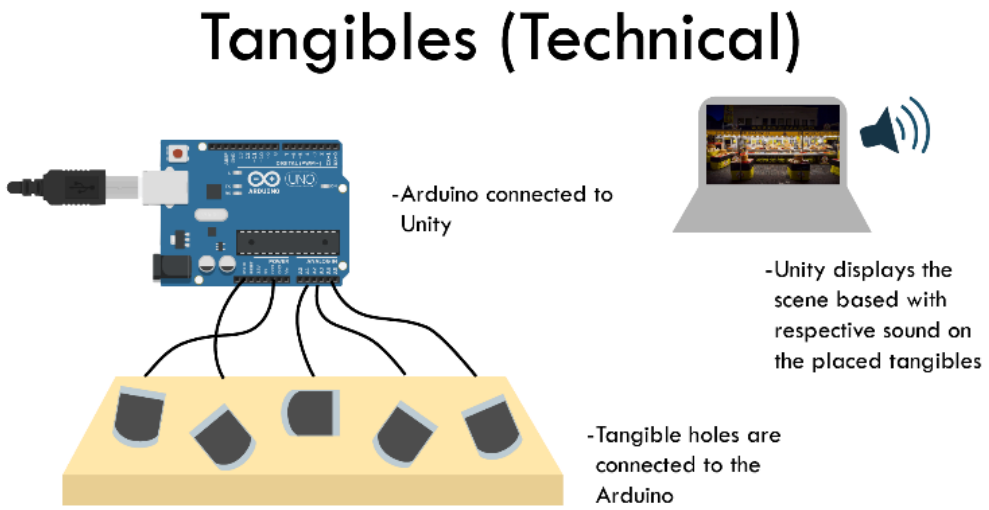


Figure 11 The technicalities of the tangibles together with the Arduino Uno and Unity

5.4 The second lo-fi prototype

A physical lo-fi prototype of the puzzle board with its tangibles was made after obtaining validation for the concept idea from the supervisor. The decision to make a lo-fi physical version next to the visualization was made because of several reasons. Firstly, the jump from a lo-fi visualization to a hi-fi (high fidelity) prototype would have been too big to discover issues in the design. Secondly, the physical lo-fi prototype also allowed for a more hands-on experience during the lo-fi test with the expert. It also enabled the expert to give opinions on the size of the puzzle board and the tangibles. Lastly, the physical lo-fi prototype made it possible to create new iterations of the prototype more swiftly.

The physical lo-fi prototype was made out of cardboard because this material was widely available and easy to manipulate. Five holes in the shape of the tangibles were cut into a piece of cardboard to serve as holes in which the tangibles could be put. A second piece of cardboard was placed under the cardboard with the holes to create a surface under the holes. The pieces of cardboard that were cut out to create the hole were used as the base of the tangibles. Then a wheel of cheese, a palm tree, and a tray with a knife and fish were made to serve as examples of objects seen in daily life. These were put on top of the cardboard bases. Furthermore, some aluminum foil was cut into thin strips that would serve as the conductive material that would recognize each tangible. Three strips were stuck on one of the holes and one of the tangibles with the use of adhesive putty. One notable aspect of the holes is that they were all placed in different orientations. The initial idea of the varying orientations was to make it visually more interesting for the user. Additionally, the orientations also made it easier to put the copper foil strips in different spots.

After assembling the board, the focus was on the technicalities of the game. The lo-fi version of the game was ideal to use for testing the puzzle identification. The first test in this process was to see if the aluminum foil was conductive enough (see *Figures 12-14*). The first and third aluminum strips under the tangible were connected with some more aluminum foil. Consequently, two crocodile clamps were clipped onto the ends of the aluminum strips on the hole and to male-to-male jumper wires. The first strip was connected to a pin on the Arduino and the third to the circuit on the breadboard. A few other wires, a resistor, and an LED light

made the circuit complete. The LED light would visually show how well the aluminum foil conducted. The code for the circuit was written in the Arduino IDE (integrated development environment). The circuit was now ready to be tested. The tangible was put into the hole to close the circuit. The result of this test was that the LED light only lit up very dimly and overall created an inconsistent connection. The test concluded that a medium that conducted better had to be found.

Figure 12 The aluminum foil under the tangible

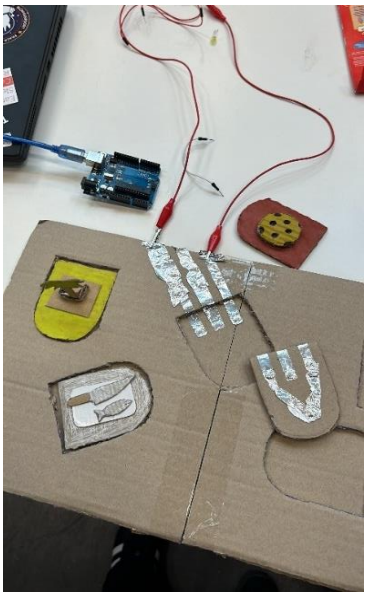


Figure 13 The puzzle board and tangibles during the conductivity

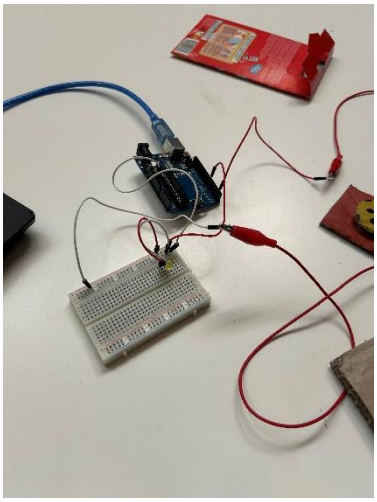


Figure 14 The conductivity test with the LED

The decision to replace the aluminum foil with copper tape was made after briefly ideating about alternatives to aluminum and consequently researching copper's conductivity. The findings were that aluminum is 39% less conductive than copper [43]. The copper tape was made out of a thin copper layer with an adhesive back. The same conductivity test was done with the copper tape. The LED was much brighter than with the aluminum foil, indicating that it conducted significantly better. However, on the second attempt to make the LED light up, it did not work anymore. After trial and error, it was discovered that the copper strips under the tangible were the issue. Sticking cut-up copper strips onto each other prevented the current from passing through due to the adhesive preventing conductivity. Instead, one whole shape had to be cut out and put under the tangible for reliable conductivity.

The solution for the tangible identification was a trial and error process. A lot of noise was often detected and it took time to identify the issue. Eventually, the problem was recognized as an open circuit issue. By utilizing the internal pull-up resistor of the Arduino Uno, the tangibles were successfully recognized.

The next step of the development was to write the code for the serial communication between the Arduino Uno and Unity game engine. After a lot of hours debugging the code and looking for answers on the Unity Discussion website, Unity would eventually play a video upon receiving the correct string of five words. These words are the words assigned to every tangible in the Arduino code.

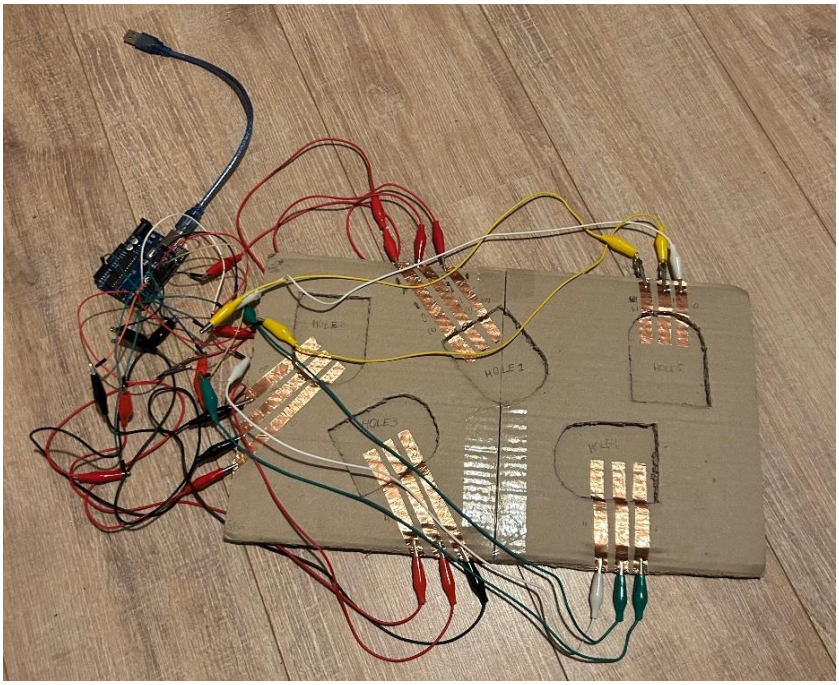


Figure 15 The physical lo-fi prototype with copper tape, crocodile wires, jumper wires, and an Arduino Uno

5.5 Evaluation of the second lo-fi prototype

A semi-structured interview with an expert was conducted for the physical lo-fi prototype. The expert interview aimed to evaluate and gain feedback on the puzzle board, tangibles, interactivity, and general idea of the tangible interactive game. In *Table 4*, the questions of the evaluation can be found per category.

The first two categories of questions were about the design of the puzzle board and the tangibles. The expert mentioned that the puzzle board's design was fine. She specifically thought the sizes of the puzzle holes are nice because they leave a slight bit of extra space that allows the tangible to be placed in with ease. She liked that due to its size, it can be easily placed and put away. The shapes of the puzzle board and tangibles were also fine according to her. Lastly, she mentioned that the size of the tangibles was fine, but that they would all need to be high enough to grab in the final prototype.

The interactivity was also discussed, despite most of the interactions not yet being developed. At the time this interview took place, the tangible recognition and the serial communication were not yet working. It was difficult to say for the expert whether or not the game was interactive enough due to the game not being developed yet. She did suggest to maybe add lights to emphasize where to put the tangibles. Based on the current prototype, she did enjoy that she could interact with the tangibles by fidgeting with them. She also thought the tactile stimulation via texture that is added to the tangibles in the final prototype was a nice addition. Lastly, the combination of the screen, tangibles, and puzzle board was discussed. The expert felt it would be engaging, but said a tablet could be a better option to integrate the screen into the rest of the game.

The expert thought overall the lo-fi prototype was nice and the idea for the game was viable. She said that if the game is easy to use, introduced well, and intuitive it can be a nice way for people to have a conversation about things with somebody they know. She advised the researcher to be careful with making the setup too technical and to make it a plug-and-play

game for people who are not as technical. Lastly, the suggestion was made to add colors to both the puzzle holes and the tangibles so the user knows where to put the tangible once they think it fits the prompt.

Table 4 The questions for the evaluation of the lo-fi prototype

Category	Questions
Puzzle board	• What do you think of the overall design of the puzzle board? • Do you like the shape of the puzzle board?
Tangibles	• What do you think of the shape of the tangibles? • Are the tangibles big enough? • Are the tangibles easy to grab?
Interactivity	• Is the interactive game interactive enough? • Is the idea of the combination of a visual element through the screen and physical activity via the tangibles engaging?
General questions	• What was your first reaction after seeing the prototype? • What did you like the most about the concept/prototype? • What did you dislike the most about the concept/prototype? • Any suggestions on how this prototype can be improved?

5.6 Final concept

The final concept of the game was a tangible interactive puzzle game that contained 15 tangibles, a puzzle board, and a laptop. The game was decided to be aimed at people with mild to moderate Alzheimer's as it seemed unlikely that people with severe Alzheimer's would be able to play the game. The game can be played either alone or with others, but it is advised to be played with others to converse about memories. The puzzle board and the tangibles' bases would be lasercut out of wood. The puzzle board would have a box compartment under it which would store all the hardware. Every puzzle hole would have three copper strips in it. The tangibles each could have three different shapes of copper strips depending on which two copper strips on the puzzle board they had to connect. The laptop would serve as the device the visuals of the game would be on. The prompts, videos, and questions are displayed on the laptop screen. The game has three prompts in total: a market prompt, a petting zoo prompt, and a beach prompt. The market prompt has a banana, a fish, a tomato, a scale, and a piece of cheese as its tangible objects. The petting zoo prompt has sunscreen, a towel, slippers, the sea, and dunes on each of the tangibles. Lastly, the beach prompt has a goat, a cow, chickens, a pig, and hay bales as its corresponding tangibles.

The user starts the game and the screen displays the first prompt, namely "What do you think of when you think of the market?" Upon choosing the correct combination of tangibles and

putting them in the correct puzzle holes, the screen displays a video of the market. The videos include audio and were all shot in The Netherlands to make them recognizable for the Dutch user. To continue to the next screen, the user has to use the left mouse button to press the “Next” buttons on the screen. Afterward, the question “Which memories do you have of the market?” would be asked to the user. The user has to reminisce about their memories, preferably with another person or more people as group settings are beneficial for PwADs according to the expert from the Expertise Center for Dementia & Technology. This might make the PwAD reminisce more actively. The process described in this paragraph will be the same for the petting zoo prompt and the beach prompt. The game has been concluded after the beach prompt.

Some suggestions from the expert such as replacing the laptop with a tablet were considered for the final concept, but due to time constraints, the researcher continued developing for use in combination with a laptop. Another suggestion from the expert which was considered was adding colors per puzzle hole so the PwAD would know where to put the tangible. This however seemed to make the game contain less of a challenge as puzzling with the copper strips would not be needed anymore.

6. Realization

The third phase of the design process was the realization phase. The final concept which was decided upon in the specification phase was developed into a hi-fi final prototype in this phase.

6.1 Interaction

The final concept for the game was decided upon at the end of the specification phase. However, during the realization process, it was decided that it would be nice to have a main menu in the game. A sequence diagram of the interactions has been made in Adobe Illustrator to visualize the interactions implemented into the final prototype and in which order they occur. The sequence diagram can be found in *Figure 16*. Starting up the game by opening the Arduino IDE and Unity has not been included as an interaction.

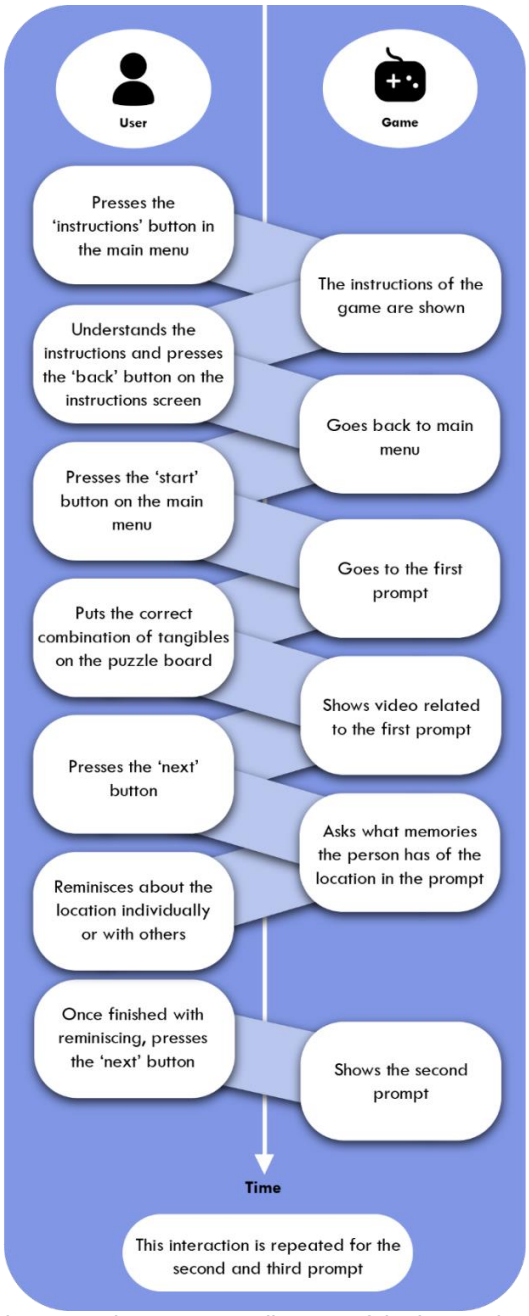


Figure 16 The sequence diagram of the interactions

6.2 Technology

The technology of the tangible interactive game consisted of hardware and software components. The hardware was in the box of the puzzle board and was connected to a laptop. Meanwhile, the software would translate the signals from the hardware to the digital part of the game on the laptop. During the specification phase, some work was already done on the technology for the recognition of the tangibles. The tangibles were able to be recognized by the Arduino with the use of copper tape, jumper wires, crocodile clamps, and programming code written in the Arduino IDE. However, some crucial parts of the game were not yet programmed. Firstly, the part of the game in Unity was not yet created. A Unity scene had to be created and programmed for every screen the user would see after a certain interaction took place. The content for these scenes also had to be made. Furthermore, the communication between Arduino and Unity also had to be programmed.

6.2.1 Hardware

A final decision was made on what hardware would be used before creating the final prototype. An Arduino Uno was used in the second lo-fi prototype, but this type of Arduino only has 14 digital pins, while 15 were needed for the recognition of the tangibles. This is why alternative options were looked at for the Arduino Uno. The Arduino Due microcontroller on the other hand had a staggering 54 digital pins, which would be more than enough digital pins for the game. This microcontroller was already in the possession of the researcher, which is why the code was tested with this microcontroller. However, compiling issues soon arose in the Arduino IDE once this microcontroller was introduced to it.

The final decision was to switch back to the Arduino Uno and use one of the analog pins on the board as a digital pin. Most of the other hardware was still the same compared to the hardware used in the second lo-fi prototype. The only difference was that every jumper wire connected to a pin on the Arduino would be soldered onto a copper tape strip. The previous method of clamping crocodile clamps onto every copper strip would namely become less feasible once the hardware was in the box of the puzzle board. A better connection with the copper tape strips would also be ensured with soldering. However, crocodile clamps were used in between jumper wires to extend their length. To prevent the metal of the clamps from interfering with each other, electrical tape was put on the clamps. Electrical tape was also used to group the wiring per puzzle hole, ensuring better wire management.

A table of the final hardware with their functions can be seen below to give a clear overview of their responsibilities (see *Table 5*).

Table 5 The hardware and their functions

Hardware	Functions
Arduino Uno	• Picking up incoming input signals via the pins and sending them to the Arduino IDE on the laptop
Jumper wires	• Serving as a medium over which electrical signals are transferred from the copper tape to the pins on the Arduino

Crocodile clamps	• Used to connect two separate jumper wires to make the wire long enough to reach the Arduino pins from the copper tape strips • Serving as a medium over which electrical signals are transferred from the copper tape to the pins on the Arduino
Copper tape	• Used on the tangibles and the puzzle holes on the puzzle board for the tangible identification. A circuit will close once a tangible is placed in a puzzle hole. This causes two pins to be connected.
Laptop	• Receives input from the Arduino Uno via the laptop's USB port • Runs the software used for the game, namely the Arduino IDE and Unity game engine

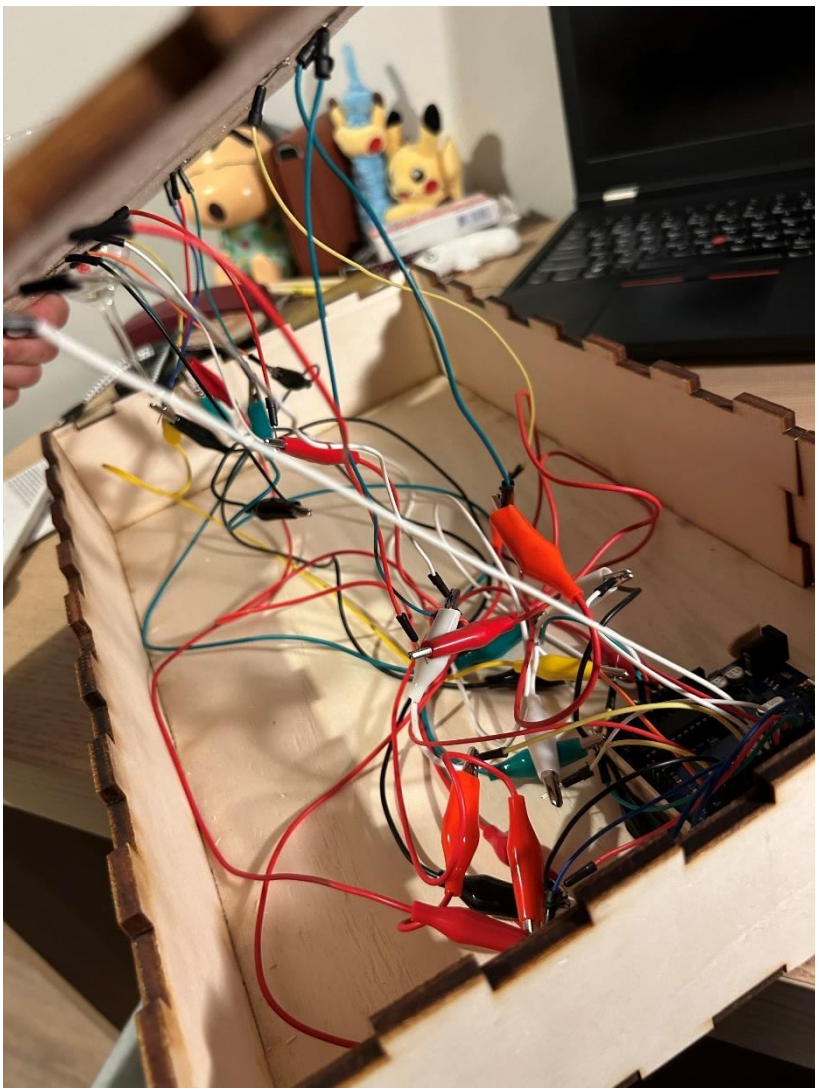


Figure 17 The hardware inside the box of the puzzle board

6.2.2 Software

Two types of software were used for the tangible interactive game: the Arduino IDE and the Unity game engine. These were considered as possible options during the ideation phase and were not deviated from throughout the design process.

Arduino

In the Arduino IDE, the code for identifying the tangibles was written. Every puzzle hole had its respective number from 1 until 5. Every puzzle hole also had three pins associated with it. Every combination of pins within the puzzle hole had a word assigned. A message in the form of a string of words was made and printed into the serial monitor. The serial monitor would constantly display the current incoming message without any delays. The code written in the Arduino IDE can be found in *Appendix 5.*

Unity

The Unity game engine was responsible for the interactive parts of the game on the laptop. In the Unity environment, scenes are used for every distinct part of the game. The scenes of the tangible interactive game were:

- Menu
- Prompt1
- ScenePlayerMarkt
- MarktHerinnering
- Prompt2
- ScenePlayerKinderboerderij
- KinderboerderijHerinnering
- Prompt3
- ScenePlayerStrand
- StrandHerinnering
- Bedankt

The first scene of the game was the main menu. Thereafter, the prompt, video, and reminiscence scenes follow. This is repeated three times in total. The ‘Bedankt’ scene is a thank you to the user for playing the game. This scene was implemented for the evaluation of the game, which is described in *Chapter 7*. Each scene had a C# script assigned to it. All the scenes had scripts that controlled the scene switching. The ‘ScenePlayer’ scenes had scripts that played the video once the correct combination of tangibles was put onto the puzzle board. The scripts for the scene switching and playing the videos can be found in *Appendix 6 and 7.*

6.3 Content

Prompts and introduction

The specific topics of the prompts were decided upon during the realization. The idea of them being recognizable to every Dutch person was already set during the ideation phase. The three final prompts were about the market, the petting zoo (Dutch: “kinderboerderij”), and the beach. Each prompt was a question to the user and started with the sentence “What do you think of when you think of the market/petting zoo/beach?” (Dutch: “Waar denk je aan bij de markt/kinderboerderij/het strand?”).

The introduction included a text with visuals supporting the explanation. The introduction explains that five objects that fit the prompt best need to be chosen. Secondly, the introduction explains that the person needs to put them in the correct puzzle hole. This can be achieved by aligning the copper strips under the tangibles with strips in a puzzle hole. The last instruction states that the left mouse button can be used to press buttons such as ‘Start the game’, ‘Instructions’, and ‘Next’.

YouTube videos

The videos shown after the user puts the correct combination of tangibles for a prompt onto the puzzle board are taken from YouTube [44], [45], [46], [47]. The videos were all filmed in the Netherlands and the Dutch language can be heard in some parts of the videos. A requirement for the footage was that it had to be of The Netherlands to be recognizable to the user. The videos were downloaded and then imported into Canva which they were edited in. Parts of the YouTube videos that included the real-life objects the tangibles referred to were sought out and were specifically kept in the edited versions of the videos. This decision was made to make the user create a connection with the tangibles and their real-life counterparts. The videos were 30 to 60 seconds each, following the design recommendation from Lazar et. al seen in the design requirements for the game [35]. Screenshots of the videos in Unity can be seen in *Figures 18, 19, and 20*.

Figure 18 A screenshot of the market video in the game

Figure 19 A screenshot of the petting zoo video in the game

Figure 20 A screenshot of the beach video in the game

6.4 Design

Visuals in Unity

The visuals for every Unity scene were made in Adobe Illustrator. The image of the main menu was made by using Illustrator's new 'Text to Vector Graphic' tool. This tool allows one to

generate a vector image by inputting a prompt. The other visuals were made by the researcher. The questions per prompt are put in a thinking bubble to symbolize the reminiscing process.

Figure 21 The main menu of the tangible interactive game

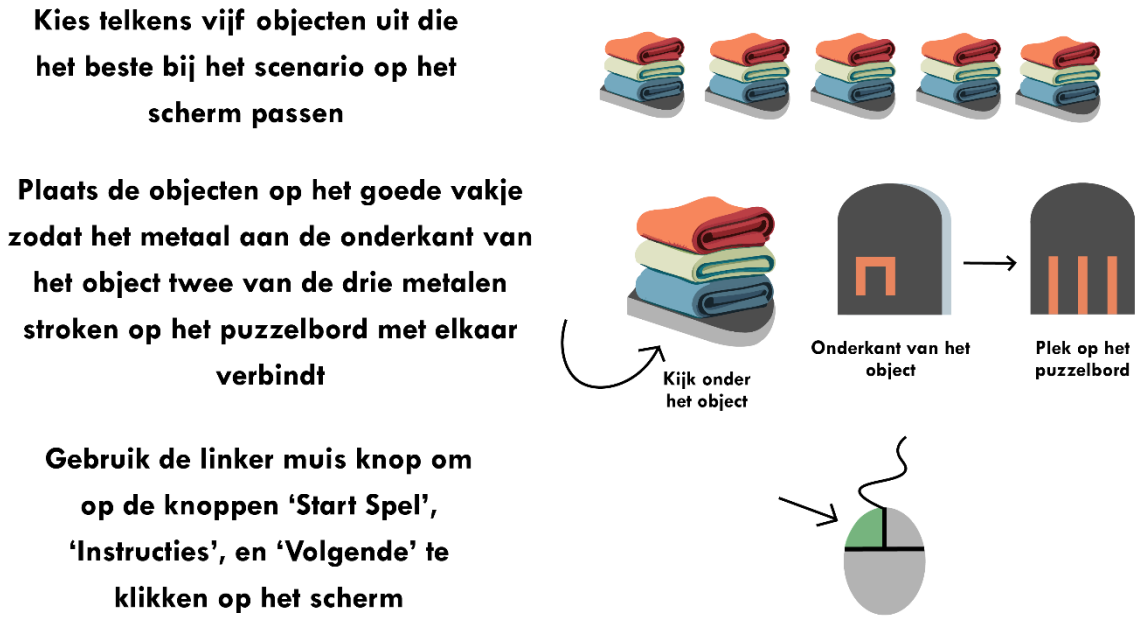


Figure 22 The instructions of the game

Figure 23 One of the three prompts in the tangible interactive game

Figure 24 The thank you screen at the end of the game

Puzzle board

The box of the puzzle board was designed on makercase.com. The length and width of the cardboard prototype were taken and used after getting positive feedback from the expert on the size. The height of the box was decided upon by making an estimation of the minimum height it needed to be for the hardware to fit inside. The comfort of the user was also taken into account. The box was not supposed to be too high, or else putting the tangibles onto the puzzle board would possibly be too difficult for the user. Another possible issue could have

been that the box would partially block the laptop screen, hindering the person's view as a result.

The design created on makercase.com was exported to Adobe Illustrator in which some necessary changes were made to the file. The box firstly needed a second layer which had the five puzzle holes in it. Furthermore, 15 bases for the tangibles also needed to be lasercut. Thus, these were also drawn in Adobe Illustrator and added to the lasercut file. The lasercut file can be seen in *Figure 25*.

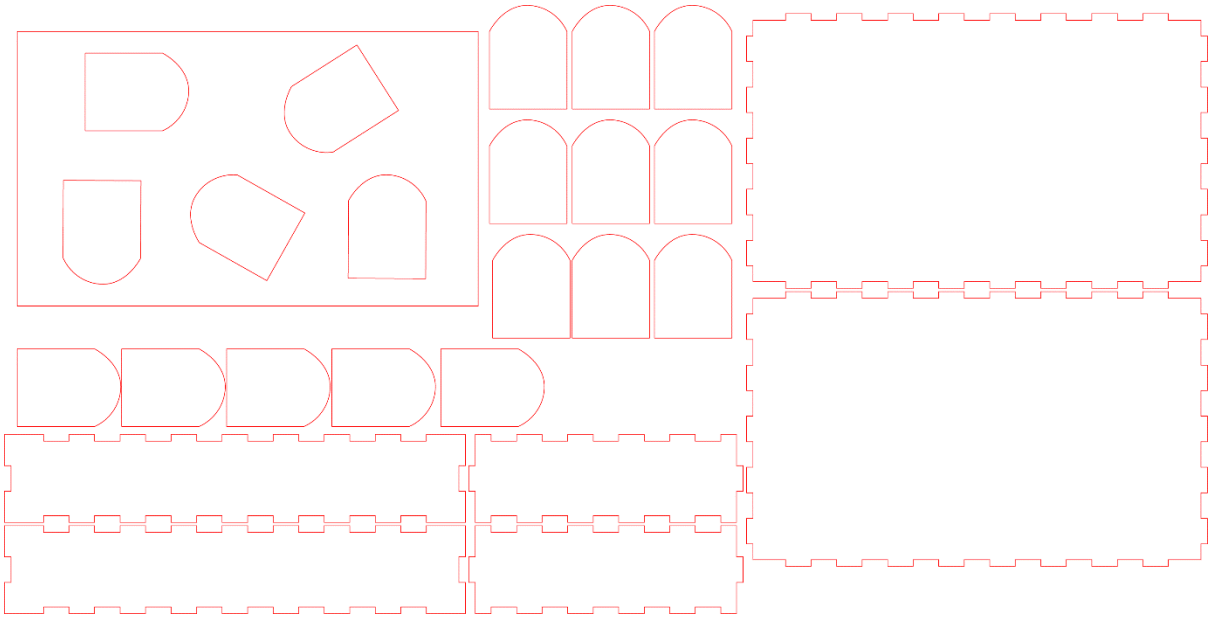


Figure 25 The lasercut file of the box, puzzle board, and bases of the tangibles

Figure 26 The assembled puzzle board with the copper tape strips

Tangibles

After the three final prompts were determined, five tangibles per prompt were thought of. The tangibles per prompt can be found in *Table 6.*

Table 6 The tangibles assigned to every prompt

Prompt	Tangibles
Market	• Cheese • Banana • Fish • Scale • Tomato
Petting zoo	• Goat • Cow • Chickens • Pig • Hay bales
Beach	• Sunscreen • Towel • Flip flops • Sea • Sand

The majority of the tangibles were crafted by hand. The materials used were acrylic paint, modeling clay, plastic bottle scraps, cloth, polyethylene foam, toilet paper, grass, sand, wood glue, and super glue. The tangibles for the petting zoo prompt were all store-bought. The main goals for the tangibles were that they are easily recognizable, would aid in improving reminiscence, and would stimulate via their textures. The textures had to be very similar to the real-life textures the tangibles had to create a connection to real life. However, some textures were difficult to replicate, such as the feeling of water and the animals used. Nevertheless, tangibles such as the hay bales, sunscreen, flip flops, towel, and sand did have textures very similar to the ones they have in real life. Some tangibles were difficult to get out of the puzzle hole. As a solution, wooden sticks were cut into smaller pieces and stuck to some of the tangibles with super glue. The tangibles can be seen per prompt in *Figures 27, 28, and 29.*

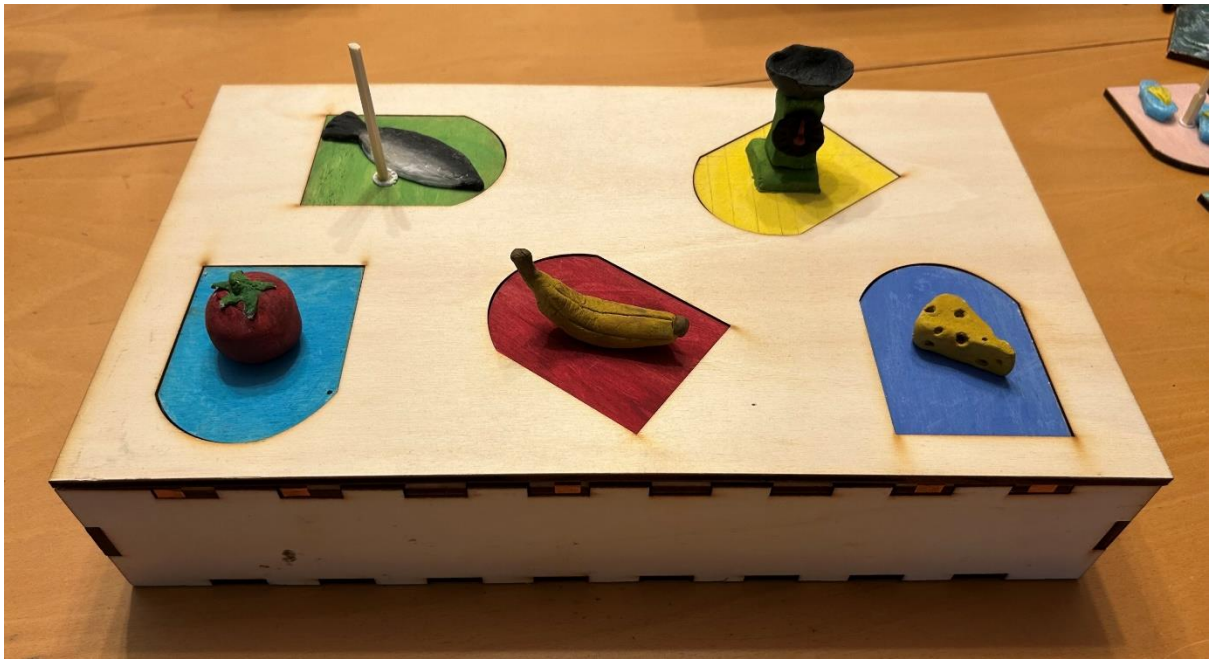


Figure 27 The tangibles of the market prompt

Figure 28 The tangibles of the petting zoo prompt

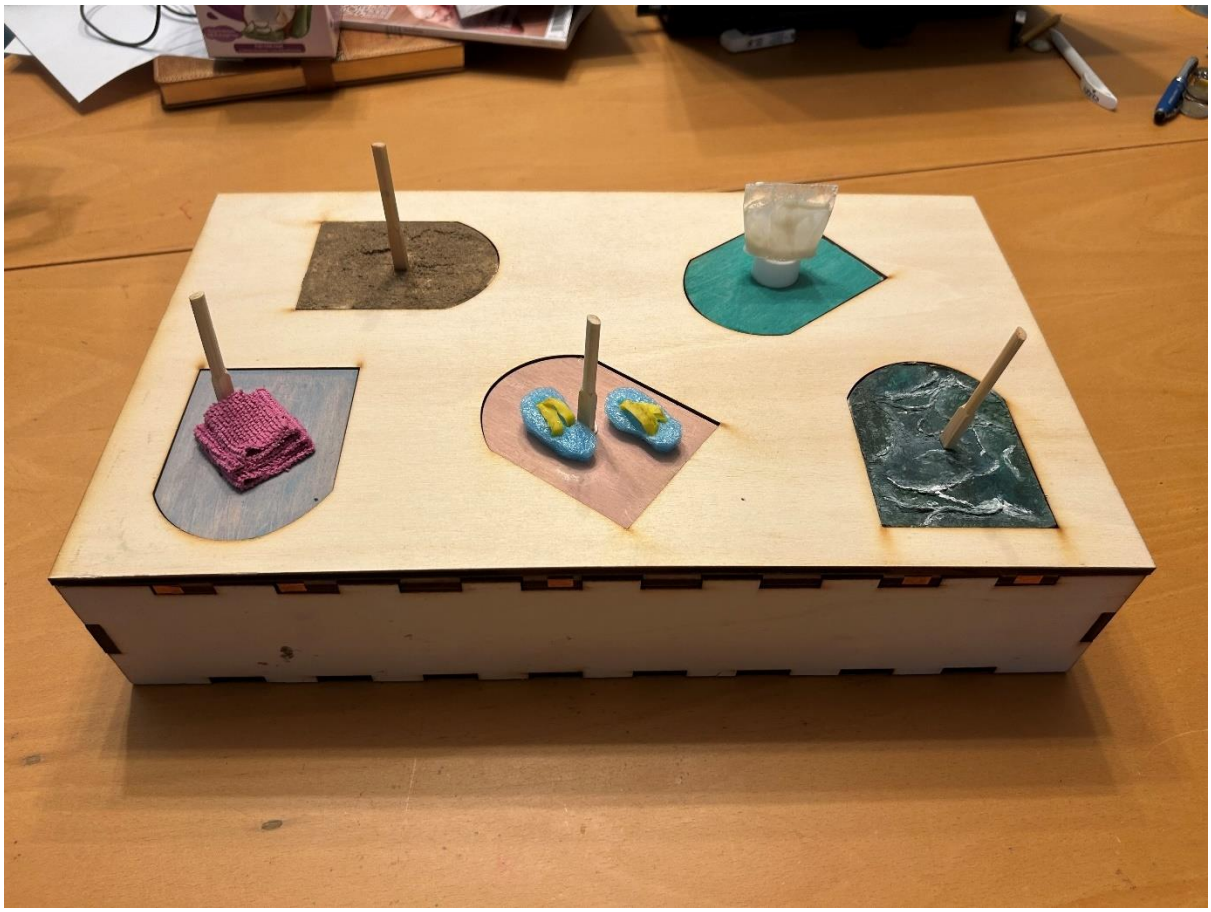
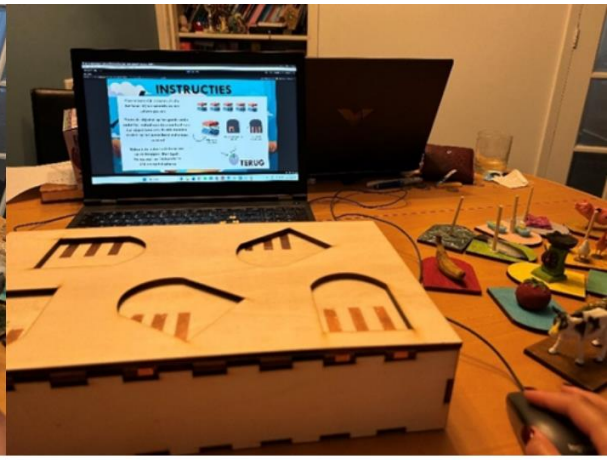


Figure 29 The tangibles of the beach prompt

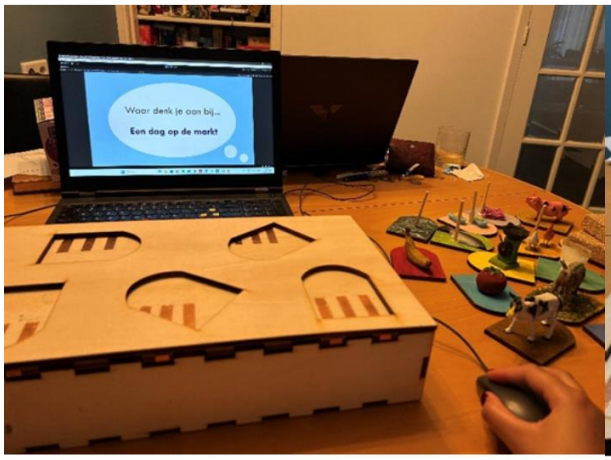
6.5 Final hi-fi prototype

After the integration of all the parts of the tangible interactive game was completed, the final prototype was finished. The final prototype can be seen in *Figure 30* in which simultaneously the interactions are demonstrated.

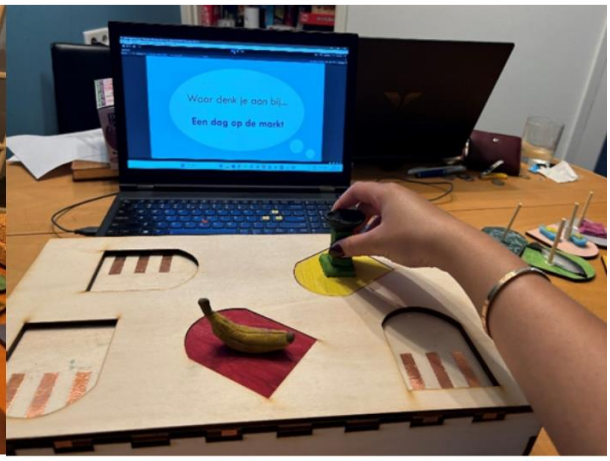
1. The user at the main menu



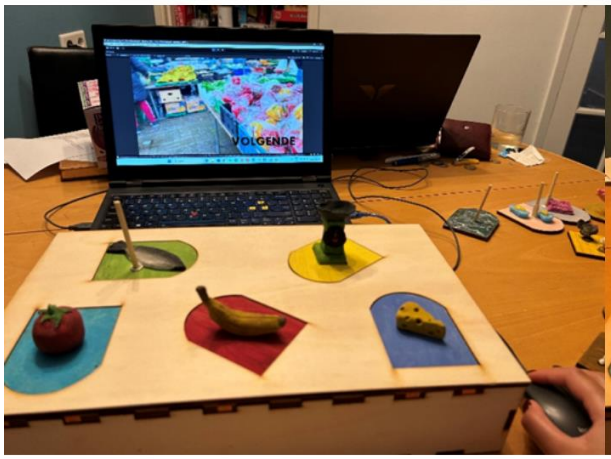
2. The user clicked on the 'Instructions' button on the main menu which brought them to the instructions screen



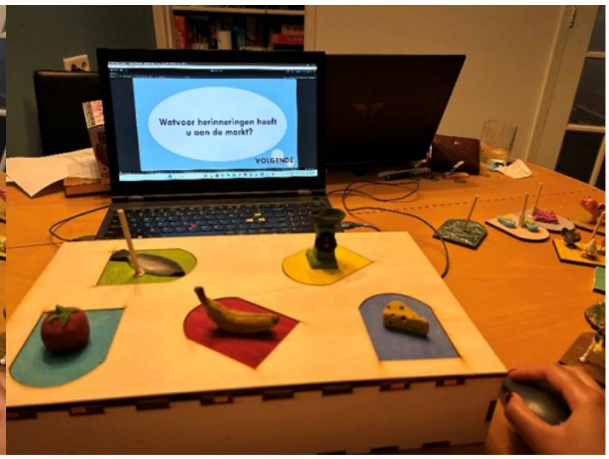
3. The user started the game which brought them to the first prompt



4. The user placing the tangibles



5. The combination was correct, the video of the market is played



6. The user is asked what memories they have of the market

Figure 30 The final prototype with a demonstration of the interactions

7. Evaluation

The evaluation phase is the last phase of the Creative Technology design process, in which the final prototype made in the realization phase, is assessed.

7.1 Qualitative usability study

A user evaluation was conducted for the hi-fi prototype. The user evaluation aimed to assess the usability of the tangible interactive game and whether the game evokes the user to reminisce. The evaluation was done in the form of a qualitative usability study. In a qualitative usability study, the participant is asked to interact with a product to uncover possible usability issues [48].

7.2 Participants

The target group of the tangible interactive game is people with mild to moderate Alzheimer's. People with Alzheimer's disease however are a vulnerable part of society. By first evaluating the final prototype with healthy older adults, the initial necessary insights can be found without having to bother PwADs. This is why the decision was made to use proxy users instead. Proxy users replace the actual target users but need to be as similar as possible in terms of characteristics. The common characteristic of the proxy users in this usability study is that they are in the age range Alzheimer's symptoms usually arise in, which is 60 years and older [49]. One prerequisite however was that the proxy users all had to be healthy individuals. The proxy users also had to be Dutch citizens. One of the participants, however, was a German citizen who speaks Dutch.

Five proxy users were found to evaluate the game. This number was decided upon per the 5-user rule by Nielsen Norman Group [40]. This rule states that by testing with at least five users, 85% of the usability issues will be found. The proxy users were found by recruiting people in the Dutch neighborhood of the researcher by going to the houses of older people to ask if they were willing to participate. The first neighbor who was visited was not available to participate but assisted in finding the five participants needed. The tests were carried out over the span of a weekend, three being on a Saturday and two on a Sunday. In *Table 7*, the characteristics of the participants can be found.

Table 7 The participants and their characteristics

Participant	Age range	Nationality	Gender
1	60-69	Dutch	Female
2	60-69	Dutch	Male
3	70-79	Dutch	Female
4	60-69	Dutch	Female
5	60-69	German	Male

7.3 Semi-structured interview and observations

To successfully evaluate the prototype, data had to be collected. The chosen approach to this was a semi-structured interview and to note down any observations made. A list of questions was formulated before the user evaluation sessions. The questions were asked after the participant had tested the game. The questions were asked per category. The categories were

‘general questions’, ‘content’, ‘tangibles’, ‘pros and cons’, and a ‘closure’ category in which participants could give additional feedback that they might still have. The questions were in Dutch as the participants were Dutch-speaking. In *Table 8*, the questions can be found translated from Dutch. The original list of questions in Dutch can be found in *Appendix 8*.

Table 8 The questions of the evaluation of the final prototype

Category	Questions
General questions	• Was the game fun to play? • Was it easy to understand what you had to do? (Clear enough instructions?) • Was the game difficult to play? If so, what was difficult? • What do you think of the design of the game? • What do you think of the combination of the laptop and the puzzle board?
Content	• Are the scenarios interesting? • Are the scenarios general enough to be • Are the scenarios general enough that they are recognizable to every Dutch person? • Do the videos help bring back memories from the past? • Does the game as a whole bring back memories from the past?
Tangibles	• Are the objects recognizable? • Is the texture of the objects stimulating? • Do you think the texture has added value? • What do you think of the sizes of the puzzle board and the objects? (Too big? Too small? Just right?) • Were the objects easy to pick up?
Pros and cons	• What are the positive aspects of the game? • What are the downsides of the game?
Closure	• Do you have any feedback/comments? • Do you have any questions?

7.4 Procedure

The user evaluation was carried out in sessions of 30 minutes in the following manner:

1. The researcher begins with a briefing which includes an introduction of themselves and the research.
2. The researcher goes through the information sheet and the consent form together with the participant. The participant signs the consent form.
3. The researcher starts the video recording on an iPhone.
4. The participant starts playing the tangible interactive game.
5. The researcher asks questions in the form of a semi-structured interview after the playtest has been concluded.
6. The researcher does a debriefing in which the participant is informed about the next steps of the research. The participant is also reminded that they can contact the researcher and can always withdraw from the study. The participant is thanked for participating in the research.

7.5 Results

After the user evaluations had been conducted, the footage was played back and observations were written down per participant. Then the answers to the questions in the semi-structured interview were transcribed. This was done in the form of an edited transcription.

7.5.1 General questions

The purpose of the general questions was to receive feedback on the game as a whole. Specifically, the overall enjoyment and the level of ease in playing and understanding the game were factors feedback was asked on. All the participants thought the game was fun. One participant stated:

“I actually don’t really like playing games, but this was fun.”

Furthermore, it was of grave importance that users understood how to play the game. The majority of the participants understood what they had to do. Overall the participants said that they understood what they had to do. Most of them however needed the researcher to demonstrate how to match the puzzle piece to the puzzle hole during the playtest. Another issue was that the text used to instruct the user was not dyslexia-friendly. The first participant had dyslexia. Her dyslexia caused difficulty reading the instructions due to the long sentences. The alternative of an animation demonstrating the game was discussed with the participant during the playtest. The participant thought an animation would be more effective in explaining the game. Thus, improved instructions are required to make the user understand the game.

The difficulty level of the game was also assessed. Three out of five users experienced the game as difficult. The difficulty mainly stemmed from matching the copper strips on the tangible to the correct puzzle hole. This was observed during the playtest as well. One participant stated that it would be even more difficult for someone with Alzheimer’s to match the tangibles to the puzzle holes. During a playtest with a participant, the alternative of replacing the laptop with a touchscreen device was discussed. This would eliminate the need for a mouse as well, which some proxy users had difficulty using. According to Lazar et. al, a touchscreen is a more intuitive option for older adults with dementia [35].

The participants were very enthusiastic about the design of the tangible interactive game. A few participants commented positively on the aesthetics of the game. One participant stated

that every element of the game fitted the game. The tangibles and their textures were also received positively, one participant remarked:

"The game is made with so much love and thought. It is nice that the haptic experience is included for people with Alzheimer's."

Lastly, the participants were asked what their thoughts were on the combination of the laptop and the puzzle board. The opinions were mixed. Four of the five participants expressed that they liked the combination. However, some concerns were raised about whether people with Alzheimer's were able to use a laptop. Furthermore, two participants had difficulty controlling the mouse due to a lack of experience.
To conclude, the proxy users enjoyed playing the game as a whole. The design of the game was positively received as well. Some aspects of the game had mixed opinions and raised a few concerns among the participants. Firstly, the difficulty level of matching the tangibles to the correct puzzle hole was too high for a few participants. We can deduce from this result that the game would possibly be too difficult for people with Alzheimer's. Furthermore, the participants liked the laptop and mouse combination. However, the capability of a PwAD being able to control a laptop was put into question. Especially, because two of the five participants struggled to control the mouse. Lastly, some improvements can be made to the instructions as some participants did not understand the puzzling aspect of the game.

7.5.2 Content of the game

The questions on the content of the game encompassed the prompts and videos shown to the user. Additionally, questions regarding the effectiveness of the content on the reminiscence were asked. Firstly, the prompts were discussed. All five participants thought the prompts were interesting and liked the diversity between them. One participant stated that they liked that the game related to nature in some parts and that children could also learn from the game. They also expressed that they are recognizable to every Dutch person. One participant noted that people who recently moved to the Netherlands would maybe not recognize every prompt. Another participant however commented that "everyone on the planet" would be able to understand the prompts.

Thereafter, the effect of the game on reminiscence was discussed. Most proxy users said the videos, tangibles, and questions aided in reminiscing. They all had memories of going to the market, the petting zoo, and the beach and verbally recalled them during the playtest. This was done very actively. One participant stated that the videos did not help with reminiscing because they were not videos of his memories. Instead, the videos felt more like an award for doing well. The tangibles and the questions on the other hand did help with reminiscing for this participant. Thus, all participants reminisced due to at least one element of the game.
Overall, the content of the game was enjoyed by all proxy users. Positives were the variety between the topics, the inclusion of nature in the prompts, and that the prompts were recognizable to Dutch people. The game provoked the proxy users to reminisce. Multiple aspects aided in this, namely the prompts, the questions, the videos, but also the tangibles.

7.5.3 Tangibles

Another aspect important for the gameplay was whether the tangibles were recognizable or not. All proxy users said they overall were, except for a few but this differed from person to person. One participant for example did not recognize the hay bales and thought the tomato

was an apple. Another participant stated that he only did not know one tangible was supposed to be sand, but that the tangibles reminded him of his youth:

"Yes, the tangibles were recognizable and they matched perfectly in my head. In my youth, we used to play with these toy animals. We had the same ones. You directly jump back into your youth…"

Moreover, an evaluation of the tactile stimulation implemented into the tangibles was also done. Three of the five proxy users felt the textures were stimulating. Two participants did not touch the textures because they thought the tangibles looked fragile. This caused them to grab the tangible from the wooden base or the sticks glued on top without touching the rest of the tangible. They also mentioned that they were more visual people in general. Another participant commented that the texture is a very significant addition to the tangibles:

"I recognized that it really stimulated me because I wanted to touch it a second time. The first touch is to discover, the second touch is to create the connection between the object and my memory. I think for old people the texture and the ability to grab is very important, especially as a form of therapy. Touching the objects and feeling the textures in combination with the screen is not something you often see in games."

Additionally, the accessibility of the tangibles was assessed. The participants unanimously agreed that the sizes of not only the tangibles but also the size of the puzzle board were perfectly fine. Furthermore, the tangibles were easily grabbable for all participants. One participant mentioned however that the movement of turning around the tangible to look at the strips is quite difficult for older people.

In general, the tangibles were recognizable. A few tangibles could be improved upon in terms of design to avoid confusion about what they were supposed to be. The accessibility of the tangibles was fine as well. PwADs could however possibly experience issues with the movement of looking under a tangible.

7.5.4 Pros and cons

In this category, the proxy users were asked what the overall positives and negatives of the tangible interactive game were. This was done to get a final idea of the positives and the downsides of the game. The positives and negatives per participant are listed in *Table 9*.

Table 9 The positives and negatives of the game according to the participants

Participant	Positives	Negatives
1	"The game is nicely made. I liked the petting zoo the most, it's a nice experience."	Well, I do not think it has any downsides. I just thought it was a bit difficult for me."
2	"I think this is a way friendlier experience for people with Alzheimer's than some I have seen (having to draw a clock or a three-dimensional cube). This is more accessible."	"That the computer did not want to work (the game got stuck at the beginning during the demo test with Participant 2, but worked afterward. This was not an issue in the other user tests). I don't have any further negative feedback."

3	“I like the game a lot. Even for myself, but of course also for people who are ill.”	Did not have any negative feedback.
4	“The video after all the puzzle pieces were placed correctly, which was connected to the game. So not only the images but also the video.”	“The instructions and that there was not a clear storyline. Introducing every new scenario as if you are going from one location to the other would be nice, for example, “Now you are going to the beach.” Then the person will be more immersed throughout the game.”
5	“I think this game is made with much love and with deep thoughts (thoroughly thought through). The plan you made for the game is perfect: connecting a modern technique (the technology) with a traditional technique (the physical puzzle). The copper strip technique has two aspects, it is electronic, but not as modern as the video. And the wooden tangibles the copper strips are on bring me back to my childhood room. It brings me back to when I played cashier in my room. The tangibles activate you to play the game. When I first grabbed the tomato and then I was directly teleported back to my childhood and I started to play with the tomato.”	Did not have any negative feedback.

The majority of the proxy users did not say the game had any major downsides. From this, we can conclude that the game was a positive experience for the participants. Some points of improvement which were made before were highlighted again, such as providing clearer instructions and making changes to the level of difficulty. The lack of a storyline was the only negative which was not yet mentioned before. This could also be implemented in the future.

7.5.5 Closure

In the last part of the interview, participants had the opportunity to give any feedback they still had and ask any questions they had for the researcher. One participant advised to make the sticks on the tangibles shorter. This would make the PwADs already feel the texture of the tangible when grabbing onto the stick, prompting them to explore the textures more. None of the participants had any further questions.

7.5.6 Observations

Lastly, some general observations were noted down which did not come forward through the semi-structured interview:

- People who never did puzzles and mentioned they were not good at puzzling had a harder time doing the puzzling than the participant who mentioned that they often did puzzle games and games that require thinking and logic
- Participants had the most difficulties with the two pieces that needed to be placed in the holes with a 45-degree angle
- Despite it not necessarily being an important aspect, the exact location of the beach in Scheveningen in the video for one of the prompts was directly identified by all 5 participants, despite not originating from the area
- More memories resurfaced when the researcher engaged in the conversation compared to when the researcher let the participant reminisce without conversing with them

From these observations, we can conclude that personal experience with puzzles can have a significant impact on how the game is perceived in terms of difficulty level. Moreover, the struggles with the puzzle holes that were in a 45-degree position suggest that an easier position needs to be chosen for these. Lastly, conversations have shown to be important for reminiscence. From this observation, we can deduce that playing a tangible interactive game with someone can have a more positive effect on the amount of memories that resurface while the user is reminiscing.

8. Discussion and Future Work

Based on the evaluation, the tangible interactive game has been received positively and could be a promising product for people with Alzheimer's. Nonetheless, the findings and their implications need to be discussed to reflect on the entire development of the tangible interactive game. The strengths and limitations, as well as recommendations for future work, will be discussed.

8.1 Discussion and Interpretation of Findings

The aim of this thesis was to design an interactive game for people with Alzheimer's that incorporates tangible objects and aims to improve reminiscence. Various literature research on existing therapies and forms of stimulation for PwADs were explored. Elements from these therapies and forms of stimulation that proved to have a positive effect on reminiscence were implemented into the tangible interactive game. Furthermore, existing recommendations for games and systems for PwADs were also consulted to create a basis for the design requirements of the game. The game was created through a design process in which multiple iterations of the game were made.

Before this design process was initiated, however, a few sub-research questions needed to be answered which would aid the development of the game. The first four sub-questions have been successfully answered in the conclusion of the literature review. The last SRQ, however, has not been answered yet. This SRQ was: *"How effective is the tangible interactive game in stimulating reminiscence?"* This SRQ can be answered by discussing the evaluation of the tangible interactive game. The evaluation consisted of a qualitative usability study. The qualitative usability study was divided into two parts: a playtest and a semi-structured interview.

The tangible interactive game gained a positive response in general from the proxy users during the evaluation of the game. They all enjoyed playing the game. However, it is unknown whether the same positive response would be given by people with Alzheimer's disease since they have not tested and evaluated the game in this thesis. The usability of the tangible interactive game needs to be tested again with people with Alzheimer's in future research. Nonetheless, the evaluation with the proxy users was very valuable in discovering the initial usability issues of the game and the positive aspects of the game.

The content of the game was received very positively. The diversity of the prompts was praised. This is in agreement with the recommendation proposed by Lazar et. al, which states that diverse content is advised to serve a wider variety of people [35]. One participant, however, proposed that a storyline needs to be introduced to create a more logical transition between the prompts. Furthermore, the proxy users thought the content was recognizable for every Dutch person, which stands in line with the assumptions, namely that Dutch people would recognize a market, a petting zoo, and a beach. These can all be found in The Netherlands. The scenarios needed to fit into the Dutch culture to be culturally relevant. Cultural relevancy was regarded as an important factor by the expert from the Expertise Center for Dementia & Technology. Something that the researcher did not expect was that the video content was too general to stimulate reminiscence for one of the participants. Based on the literature, the assumption was made that reminiscence can still take place even when the content is not personalized [7].

The tangibles were met with positive feedback. The proxy users liked the aesthetics of the tangibles and the haptic experience they provided among others. The stimulation of the

textures was also enjoyed by the majority of the participants. One key finding, however, was that the textures on the tangibles were not interacted with by two of the proxy users. The reasoning behind this was that they were more visual people. The multiple forms of stimulation are perfect in this situation because if one form does not work for a person, another might instead. One participant made the valuable suggestion to lead the PwADs to the textures by making the sticks on the tangibles shorter so they get into contact with the textures upon grabbing the tangibles.

There are a few usability issues that need improvement. The instructions need to be improved as the text was not clear enough and difficult to read for some participants. The language needs to be made out of short and simple sentences according to Lazar et. al [35]. Furthermore, some participants had issues with the difficulty level of matching the copper strips. However, others thought the difficulty level was fine. This raises the question of whether or not the game will still be challenging for certain people once the difficulty level is decreased. The element of challenge is beneficial to games for PwADs as they can become bored otherwise [35], [36]. Lastly, the mouse was an issue to use due to a lack of experience with it among some of the users. Concerns were also raised about the use of a laptop. It was not considered a user-friendly option for PwADs according to one participant. According to literature and the expert of the lo-fi test, a tablet could be more intuitive and user-friendly for PwADs [35].

To answer the last sub-research question of this thesis, the findings on reminiscence are discussed. The game successfully stimulated reminiscence among all five participants. The tangibles, textures, videos paired with audio, and questions linked to each prompt caused reminiscence to take place. These findings agree with the existing literature which states that reminiscence can take place due to various forms of sensory stimulation and by being prompted to speak [8], [9], [10], [11], [12], [13].

Now that all the five sub-research questions have been answered, there should be an answer to the main research question of this thesis. The main research question of this thesis was:

"*How can we design an interactive game for people with Alzheimer's that incorporates tangible objects and aims to improve reminiscence?"*

A tangible interactive game for people with Alzheimer's disease that aims to improve reminiscence can be designed in several steps. Firstly, existing literature needs to be explored to discover which elements from existing methods that stimulate reminiscence are effective. Elements from these methods should be considered to be implemented into the game. Additionally, a set of custom guidelines should be compiled based on the concept of the game. Multiple iterations should be made of the game which need to be evaluated to find usability issues and to gain useful feedback. Based on the evaluations, the final game can be developed.

However, a conclusion as to whether the reminiscence has been improved or not cannot be made due to various reasons. Due to the absence of testers with Alzheimer's, no conclusions about the effect of the game on the reminiscence of people with Alzheimer's can be made. Secondly, medical experts are needed to determine whether the game shows an improvement in reminiscence. The game needs to be tested for an extended period of time to determine this as well.

8.2 Implications of Findings

A few conclusions can be drawn from the findings of this thesis. Which forms of stimulation are effective on people has been seen to differ from person to person. This seems to be based on what type of person you are. One person can be more visual while the other tends to touch objects quicker. By integrating many opportunities for stimulation to take place, we increase the chance that at least one of them is effective in letting reminiscence take place.
Another implication is that people who play logic games and train their game with puzzles have an easier time with puzzling than those who do not. The participant in the user evaluation who plays such games often was significantly faster in putting the tangibles in the correct puzzle holes than participants who did not play puzzles often. The game could be improved by providing multiple difficulty levels from which the participants can choose.

Lastly, it has been implied during the evaluation that more memories resurface while actively asking follow-up questions in the conversation with the proxy user rather than being present, but only letting the person talk. This is why actively asking more questions when the PwAD reminisces is advised.

8.3 Strengths

Multiple strengths of this thesis were detected. Due to the wide range of therapies and treatments studied, many different ways of stimulating reminiscence were implemented into the game. The ones deemed effective, namely auditory stimulation, tactile stimulation, and the active reminiscing seen in reminiscence therapy were applied. Visual stimulation was also implemented but based on the existing literature it was difficult to determine the level of effectiveness this has on enhancing reminiscence. This was due to it often being implemented in multi-sensory experiences in which other factors make it more complicated in many studies to draw a concrete conclusion.

Another strength of this thesis is that barely any game can be found that is comparable to the tangible interactive game of this research. Only one game was found that was similar, namely Memorology. A major difference however was that the puzzle board did not respond to interactions and did not include technology in general while the tangible interactive game does.

The multiple iterations made during the design process are a strength as well. Each iteration was improved upon by using the knowledge gained during the design process. The second lo-fi prototype allowed technical hardships to be detected earlier on instead of during the realization. Additionally, this prototype made it possible to obtain validation from an expert on the design and sizes and created an opportunity for additional suggestions.

Lastly, a strength was recognized from the evaluation. The evaluation was beneficial to the research because all the proxy users actively voiced their honest opinions. When they did not like something or had doubts about a feature, the participants did not give a nuanced version of their thoughts. This was greatly appreciated by the researcher.

8.4 Limitations

Time constraints

A few functionalities and features could not be implemented due to time constraints. The game was supposed to provide more guidance to the user. The current textual guidance is very limited and does not make use of clear language. An example of this is that the current buttons

to continue within the game only say “Next” instead of “Next prompt”. This makes it unclear for the user what to expect. Furthermore, despite most of the design guidelines being met, some were not. This includes providing guidance, but also a few other guidelines. Constant feedback was not provided either. The initial form of feedback was not implemented in the final prototype due to time constraints. The screen was supposed to display “Try Again” when an incorrect combination was put on the board. The game did not switch to the reminiscence question either when the person put in an incorrect combination a second time. Currently, the user only sees something happen once they place the five correct tangibles onto the puzzle board. In between the placements of the tangibles, they have no idea if they are doing well. Additionally, a video of the location the prompt described directly plays once the correct combination has been placed. However, it does not explain why on the screen. The sudden switch to the video can also startle the PwAD. Again, the user does not know what to expect and this might affect the user negatively.

Literature research

Some limitations were recognized in the existing literature. Firstly, it was noticed that there was an extremely limited amount of research specifically on tangible interactive games that aimed to improve reminiscence among PwADs. Only one corresponding example was found and discussed as one of the existing technological solutions for PwADs. However, this game was not tested by people with Alzheimer’s. This makes it unclear whether or not the game was effective in enhancing reminiscence among PwADs. Another identified limitation was that research on multi-sensory games and experiences was often uncertain about which factors exactly caused reminiscence to take place. This made it more difficult for the researcher to determine which sensory stimulations were effective and which were not. Lastly, the existing guidelines for interactive games for PwADs are very limited. Only a few extensive sets of guidelines were found. A limitation of these guidelines was that did not include guidelines on the implementation of tangibles in an interactive game. Additionally, they barely include recommended guidelines for reminiscence. Lazar et. al solely included two recommendations for reminiscence media [35].

Evaluation of the game

A significant limitation in the evaluation of the game was that the target group did not test the game. This caused uncertainty in the effectiveness of many areas of the game, but most importantly if the game improves the reminiscence of people with Alzheimer’s disease. Moreover, the small sample size of the evaluation was sufficient to unveil most of the usability issues according to the Nielsen Norman Group [40]. However, bigger sample sizes could still unveil more usability issues. Lastly, the final prototype was only evaluated once, which only made it possible to conclude that reminiscence takes place but not whether or not this has been improved. Detecting an improvement also requires medical expertise, which the researcher did not possess.

8.5 Recommendations for future work

Time constraints

An improved version of the final prototype needs to be realized with several additions. The user should be guided as much as possible throughout the game. Including additional context in every part of the game is necessary. When the prompt is shown, for example, the user can

be reminded that they need to place five tangibles that fit the prompt the best. At the reminiscence question, a text could be displayed suggesting that the PwAD talks about the memories with another person. A help button could also be integrated into every part of the game that guides the PwAD by telling them what action needs to be performed at the given moment. Furthermore, consistent feedback needs to be given to the user about their progress. A way to do so is for example via an auditory cue. A 'ding' sound could for example be heard when the user places a tangible in the correct puzzle hole. Alternatively, the puzzle hole could light up with a green color once upon placing the tangible in the correct puzzle hole. Lastly, confusion can be avoided by informing the user about what will come next.

Literature research

There is a need for more research on various topics. More studies need to be done on tangible interactive games for people with Alzheimer's, specifically aimed at improving reminiscence. This will be very valuable for the current body of information available in the scientific literature and thus for other researchers developing similar games in the future. In addition, clearer results are needed on the singular impact of sensory stimulation techniques in multi-sensory experiences. Moreover, a wider body of guidelines needs to be developed for interactive games for PwADs. Guidelines on the use of tangibles and enhancing reminiscence within this context are especially needed.

Evaluation of the game

The tangible interactive game needs to be tested by people with mild to moderate Alzheimer's to discover more usability issues and to find out if it is effective in improving reminiscence. Medical experts will be needed to validate the improvements in reminiscence of the person with Alzheimer's. Testing the game over a longer period of time is recommended to see whether there are significant improvements.

Improve upon current features

A few possible improvements came forward in the evaluation based on the usability issues and further suggestions and feedback given by the proxy users. The instructions need to be clearer because some of the proxy users did not understand how the game worked at the start of it. Especially the part of the instructions on how the puzzling works need to be explained better. Moreover, an alternative to the instructions in written text needs to be considered. One of the proxy users had dyslexia which caused issues with reading. People with Alzheimer's also struggle with language-based issues, so instructions in the form of an animation with narration could be more promising [3].

The replacement of the laptop with a tablet attached to the puzzle board is recommended as well. The laptop does not enhance the accessibility of the game. A Unity game engine and the Arduino IDE need to be set up to play the game, which is a complicated process, especially for a PwAD. Furthermore, the proxy users had issues controlling the mouse. This makes the probability of PwADs having issues with controlling a mouse even higher. The use of a tablet was recommended by the expert from the lo-fi prototype evaluation and is also proven to be more intuitive by existing recommended guidelines [35].

The difficulty level of the puzzling in the game was too high for a few proxy users. Additionally, the movement of having to turn around the tangible every time to see the strips under it could be a challenging movement for PwADs according to one proxy user. A solution to these two

issues is to add colors to the puzzle holes which correspond to the tangible as an indication of where the tangible needs to be placed. This makes the game a bit easier and eliminates the need to look under the tangible to match the copper strips. Alternatively, the game could provide a personalization option so every user can adjust the difficulty level based on their capabilities.

Lastly, a proxy user mentioned that there is no clear connection between the prompts. The proxy user suggested adding a storyline to the game. The addition of the storyline can give more meaning to the game and might engage the user more.

9. Conclusion

A tangible interactive game was made to increase the quality of life of people with Alzheimer's disease by aiming to improve reminiscence. A literature review was conducted first to research the issues people with Alzheimer's suffer from and the existing treatments, technological solutions, and guidelines for people with Alzheimer's. Based on this, various aspects of non-pharmacological treatments that stimulated reminiscence among people with Alzheimer's were considered for implementation in the game. Findings from the research papers on technological solutions provided valuable insights. Furthermore, existing guidelines for games for people with Alzheimer's were utilized in a set of custom design requirements for the game. The game was eventually developed with the use of the Creative Technology Design Process, the findings from the literature review, and the use of valuable information gained via two expert interviews. The game was evaluated with five healthy proxy users of 60 years old and above via a qualitative usability study to assess the usability of the game. The game was received positively and stimulated reminiscence among all five participants. However, it is unclear whether the game improves reminiscence among people with Alzheimer's disease. Due to the limitations, this is something that needs to be tested in future research. Despite the limitations, the research question of this thesis can be answered, which is:

"*How can we design an interactive game for people with Alzheimer's that incorporates tangible objects and aims to improve reminiscence?"*

Elements from existing methods that effectively stimulate reminiscence should be implemented and a set of custom design guidelines need to be created for the development of a tangible interactive game that aims to improve reminiscence among people with Alzheimer's. Multiple iterations should be made of the game which need to be evaluated to find usability issues and to gain useful feedback. Based on the evaluations, the final game can be developed. Based on the evaluation, the tangible interactive game has great potential to be an effective way to enhance the quality of life of people with Alzheimer's disease by providing an enjoyable recreational activity and subsequently improving reminiscence. However, future research needs to be performed in which this is validated.

10. AI statement

For this thesis, artificial intelligence has been utilized to debug and optimize the Arduino code and C# scripts of the Unity scenes. The code was written by the researcher first and was put into ChatGPT on several occasions to debug errors encountered during this research and to optimize already working code by asking ChatGPT to simplify the process. This statement was made to provide transparency and justify that the basis of the code was not written by artificial intelligence but by the researcher.

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Appendix

1. Information sheet

Information Sheet for “Developing a Tangible Interactive Game to Improve Reminiscence among People with Alzheimer’s Disease”.

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Purpose of the study

Alzheimer’s disease is a form of dementia that an estimated 32.3 million people around the world have to live with. With so many having to cope with this disease, improving their quality of life in any way is of grave importance. Alzheimer’s disease comes with a number of issues, of which one is the impairment of the memory. To combat memory loss, the use of reminiscence therapy (RT) is commonly used to improve cognitive functioning of the person with Alzheimer's disease (PwAD). Whilst there are effective methods in existence such as reminiscence activities, it has been shown that there are not enough technological tools on the market that aim to improve the reminiscence of PwADs. This study is to develop an interactive game that helps people with Alzheimer's disease in improving their cognitive functions and enhancing their reminiscence. The interactive game will pair technology with tangible objects, as people with forms of dementia, such as Alzheimer’s disease, feel a strong need to physically interact with objects. By applying existing recommendations, guidelines and principles for technological systems for people with Alzheimer’s disease and building upon them with the help of caretakers and experts, a technological system will be made that will positively affect the day to day lives of PwADs and specifically their reminiscence capabilities.

Procedures for withdrawal from the study

You are free to leave this interview and study at any moment. The data collected from you for the research will be deleted. If you want to leave the research, contact the researcher via email or mention this to the researcher during or after the interview. By doing this, there will be no repercussions.

Use of personal information

Every piece of data that could identify you, such as this consent form and audio recordings, will be kept offline and safe. Audio recordings will not be made public and will only be accessible for the researcher. Potential audio transcripts will be made anonymous. This type of personal data will be deleted after the research has been completed in July 2024.

Usage of data during research

Data collected from this research will be in a protected online data cloud. The data will be protected with the use of encryption. The data put here will only be accessible to the researcher. The data can be used in the report written for this research, but this will be done in a manner in which you as a participant will be anonymous. The report will be published publicly so it will be accessible to not only the supervisors, but also anyone interested in reading it. Once the research is completed, the personal information and audio recordings collected will be deleted. The final report and anonymous

data will be kept online. For any further information/questions, the researcher can be contacted via this email address: a.a.braaksma@student.utwente.nl.

Contact information for questions concerning your rights as a research participant

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

2. Consent form

Consent Form for "Developing a Tangible Interactive Game to Improve Reminiscence among People with Alzheimer's Disease"

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study 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 and 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. Once the research has been completed, all personal information and audio recordings will be destroyed, only anonymous data and the final report will be kept online.	○	○
Use of the information in the study		
I understand that information I provide will be used for a research report that will be published publicly. However, the information provided by you as a participant will be anonymous in the report.	○	○
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 study team.	○	○

I agree that my information can be quoted in research outputs. ○ ○

I agree to be audio/video recorded. ○ ○

Signatures

Name of participant [printed] 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 [printed] Signature Date

Study contact details for further information: ***Ashley Braaksma,*** ***a.a.braaksma@student.utwente.nl***

3. Questions of the expert interview

Questions for expert

Introduction

- Can you tell about your background?
- What is your expertise?
- What is your role in the expertise center of Dementia & Technology at the TU/e?
- We saw one of your projects for PwD on Aesthetic play. Can you tell us a bit about this?
- What other projects for PwD have you worked on?

People with dementia

- Do people with dementia generally have the same knowledge of the world?
- Could cultural differences between people with dementia have an impact on their game experience? If so, in what ways?
- (Reminiscence)

Games

- Do PwADs like to play games?
- What type of games do PwADs usually prefer?
- What would be the limitation(s) of PwADs when playing game(s)?
- What elements should a game for people with dementia absolutely not have?
- Is either a group setting or an individual setting better for a tangible interactive game for PwADs?

Tangibles

- Do you think tangibles have more impact on reminiscence than non-tangible objects?
- What effect does the texture of a tangible object have on PwADs?
- Does the size of the object and thickness matter to PwADs? If so, what would be the ideal size and thickness?
- Are certain shapes of tangible objects preferable over others for PwADs?
- How many tangible objects are too many for PwADs?
- It has been proven that Alzheimer's also decreases the mobility and manual dexterity of a person. How can tangibles become friendly to those issues, thus accessible to a wider audience of PwADs?

Design

- What guidelines do you set yourself when designing objects for people with dementia?
- What aspects of a design can make or break the experience for a person with dementia?

Technology

- What kind of technology does the expertise center currently use for solutions for people with dementia?
- Does the expertise center develop (tangible interactive) games for PwDs?
- Do the PwDs have enough skills to work with technology?
- How much guidance does the expertise center give PwDs when working with technological solutions?
- Which technology has been seen to be effective in solutions for PwDs?

4. Questions for the lo-fi prototype evaluation

Questions lo-fi testing

Design

- What do you think of the overall design of the puzzle board?
- Do you like the shape of the puzzle board?

Tangibles

- What do you think of the shape of the tangibles?
- Are the tangibles big enough?
- Are the tangibles easy to grab?

Interactivity

- Is the interactive game interactive enough?
- Is the idea of the combination of a visual element through the screen and physical activity via the tangibles engaging?

General questions

- What was your first reaction after seeing the prototype?
- What did you like the most about the concept/prototype?

- What did you dislike the most about the concept/prototype?
- Any suggestions on how this prototype can be improved?

5. Arduino code

```
const int pinSeven = 7;

const int inPinTwo = 2;

const int inPinThree = 3;


const int inPinEight = 8;

const int inPinNine = 9;

const int pinTen = 10;


const int inPinFour = 4;

const int inPinFive = 5;

const int pinSix = 6;


const int inPinEleven = 11;

const int inPinTwelve = 12;

const int pinThirteen = 13;


const int pinFifteen = 15;

const int inPinOne = 1;

const int inPinZero = 0;


const int pinsHole1[] = {2, 3, 7};

const int pinsHole2[] = {8, 9, 10};

const int pinsHole3[] = {4, 5, 6};

const int pinsHole4[] = {11, 12, 13};

const int pinsHole5[] = {14, 15, 0};


String message1 = "";

String message2 = "";
```

```
String message3 = "";
String message4 = "";
String message5 = "";

void setup() {
 Serial.begin(9600);  // Use 9600 as a standard baud rate
}

void loop() {
 message1 = "";
 message2 = "";
 message3 = "";
 message4 = "";
 message5 = "";

 // Puzzle hole 1
 pinMode(pinsHole1[1], INPUT_PULLUP);
 pinMode(pinsHole1[2], INPUT_PULLUP);
 pinMode(pinsHole1[0], OUTPUT);
 digitalWrite(pinsHole1[0], LOW);

 if (digitalRead(pinsHole1[1]) == LOW) {
  message1 = "slippers";
 }

 if (digitalRead(pinsHole1[2]) == LOW) {
  if (message1.length() > 0) {
   message1 += ", banaan";
  } else {
   message1 = "banaan";
  }
```

```
}

pinMode(pinsHole1[0], INPUT_PULLUP);
pinMode(pinsHole1[1], OUTPUT);
digitalWrite(pinsHole1[1], LOW);

if (digitalRead(pinsHole1[2]) == LOW) {
  if (message1.length() > 0) {
    message1 += ", hooi";
  } else {
    message1 = "hooi";
  }
}

// Puzzle hole 2
pinMode(pinsHole2[1], INPUT_PULLUP);
pinMode(pinsHole2[2], INPUT_PULLUP);
pinMode(pinsHole2[0], OUTPUT);
digitalWrite(pinsHole2[0], LOW);

if (digitalRead(pinsHole2[1]) == LOW) {
  message2 = "koe";
}

if (digitalRead(pinsHole2[2]) == LOW) {
  if (message2.length() > 0) {
    message2 += ", zee";
  } else {
    message2 = "zee";
  }
}
```

```
pinMode(pinsHole2[0], INPUT_PULLUP);
pinMode(pinsHole2[1], OUTPUT);
digitalWrite(pinsHole2[1], LOW);

if (digitalRead(pinsHole2[2]) == LOW) {
  if (message2.length() > 0) {
    message2 += ", kaas";
  } else {
    message2 = "kaas";
  }
}

// Puzzle hole 3
pinMode(pinsHole3[1], INPUT_PULLUP);
pinMode(pinsHole3[2], INPUT_PULLUP);
pinMode(pinsHole3[0], OUTPUT);
digitalWrite(pinsHole3[0], LOW);

if (digitalRead(pinsHole3[1]) == LOW) {
  message3 = "zonnebrandcreme";
}

if (digitalRead(pinsHole3[2]) == LOW) {
  if (message3.length() > 0) {
    message3 += ", weegschaal";
  } else {
    message3 = "weegschaal";
  }
}
```

```
pinMode(pinsHole3[0], INPUT_PULLUP);
pinMode(pinsHole3[1], OUTPUT);
digitalWrite(pinsHole3[1], LOW);

if (digitalRead(pinsHole3[2]) == LOW) {
  if (message3.length() > 0) {
    message3 += ", varken";
  } else {
    message3 = "varken";
  }
}

// Puzzle hole 4
pinMode(pinsHole4[1], INPUT_PULLUP);
pinMode(pinsHole4[2], INPUT_PULLUP);
pinMode(pinsHole4[0], OUTPUT);
digitalWrite(pinsHole4[0], LOW);

if (digitalRead(pinsHole4[1]) == LOW) {
  message4 = "vis";
}

if (digitalRead(pinsHole4[2]) == LOW) {
  if (message4.length() > 0) {
    message4 += ", zand";
  } else {
    message4 = "zand";
  }
}

pinMode(pinsHole4[0], INPUT_PULLUP);
```

```
 pinMode(pinsHole4[1], OUTPUT);
 digitalWrite(pinsHole4[1], LOW);

 if (digitalRead(pinsHole4[2]) == LOW) {
   if (message4.length() > 0) {
     message4 += ", kippen";
   } else {
     message4 = "kippen";
   }
 }
//Puzzle hole 5
 pinMode(pinsHole5[1], INPUT_PULLUP);
 pinMode(pinsHole5[2], INPUT_PULLUP);
 pinMode(pinsHole5[0], OUTPUT);
 digitalWrite(pinsHole5[0], LOW);

 if (digitalRead(pinsHole5[1]) == LOW) {
   message5 = "handdoek";
 }

 if (digitalRead(pinsHole5[2]) == LOW) {
   if (message5.length() > 0) {
     message5 += ", geit";
   } else {
     message5 = "geit";
   }
 }

 pinMode(pinsHole5[0], INPUT_PULLUP);
 pinMode(pinsHole5[1], OUTPUT);
 digitalWrite(pinsHole5[1], LOW);
```

```
if (digitalRead(pinsHole5[2]) == LOW) {
  if (message5.length() > 0) {
    message5 += ", tomaat";
  } else {
    message5 = "tomaat";
  }
}

// Print combined message
String combinedMessage = "";

if (message1.length() > 0) {
  combinedMessage = message1;
}

if (message2.length() > 0) {
  if (combinedMessage.length() > 0) {
    combinedMessage += ", ";
  }
  combinedMessage += message2;
}

if (message3.length() > 0) {
  if (combinedMessage.length() > 0) {
    combinedMessage += ", ";
  }
  combinedMessage += message3;
}

if (message4.length() > 0) {
```

```
  if (combinedMessage.length() > 0) {
    combinedMessage += ", ";
  }
  combinedMessage += message4;
 }

 if (message5.length() > 0) {
  if (combinedMessage.length() > 0) {
    combinedMessage += ", ";
  }
  combinedMessage += message5;
 }


 if (combinedMessage.length() > 0) {
  Serial.println(combinedMessage);
 }
}
```

6. Unity code: scene switching

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

public class SceneSwitch : MonoBehaviour
{
    public void PlayNextScene()
    {
        SceneManager.LoadScene(SceneManager.GetActiveScene().buildIndex + 1);
    }
}
```

7. Unity code: video player

```
using System.Collections;
using System.IO.Ports;
using UnityEngine;
using UnityEngine.SceneManagement;

public class MarktPromptToVideo : MonoBehaviour
{
    public string portName = "COM6"; // Change to your Arduino port
```

```
    public int baudRate = 9600;
    private SerialPort serialPort;

    void Start()
    {
        // Initialize the serial port
        serialPort = new SerialPort(portName, baudRate);
        serialPort.Open();
    }

    void Update()
    {
        if (serialPort.IsOpen)
        {
            try
            {
                string message = serialPort.ReadLine();
                if (message.Contains("banaan, kaas, weegschaal, vis, tomaat"))
                {
                    SceneManager.LoadScene(SceneManager.GetActiveScene().buildIndex +
1);
                }
            }
            catch (System.Exception)
            {
                // Handle exceptions
            }
        }
    }

    void OnApplicationQuit()
    {
        // Close the serial port when the application quits
        if (serialPort != null && serialPort.IsOpen)
        {
            serialPort.Close();
        }
    }
}
```

8. The questions and answers for the evaluation of the final prototype

Vragen and antwoorden hi-fi prototyping

- Was het spel leuk om te spelen?
    - Participant 1: “Yes, I liked it a lot. I thought it was really nicely made too. I did think it was a bit difficult. Maybe I have Alzheimer's, who knows. I think if you do it with people with Alzheimer's, they would not be able to correctly connect the copper strips.”
    - Participant 2: “Yes it was. I actually don’t really like playing games, but this was fun.”
    - Participant 3: “Yes, I liked all of it. I like that some parts are related to nature, children should also play this game. Nowadays the games include shooting, I would rather want them to play a game like this. They would learn a lot from this too.”
    - Participant 4: “Yes, but I had to think a lot and I am not a practical person in my opinion. I think too difficultly about things.”
    - Participant 5: “It was nice, because it trains your memory. And it fits different parts, it fits the part of my youth (with the tangibles he used to play with as a child such as the farm animals and the groceries) and the videos match with the real-life experiences. So connections are made with many parts in the game. And with

matching the puzzle piece to the correct puzzle hole requires out of the box thinking”

- Was makkelijk om te begrijpen wat je moest doen? (Instructies duidelijk genoeg?)
    - Participant 1: “Yes it was, but the instructions were difficult to read because I have dyslexia.”
    - Participant 2: “Yes it was.”
    - Participant 3: “Yes the instructions were clear. I have never played this game before so I was proud of myself that I was able to understand it.”
    - Participant 4: “No, at first it was not. The instructions were not clear enough.”
    - Participant 5: “Yes, it was easy to understand what I had to do.”
- Was het spel moeilijk om te spelen? Zo ja, wat was moeilijk?
    - Participant 1: “Yes it was. Connecting the tangible to the correct copper strips in the puzzle hole was difficult for me. I think people with Alzheimer’s would have an even harder time matching the tangibles to the puzzle holes."
    - Participant 2: “The first puzzle piece (because he did not understand at first).”
    - Participant 3: “I did not think it was that difficult. I could make the connections between the objects and real life.”
    - Participant 4: “Yes, it was difficult to match the copper strips on the tangible to the correct puzzle hole.”
    - Participant 5: “It was okay (not too easy, not too difficult).
- Wat vind je van het ontwerp van het spel?
    - Participant 1: “I liked it a lot, I think it is cute.”
    - Participant 2: “I thought it was fun.”
    - Participant 3: “I thought it looked nice. The video also fitted perfectly, everything fitted the game.”
    - Participant 4: “Nice and simple design. It is fun, because you can look at everything and feel the objects. The objects are very clear, you know what they are supposed to be.”
    - Participant 5: “The game is made with so much love and thought. It is nice that the haptic experience is included for people with Alzheimer’s. Although the movement that has to be made to turn around the pieces the whole time is quite difficult for old people.”
- Wat vind je van de combinatie van laptop en puzzeldoos?
    - Participant 1: “I thought it was nice to have the screen and the puzzle box. But I did have a difficulty with the mouse. Maybe better if someone else presses the buttons.”
    - Participant 2: “I think people with Alzheimer's are not good at using laptops.”
    - Participant 3: “Yes, I liked it (although she did have difficulty with the mouse).”
    - Participant 4: “I don’t think there are any issues with it.”
    - Participant 5: “For older people it is not normal to have a screen. I know this from my parents, they don’t have a screen. But it is a big chance. They have the haptic experience, thinking out of the box with the puzzling. But the video gives them a deeper and more emotional connection to their past memories. The screen is a very nice addition.”

- Zijn de scenario's interessant?
    - Participant 1: "Yes, I liked them."
    - Participant 2: "Yes, they were very diverse."
    - Participant 3: "Yes, I thought they were all fun. I liked that they all differed from each other."
    - Participant 4: "Yes I thought they were very interesting."
    - Participant 5: "They were very interesting."
- Zijn de scenario's algemeen genoeg zodat ze herkenbaar zijn voor elke Nederlander?
    - Participant 1: "I would say yes for every Dutch person. But maybe not for people who recently immigrated to the Netherlands."
    - Participant 2: "Yes, they were."
    - Participant 3: "I think a lot of Dutch people would recognize them. They grew up with these things."
    - Participant 4: "Yes."
    - Participant 5: "I think everyone on the planet would be able to understand it."
- Helpen de filmpjes met herinneringen uit het verleden opbrengen?
    - Participant 1: "Yes, I think they do.
    - Participant 2: "No, they didn't for me. It's more so an award for doing well. When I look at the video, it is a video of something else, not of my memories. The objects made me think more about memories than the videos."
    - Participant 3: "Yes then I think "Oh, I have done all these things as well." I have been to the beach, I have also been to Scheveningen. Although I do not swim at the beach, I do sit and look around at the beach."
    - Participant 4: "Yes, definitely."
    - Participant 5: "Yes extremely, because we are visual animals, so extremely. For me, I could smell and taste the salty air for example when seeing the beach video. You're directly in your own historical film. It's a nice connection, especially for old people. My dad is 97 years old and the last time he was at the beach was 50 years ago. Movies from his time become greyer and greyer the further you go into the past. A colorful video like this is powerful in making the memories arise again."
- Roept het spel in zijn geheel herinneringen op uit het verleden?
    - Participant 1: "Yes, it does."
    - Participant 2: "Well yes, it has to since I have to talk about my memories."
    - Participant 3: "Yes the game does, because everything nicely belongs to each other. The tangibles and the video also fit each other."
    - Participant 4: "Yes, the game makes me think of memories from the past."
    - Participant 5: "Oh yes. Although I never had flip flops, all things have a direct connection to your past memories. It's a very famous thing for the German guys to put the towels on the swimming pool lounge chairs. I also love the haptics. To remember better, haptics are very important."

Objecten

- Zijn de objecten herkenbaar?
    - Participant 1: "Yes."
    - Participant 2: "Yes, they are."
    - Participant 3: "Yes most of them, for a few I had to ask what they were."
    - Participant 4: "Yes for most of them. I couldn't recognize the hay bales, because they did not have grass. I also thought the tomato was an apple. Maybe the sunscreen

could also use the name of a well-known brand, then you know what it is more easily."
    - Participant 5: "Yes they were and they matched perfectly in my head. In my youth, we used to play with these toy animals. We had the same ones. You directly jump back into your youth. But I didn't understand what this (the sand) was at first."
- Is de textuur van de objecten stimulerend?
    - Participant 1: "I actually tried to not grab them, but the wooden base instead because I was scared to accidentally break something. Also, you do not feel the tangible because of the sticks on top of some of the tangibles (to pick them up more easily). But in general I am a visual person: I can see it is grass, but I am not going to stroke it. Although with Alzheimer's, you can become a bit more playful too sometimes so maybe people with Alzheimer's will try to feel the textures more."
    - Participant 2: "No, because I did not try to feel the textures."
    - Participant 3: "Yes, they are."
    - Participant 4: "Yes, I could feel the textures and they make the tangibles feel more realistic."
    - Participant 5: "Yes it is really stimulating. I recognized that it really stimulated me because I wanted to touch it a second time. The first touch is to discover, the second touch is to create the connection between the object and my memory."
- Vind je dat de textuur een toegevoegde waarde heeft?
    - Participant 1: "Maybe for people with Alzheimer's, but I am a more visual person."
    - Participant 2: "I think the tangible is 95% visuals and only afterward you think about the texture. I don't think you would go and feel the objects that quickly, because the tangibles look quite fragile. It only slightly adds something to the tangibles, but it is nice."
    - Participant 3: "Yes, because if you were to remove the texture, people would not know what it is."
    - Participant 4: "It definitely does."
    - Participant 5: " I think for old people the texture and the ability to grab is very important, especially as a form of therapy. Touching the objects and feeling the textures in combination with the screen is not something you often see in games."
- Wat vind je van de groottes van het puzzelbord en de objecten? (Te groot? Te klein? Precies goed?)
    - Participant 1: "They were fine to me."
    - Participant 2: "I think they are fine."
    - Participant 3: "I think the sizes are fine."
    - Participant 4: "I think the sizes are ideal."
    - Participant 5: "They are perfectly sized."
- Waren de objecten makkelijk op te pakken?
    - Participant 1: "Yes, they were for me."
    - Participant 2: "Yes they were."
    - Participant 3: "Yes, they were easy to grab to me."
    - Participant 4: "Yes, definitely."
    - Participant 5: "Yes they were. But I didn't want to directly grab the sunscreen but on the sides of the wooden base. This shows it is realistic, because you think it is oily, so you don't want to grab it. All the other things I wanted to grab. I liked the weight of the tomato tangible."

Plus en minpunten

- Wat zijn de pluspunten van het spel?
    - Participant 1: “First of all, it is nicely made. I liked the petting zoo the most, it’s a nice experience.”
    - Participant 2: “I think this is a way friendlier experience for people with Alzheimer's than some I have seen (such as having to draw a clock or a three-dimensional cube). This is more accessible.”
    - Participant 3: “I like the game a lot. Even for myself, but of course also for people who are ill.”
    - Participant 4: “The video after all the puzzle pieces were placed correctly, which was connected to the game. So not only images but also video.”
    - Participant 5: “I think this game is made with much love and with deep thoughts (thoroughly thought through). The plan you made for the game is perfect: connecting a modern technique (the technology) with a traditional technique (the physical puzzle). The copper strip technique has two aspects, it is electronic, but not as modern as the video. And the wooden tangibles the copper strips are on bring me back to my childhood room. It brings me back to when I played cashier in my room. The tangibles activate you to play the game. When I first grabbed the tomato and then I was directly teleported back to my childhood and I started to play with the tomato.”
- Wat zijn de minpunten van het spel?
    - Participant 1: “Well, I do not think it has any downsides. I just thought it was a bit difficult for me.”
    - Participant 2: “That the computer did not want to work (the game got stuck at the beginning during the demo test with Participant 2, but worked afterward. This was not an issue in the other user tests). I don’t have any further negative feedback.”
    - Participant 3: *Did not have any negative feedback*
    - Participant 4: “The instructions and that there was not a clear storyline. Introducing every new scenario as if you are going from one location to the other would be nice, so for example “Now you are going to the beach”. Then the person will be more immersed throughout the game.”
    - Participant 5: *Did not have any negative feedback*

Sluiting

- Heb je nog enige feedback/opmerkingen?
    - Participant 1: “Yes, maybe if you want the people with Alzheimer’s to actually feel the textures, you should make the sticks they can grab onto a bit shorter. Then your fingers will already touch the texture a bit while grabbing the stick. Then you already direct them to having to feel.”
- Heb je nog vragen
    - Nobody had any other questions