Cognitive Enhancement through Play: Crafting an Engaging Game-Based Intervention for Alzheimer's Disease.

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Dementia, a condition affecting more than 50 million people worldwide, is the biggest cause of disability in the elderly. Alzheimer's Disease (AD) continues to be the most common form of dementia. Currently, there is no cure for AD, but there are some treatment options available, such as medical and non-medical interventions. One of the non-medical interventions is the use of interactive games. This research aims to explore the potential of using interactive games to stimulate cognitive function in individuals with AD. This research analyses the existing types of interactive game technology for cognitive stimulation and proposes a set of guidelines for developing interactive games for people with AD. These guidelines are used to develop a prototype of an interactive table game. Subsequently, an expert is interviewed to validate the effectiveness and practicality of the prototype. The result of this interview is that the prototype holds great potential to be used as a cognitively stimulating game for people with AD.

Additional Key Words and Phrases: Cognitive Function, Interactive Games, Alzheimer's Disease

1 INTRODUCTION

Dementia is the umbrella term for various disorders that affect cognitive functions. People who suffer from dementia often experience loss of memory, and personality changes, and have difficulty finding words or performing daily tasks [1]. Dementia affects more than 50 million people worldwide and is the biggest cause of disability in elderly people. Alzheimer's Disease (AD) is the most common form, affecting around 50 - 60% of all people with dementia [1]. Despite affecting a significant population, there is currently no cure for this disease. However, there are possibilities for people with AD to undergo some treatments to slow down the progression of the disease. Given the significant impact of AD and the absence of a cure, it is crucial that extensive research into treatments is done.

Currently, there are two types of treatment available: pharmacological intervention and non-pharmacological intervention. The first type refers to the use of medication to slow down the progression of the disease. The second type is aimed at maintaining cognitive functions on the one hand, and improving quality of life by reducing behavioural symptoms on the other hand [2]. Since medication can have side effects [3], a non-pharmacological intervention is preferred. One form of this is the use of interactive games. There exist many different types of interactive games that are aimed at cognitive stimulation. Examples include tangible games, mobile applications, Virtual Reality games and interactive table games. Through the analysis of these existing interactive games and their effect on individuals with AD, it is possible to propose a set of guidelines for the development of new cognitively stimulating interactive games. Consequently, this research aims to contribute valuable knowledge to the domain. To accomplish this, the following research question is formed:

How can interactive games be designed to stimulate cognitive functions in individuals with Alzheimer's Disease?

This research question can be split into the following two subquestions:

1. What types of interactive game technology currently exist for cognitive stimulation?
2. What design principles should be taken into account when developing interactive games for individuals with Alzheimer's Disease that are aimed at stimulating their cognitive functions?

While addressing these questions, this paper provides an analysis of the currently available types of interactive game technology, as well as proposes a set of guidelines to develop new games. Subsequently, these guidelines are used to design a low-fidelity prototype for a new interactive table game. This prototype is validated by an expert in the field of dementia and AD to ensure its practicality and effectiveness. The findings from this validation are documented. Finally, the paper draws conclusions from these findings and provides recommendations for future research in this domain.

2 RELATED WORK

2.1 Dementia and Alzheimer's Disease

Dementia is an umbrella term to describe a collection of symptoms that are caused by abnormal brain changes [12]. These symptoms can include memory loss, language, problem-solving and other thinking abilities. They can cause a decline in cognitive abilities severe enough to impair the daily life, independent function, behaviour, feelings and relationships of the person suffering from dementia. The two

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most common causes of dementia are Alzheimer's Disease (AD) and Vascular dementia.

The first case of AD was found in 1906 by German physician Alois Alzheimer [13]. Now it is the most common form of dementia, affecting around 50-60% of individuals with dementia worldwide [1]. AD is a progressive disease, which means that it gets worse over time. On average, an individual with AD lives four to eight years after being diagnosed [14]. There has been extensive research to uncover as many aspects of AD as possible. Today, there is still a lot of research into finding a cure for AD, which does not exist yet.

AD generally progresses in three stages [17]. The first is early-stage Alzheimer's, which is also called mild Alzheimer's. In this stage, the person can still function independently but has some memory issues. The next stage is middle-stage Alzheimer's, or moderate Alzheimer's. This stage is generally the longest and can last for years. The person will require more care from others and can experience heavier symptoms. These can include experiencing confusion about words, situations or places. Furthermore, they can experience changes in their mood and behaviour. At this stage, there is brain damage which makes it harder to express thoughts and perform routine tasks independently. The last stage is late-stage Alzheimer's, also called severe Alzheimer's. In this stage, the person requires around-the-clock assistance. The person will experience symptoms that can include losing awareness of experiences, surroundings, conversations and movements. They will have difficulties communicating and will undergo a severe decline in cognitive and physical abilities. During this stage, the focus is on providing comfort rather than trying to fight the disease.

2.2 Cognitive stimulating games

Cognitive stimulation is participating in activities that enhance cognitive and social functioning [18]. Cognitive functions include learning, reasoning, thinking, problem-solving, remembering, decision making and attention. To train cognitive functions, one can partake in cognitive stimulating activities, or Cognitive Stimulation Therapy (CST). CST is a nonpharmacological intervention which has been proven to improve the cognition and well-being of individuals with AD. It is also cost-effective and appears to have comparable effects with the currently available antidementia drugs [15]. Gasteiger et al. [16] developed a robot with six interactive cognitive stimulation games for older adults. These games were developed in Korea and are meant to train cognitive functions such as language, memory, calculation, visuospatial function and executive function. All games have 10 difficulty levels and users can switch between them at any point. The results of the research of Norina et al. are promising. Participants were satisfied with the games and the games proved to be beneficial for improving cognitive abilities.

2.3 Interactive games for elderly with AD

There are two types of treatment available for AD, pharmacological and non-pharmacological treatments. However, due to the side effects of pharmacological treatments [3], people prefer the non-pharmacological option. Several studies have explored non-pharmacological interventions, including interactive games, for people with AD. Technology can be exceptionally helpful as a treatment for people with AD for various reasons [10,11]. Unfortunately, many games and interfaces are not dementia-friendly [8], which is why it is crucial to do research into this topic. There has been some research into several games, which will be elaborated upon in this section.

2.2.1 Helpful technology: In their 2018 paper, Lazar et al. [11] highlight the design recommendations for recreational systems involving older adults living with dementia. They find that meaningful and enjoyable recreational activities are extremely beneficial for people with dementia. These activities are associated with positive effects such as better well-being, delays in cognitive impairment progression and even a reduction in antipsychotic medication administration. Additionally, they help manage symptoms of dementia, including restlessness, agitation and irritability. Lazar et al. argue that these activities should be utilised before pharmacological interventions. However, they are lacking in many assisted living facilities for people with dementia. This is where technology could provide a means to facilitate these activities. The researchers gave some recommendations on important aspects of this technology, including guiding principles and recommendations on hardware, content, games, media and navigation.

Coppola et al. [10] describe in their paper how mobile application development can help dementia and AD patients. Research has shown that many AD patients suffer from sundowning, which means that they get agitated in the late afternoon or early evening when the sun goes down. To help those, they can get "busy boards". With these, AD patients need to perform tasks and get rewarded afterwards with sounds. Coppola et al. developed some kind of busy board application for a tablet. The researchers tested the application with individuals suffering from AD and in group settings. They found that the group setting showed more response as the patients would comment on it with each other.

2.2.3 Interfaces: Designing technology for the elderly and people with AD can be challenging at times. In their 2013 paper, Ancient and Good [8] outline the issues that arise when designing dementia-friendly interfaces. They mention design considerations for elderly people as well as people with dementia. The work of Pang and Kwong [9] also contains considerations on the design of apps for the elderly with mild-to-moderate dementia. They argue that the principles for the design of apps for the elderly to improve their cognitive functions are: reduction of complexity, clear

structure of tasks, consistency of information, rapid and distinct feedback, user support and interface optimisation. They also developed an app, called "Alive Inside", for the cognitively impaired. This app stimulates the memory of those suffering from AD through music from their youth.

2.2.1 Game devices: Not only the interfaces but also the game devices can be challenging. One example of research into this is the work of Palacio et al [5]. In their paper, they describe their research on the usability perception of different video game devices in elderly users. They explain that playing video games requires certain cognitive and motor skills, including concentration and memory, but also coordination and reaction speed. These are the areas that elderly people, especially people with AD, struggle with. In their paper, the authors point out that there have not been many studies about the effects of video games on elderly people, or people with AD. In their study, they found that video games can improve many skills, including attention, short-term memory, problem-solving, reaction time, eye-hand coordination, fine motor skills and even emotional well-being. They found that playing games helps the elderly feel better, stay healthy, and keep in touch with friends and family. In other words, technology is great for the elderly, yet the authors claim that most technology is not designed to be used by older people. For it to be more approachable, there should be changes in the user interfaces.

2.2.2 Immersive technology: One type of technology is further explained in the 2021 paper of Seifert and Schlomann [6]. They highlight the potential and challenges of the use of Virtual Reality (VR) and Augmented Reality (AR) by older adults. One specific VR game is explained by Paczynski et al. [7]. Their paper discusses the effects of visual art technology on older adults. Research shows that there is a positive relationship between art therapy and successful ageing. However, this can be challenging for older adults, especially those with physical and/or cognitive impairments. This is where technology can be helpful. Creating art in Virtual Reality means that there is no need for fine motor control and there is no (physical) mess. Research shows that engaging in art-making gives older adults a sense of purpose. Additionally, it satisfies them, gives them positive feelings about their self-worth and gives them a means to escape from their worries. That is why Paczynski et al. developed the Kinect Virtual Art Program (KVAP). The program was designed so that an individual could make art by moving their limbs. After multiple sessions, it was observed that the arm movements of the elderly improved, along with enhancements in their mood and mental well-being. However, as Palacio et al [5] also mention in their paper, many technologies have not been developed for elderly individuals. Furthermore, older adults did not grow up with technology, which means they have to learn it, which takes more effort for an older person than for younger individuals. Especially those who are in a long-term care facility have to overcome certain barriers arising from their cognitive and physical impairments and their financial and social resources. So, there are many aspects and factors that need to be taken into account when designing technology for the elderly.

3 RESEARCH METHOD

To address the research questions and achieve the aim of this research, several steps are performed. This section elaborates on the process of the research. This process can also be seen in Figure 1.

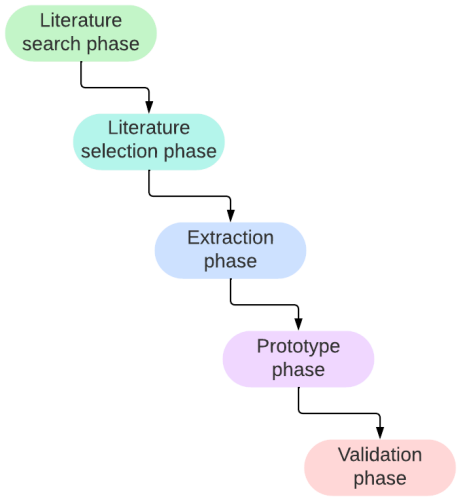

Fig. 1. Research process

3.1 Literature search and selection

During the literature search and selection process, several relevant papers are selected. This literature covers the subjects relevant to the study, including interactive games and interfaces, cognitively stimulating games, elderly and individuals with dementia and AD, and combinations of these subjects. Subsequently, these papers are read and analysed to gain knowledge on the domain and create an overview of the currently existing interactive game technology.

3.2 Extraction

After the literature search and selection process is the extraction phase. The currently available interactive game technology will be analysed for effectiveness on people with AD. This analysis serves as a basis for proposing a set of guidelines for developing new, interactive, cognitively stimulating games for people with AD.

3.3 Prototype

Using the defined guidelines, a low-fidelity prototype will be designed. This prototype includes a new cognitively stimulating game for the elderly with AD.

3.4 Validation

To validate the effectiveness and practicality of the prototype, an expert in the field of dementia and AD will be interviewed. Prior to this interview, an ethics application (number 230633), including a consent form, has been processed and approved by the ethics committee of the faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS) of the University of Twente. Following this, I will send the consent form to the expert via email and arrange the interview. This will take place online since the expert is not located in the Netherlands. The findings of this interview will be reflected upon and documented in section 5.4 Validation of the game.

4 LITERATURE RESULTS

In the literature phase, I received 19 papers from my supervisor and I used Google Scholar to find more. The keywords for searching papers included one or more of the following: Alzheimer's Disease, cognitive stimulation, dementia, interactive, game, technology. During the literature search, a total of 37 papers are selected. Among these, 17 are specifically used to provide information about the types of currently available interactive game technology. Subsequently, from the initial 37 papers, eight are chosen as the foundational basis for the proposed set of guidelines. From these eight papers, a total of 73 guidelines are extracted. The remaining papers are used as valuable references in the other sections of the paper.

4.1 Types of interactive game technology

Nowadays many different types of technology exist, also when it comes to games. To be able to propose a set of guidelines for interactive games for people with AD, it is crucial to be aware of the available types of technology for games. From the 17 papers selected from the literature research, the four most important categories for interactive game technology are chosen and elaborated upon in this section of the paper.

4.1.1 Mobile games: Mobile games are games that are developed for smartphones and tablets. In 2023 the number of smartphone users in the world is 6.93 billion, which means that 85.74% of the world population owns a smartphone [20]. Since so many people own a smartphone, also the number of people who play mobile games is increasing. In 2023 there were approximately 1.6 billion mobile game users and this number is expected to reach 1.9 billion by 2028 [21]. While many of these games have been developed for entertainment, there are also cognitively stimulating games. These games aim to stimulate cognitive functions in, for example, the elderly or people with dementia. Research has shown that these cognitively stimulating games reduce the symptoms of AD. Since technology nowadays allows for many possibilities concerning mobile gaming applications, it is relatively easy to develop games with a friendly user interface [22]. This way, the games can also be utilised by the elderly. However, there are also many limitations to mobile games for cognitive stimulation of the elderly with AD. Many elderly have for example never interacted with a smartphone or tablet and have to learn that. Research has shown that touchscreen is not intuitive for them [10]. Additionally, people with AD often suffer from physical and cognitive impairments which not only make the games more challenging, but also holding the phone or tablet is not always possible.

4.1.2 Virtual and Augmented Reality games: A different type of game is a Virtual Reality game. The meaning of Virtual Reality (VR) is already in the name. It is an imitation of the real world, or, in technical terms, a 3D computer-generated environment that people can interact with [23]. It engages the human senses, creating a sensation of reality while it is not real [23]. Because of this, it holds great potential for cognitive stimulation games, as the engagement of the senses has been shown to stimulate cognitive functions [24]. VR could make it possible to create art without the need for fine motor control and physical mess [7]. Furthermore, VR could make it possible for the elderly with motor issues to engage in sports [25]. The potential of VR and AR is especially high in five areas [6]. Firstly, AR can be helpful in real-world orientation as the elderly often struggle with navigating new settings or familiar areas due to memory issues or cognitive declines. Secondly, VR and AR can be used to change learning methods based on individual preferences. This is crucial since the elderly have different learning speeds and orientations than younger people. VR technology can be used to establish new forms of learning, including gamification and virtual lessons. Additionally, VR and AR can promote health and well-being in elderly people. It can be integrated with psychotherapy and rehabilitation. It can also be helpful to maintain motor abilities and cognitive functions in older adults. Furthermore, as was also mentioned in the paper from Palacio et al [5], technology can be extremely entertaining. Although many AR and VR games are targeted towards younger people, the elderly also benefit significantly from these. Lastly, AR has the potential to support social interaction with the elderly who are physically impaired. They can for example have social interactions with other people by playing virtual games with them while they are both in a different location. This enables lonely elderly and individuals with an impairment to have social interactions. However, the development of VR games for the elderly with AD also poses a great deal of challenges. Many elderly have not been in contact with VR before and have to learn it [6]. Furthermore, they could experience cyber-sickness, including nausea, dizziness or confusion, when engaging in VR games [26]. Additionally, some elderly with AD do not have the physical or cognitive abilities to engage in VR games, so the games need to be simple enough or have the possibility of being adapted to personal preferences [27].

4.1.3 Somatosensory games: Another type of technology for interactive games is somatosensory games. The human

somatosensory system is the part of the sensory system that is focused on the conscious perception of touch, pressure, position, movement and vibration [28]. Therefore, somatosensory games are games that stimulate those senses. These games also require a motion sensor or a device that is capable of haptic feedback. Two examples of such technology are the Nintendo Wii motion controller and the Xbox Kinect controller [5]. Research has shown that somatosensory games have the potential to positively impact the physical health and cognitive function of individuals with AD [32]. This is because these types of games generally require physical movements from the player, which increases their physical health and motor functions. Furthermore, these games allow for social interaction because many of them are multiplayer. Therefore these games also positively impact the mental health of individuals with AD [5]. Even though there is a lot of potential for these types of games, there has not been a lot of research done on these types of games for people with AD [5].

4.1.4 Interactive table games: An alternative type of interactive game is interactive table games. An interactive table uses a projector to project light animations onto a table and by using infrared sensors, it can detect movements [4]. Therefore, users are playing with light, which means that even people with physical impairments can play games. These interactive tables are used in many care facilities for the elderly, and people suffering from dementia and AD [4]. These interactive tables are growing in popularity and show very positive effects on the physical and cognitive functions, and mental wellbeing of individuals with AD [33,34]. Because of the accessibility and promising results in the physical, cognitive and mental well-being of people with AD when engaging with this type of technology, I chose to develop a prototype for an interactive table game.

4.2 Guidelines

The extracted guidelines from the literature are divided into four main categories and some sub-categories, as can be seen in Figure 2. The main categories are instructions and guidance, user interface and accessibility, game design and functionality, and user experience and enjoyment. The instructions and guidance category mainly focuses on the instructions that are provided during the game, as well as feedback messages and guidance throughout the game. The user interface and accessibility category highlights the design considerations for the interface, like visual elements, text representation and auditory elements. The game design and functionality category emphasises the importance of the difficulty level and the dynamics of the game itself. Lastly, the user experience and enjoyment category targets the engagement and social interaction of the players. The full set of guidelines can be found in Appendix A.

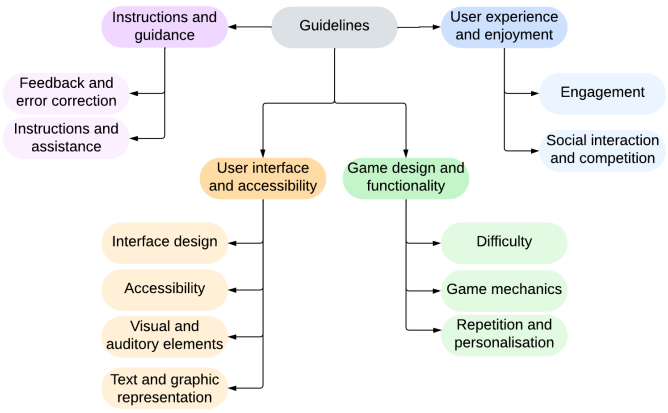

Fig. 2. Guidelines categories

5 PROTOTYPE AND VALIDATION

To assess the efficacy of the guidelines, I constructed a low-fidelity prototype. A lo-fi prototype is a simple diagram or wireframe of an early-stage design concept [35]. This prototype consists of wireframes made with the program Balsamiq, which is an online tool to easily construct simple interface designs [36]. This tool also ensures the possibility of adding functionality to buttons and other components, which is very convenient for making a simple prototype of a game with basic functionality. The prototype designed for this research also has some basic functionality which makes it feel a bit like an actual game already. After designing the prototype in Balsamiq, it is exported as a PDF file in which the buttons are clickable. This way, it is easy to test it and let it be validated by the expert.

5.1 Aim of the game

This prototype is developed for people with mild-to-moderate AD. These people can experience confusion about words but also have trouble remembering certain aspects. The game aims to stimulate the cognitive functions of these people such that their cognitive decline is reduced. Additionally, the game is meant to be fun and socially stimulating as it can be done in groups as well as individually.

The reason for choosing animals is because they provide a familiar and neutral theme. This way, the game is accessible and familiar to most people, which is important for people with dementia and AD [11]. The reason for choosing a search-and-find type of game is because then the game is easily adjustable to personal preferences and abilities, and stimulates cognitive functions while not focusing too much on the challenges associated with dementia and AD. Additionally, looking at some of the existing interactive table games [37] inspired me to make something new and see what an expert would think of it.

5.2 Functionality of the game

The prototype shows a simple game developed for the elderly with mild-to-moderate AD. The game is a search-and-find game where the user has to find the correct

animal among other animals on the screen. The only interaction that the user has with the screen is clicking. The user does not have to swipe or scroll. The flowchart in Figure 3 shows the structure of the game. On the start screen, the user can select a difficulty, easy or difficult. Figure 4 illustrates the instructions on the start screen of the game. The easy setting is meant for people who experience heavy symptoms such as struggling to remember what animals look like or confusing words and animals, but also those who experience a visual decline. The difficult setting is meant for those who experience less heavy symptoms and are still somewhat able to distinguish different animals. It is crucial that the difficulty is not too high [11], which is why the game has two difficulty levels. Besides the difficulty settings, there are multiple levels in the game. These levels do not necessarily increase in difficulty, but they ensure variety. At every level, the user has to find a specific animal that will be shown at the start of the level. While searching for the correct animal, the user can also make use of the hint button on the top of the screen, in case the user is struggling to remember the goal animal. There is also always a 'stop' button on the screen so the user can stop the game anytime they want. If the user presses the wrong animal in a level, there will be a screen which shows the correct animal again. If the user presses the correct animal, they will win a star and can progress to the next level.

Currently, the game contains three levels. Figure 5 shows a screenshot of the third level where the user has to find the pig. After all levels have been succeeded, the screen shows that the player has earned three stars, and provides the option to stop the game or play the game again. Appendix B shows some more screenshots of the game.

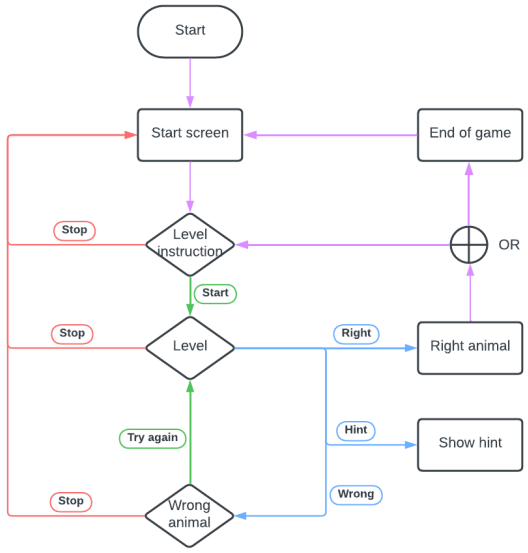

Fig. 3. Flow chart of the game

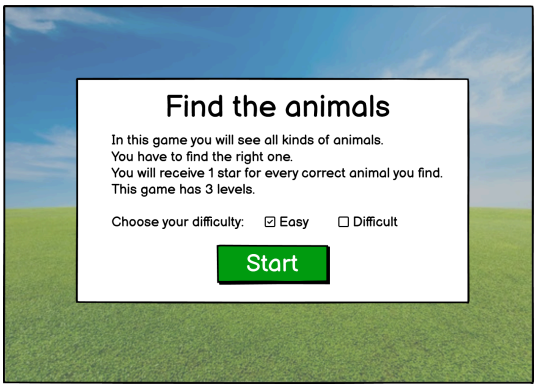

Fig. 4. Start of the game

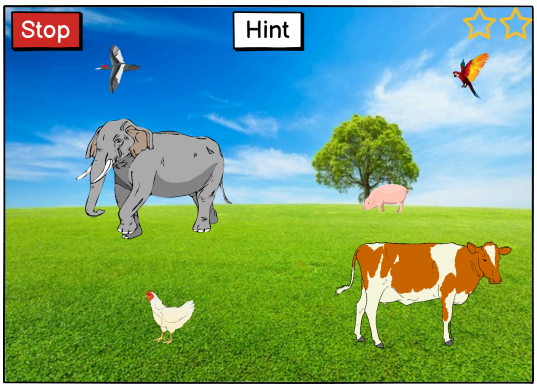

Fig. 5. Level 3

5.3 Guidelines of the game

The prototype was designed following the established guidelines. This section elaborates on the guidelines, per main category, that the prototype follows. For a detailed overview of which guidelines the prototype follows, see the proposed guidelines in Appendix A.

5.3.1 Instructions and guidance: In this category, the prototype follows many guidelines, including, among others, providing the option to correct errors, keep instructions brief, and recap the action that the person just executed. However, it does not follow all guidelines in this category. The prototype does not have a step-by-step wizard for complex interactions, because it does not contain complex interactions. The prototype also does not provide an example round or show how many questions or tasks are left. The reason for this is that it is crucial to keep the screen as clear and simple as possible to not confuse the user [30]. However, an example round could be included in the game in the future.

5.3.2 User interface and accessibility: Of the 35 proposed guidelines in this category, 21 are implemented in the prototype, seven are not implemented in the prototype and seven are not applicable. Some important guidelines that are implemented are about the interaction with the user interface. It is crucial that the interface is as easy as possible and does not require any swiping, scrolling or typing [8,9] and so the

only interaction with the interface is clicking on buttons and animals.

The guidelines in this category that are not applicable are about auditory signals and voice outputs that read text aloud. The reason for not including these is because the prototype is low-fidelity which means that it has little to no functionality, so it is not capable of playing sounds. It is something to include in future versions of the prototype. The guidelines that are applicable but not included in the prototype are mainly about the number of elements on the working page and the possibility of including a pause button and a navigation bar. In most screens of the prototype are two buttons and several clickable animals available, which results in having more than two to five items on the working page. The reason for not including a pause button is because there is no time limit on the game, so there is no need to pause the game. Lastly, since the game does not have much functionality, it was not deemed necessary to include a navigation bar. This would only result in having more items on the working page which goes against the guideline of keeping the screen clear and easy to use [30,31].

5.3.3 Game design and functionality: In this category, the game includes almost all proposed guidelines. It does not have an undo function, but there are also no consequences if a user clicks the wrong animal. Furthermore, the prototype does rely on prior steps being correct, which was a design choice because the difficulty of the levels is slightly increasing throughout the three levels. If, for example, the user would not be able to complete level two, it would also be hard to complete level three, since it is more difficult than level two. However, in future versions of the prototype, this could be adjusted.

5.3.4 User experience and enjoyment: Finally, in the last category, the prototype follows four out of six guidelines. It does not clearly promote social interaction, even though it could be played in a group setting. Lastly, the prototype does focus on challenges related to dementia, because it is a cognitively stimulating game and people with dementia have difficulties with cognitive functions.

5.4 Validation of the game

To validate the effectiveness and practicality of the prototype, an expert in the field of dementia and AD has been interviewed. The expert completed his PhD in ageing and dementia studies and currently works as a professor in the Faculty of Health Sciences at a University in Malaysia. He has over 20 years of experience in this field and often works with people with dementia and AD. The expert was recommended by my supervisor. I sent him an email containing the consent form and some information about the interview. After the consent form had been signed, the interview took place. The interview was held online via Microsoft Teams on January 16, 2024 and took about 30 minutes. The fully structured interview contained 14 questions and covered all main categories of the proposed guidelines in Appendix A. During the interview, the expert analysed the prototype, after which the questions were asked. The interview questions can be found in Appendix C.

This section of the paper is divided into the four main categories of the proposed guidelines and provides the results of the interview.

5.4.1 Instructions and guidance: The expert is satisfied with the instructions on the start screen of the game. He finds it clear and easy to follow. He agrees that there is not too much text and the sentences are short and easy. However, he does recommend making sure the text is big enough so it is also easy to read for people who suffer from visual impairments. Because of the clear instructions, the expert did not feel unsure about the next steps during the game. Additionally, he finds the "Hint" buttons an excellent idea because it is very helpful in case the user needs a clue or a hint. This way, the user is less inclined to lose motivation.

5.4.2 User interface and accessibility: According to the expert, it is easy to navigate through the game. This is important because some elderly are not used to technology and do not find it intuitive. In the expert's experience, he noticed a difference between the elderly in the Netherlands and the elderly in Malaysia. The Dutch Elderly generally have more experience with technology and are more inclined to use it than the elderly in Malaysia. This is why it is crucial that the game is intuitive and easy to navigate. Continuing on this, the expert also agreed that the buttons are placed in logical locations, which also makes the game easy to navigate. Furthermore, he does not think that any elements in the game are distracting or confusing and agrees that there should not be a time limit for this game. If there were a time limit, the game would be training cognitive functions, which is not the aim when it is designed for people with AD. Because of these reasons, the expert believes this game is excellent for people with mild-to-moderate AD.

5.4.3 Game design and functionality: The difficulty level of the game is good, according to the expert. He agrees that it is adaptable to personal preferences and that it is easy to play, which is a good thing because it should be doable for people with AD. He also mentioned that it would be good to differentiate between animals to keep the game interesting, but not to make it any more difficult because then the people with AD might lose interest in the game. Additionally, he highlighted that it is important to keep the difficulty level steady throughout the game and not increase it at every level. The reason for this is that the game should aim to keep stimulating and minimise deterioration in cognitive functions, and not try to improve cognitive functions.

The expert certainly agrees that the game is cognitively stimulating because in the second and third levels, the user has to spend more time observing the picture to find the correct animal. This is definitely cognitively stimulating.

5.4.4 User experience and enjoyment: The expert enjoyed playing the game from start to finish and would play the game again in the future. If the game is played individually, he does not have a specific suggestion to make it more enjoyable. However, if the game is played in a group setting, he suggested it would be nice to implement some questions in between to encourage social interaction. For example, he suggested asking whether the users have been to a zoo, which would encourage them to talk together about their experiences.

Overall, the expert is very pleased with the prototype and sees great potential for it to be used as a cognitively stimulating game for people with AD.

6 DISCUSSION

The results of the literature search and selection process revealed a wide range of interactive game technology. During this process, 17 papers were selected that provide relevant insights into the currently existing interactive game technology aimed at cognitive stimulation for elderly and people with AD. With these papers, the first sub-research question could be answered.

The literature showed the four most important categories of technology. The first category involves mobile games designed for smartphones and tablets. These games show lots of potential due to their wide accessibility. However, challenges arise too since many elderly users are unfamiliar with touchscreen and user interfaces. The second category involves Virtual and Augmented Reality games. This type of technology also holds great potential since it poses possibilities for the elderly and people with AD to engage in sports and art creation without the need for certain motor skills. Unfortunately, this type of technology also presents difficulties. For example, adaptability to personal preferences and cyber-sickness. The third category involves the somatosensory games. These games show great promise for the physical, cognitive and mental well-being of people with dementia and AD. However, despite their potential, there has not been much research done on this topic. Finally, the last category involves interactive table games. These games have proven to be successful in the cognitive stimulation of people with dementia and AD, due to their adaptability to personal preferences and abilities, and their use in many care facilities.

After having explored the different types of technology for cognitively stimulating games, the second sub-research question could be answered. Eight papers were chosen from which a total of 73 guidelines were extracted. These guidelines were divided into four main categories: instructions and guidance, user interface and accessibility, game design and functionality, and user experience and enjoyment. These proposed guidelines provide some guidance while developing new cognitively stimulating, interactive games for the elderly with AD.

Combining the insights obtained from the literature phase and the extraction of guidelines forms an in-depth basis for answering the main research question of how interactive games can be designed to stimulate cognitive functions in individuals with AD.

7 CONCLUSION

In conclusion, this research investigated interactive, cognitively stimulating game technology for people with Alzheimer's Disease (AD). Dementia and AD, affecting millions of people globally, are the biggest cause of disability in elderly people. Without a cure, it is crucial to explore the possible treatment interventions. One of the currently available non-pharmacological treatment options is cognitive stimulation through interactive games.This research analysed the existing types of interactive game technology and proposed a set of guidelines for designing new interactive games aimed at stimulating cognitive functions in elderly with AD. To assess the efficacy of these proposed guidelines, a low-fidelity prototype for an interactive table game was designed. This prototype was then evaluated by an expert in the field of dementia and AD. According to the expert, the prototype shows great potential to be used as a cognitively stimulating game for people with AD.

7.1 Limitations

While this research aimed to provide some valuable insights, there are also some limitations to be acknowledged. Due to the short duration of this research, it was not possible to include all relevant literature on this topic. This means that this research only contains a selection of the available information and may miss relevant literature. Furthermore, there is a possibility that not all relevant guidelines are present in this research.

Due to time constraints, it was only possible to interview one expert in the field of dementia and AD. Although the insights he provided are valuable, it is crucial to interview more experts in this field to gain extensive validation into the practicality and effectiveness of the prototype.

7.2 Future work

While this research has provided valuable insights into designing interactive games for the cognitive stimulation of individuals with AD, there exist opportunities for further research. One of these opportunities is to interview more experts in the field of dementia and AD to obtain a more in-depth validation of the effectiveness of the prototype. This also leads to the option of improving the prototype accordingly and performing user tests on people with AD. These future initiatives show great potential to deepen this research and expand the knowledge of how interactive games can positively impact the physical, cognitive and mental well-being of people with Alzheimer's Disease.

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A GUIDELINES

Category	Prototype adherence	Guideline
Instructions and guidance		
Feedback and error correction	Yes Yes Yes Yes Yes Yes	● Provide the option to correct errors [11,30] ● Place confirmations whenever possible [9] ● Provide continuous feedback [9, 31] ● Minimise errors [9] ● Keep feedback neutral to positive [11] ● Recap the action that the person just executed [11]
Instructions and assistance	Yes No Yes No Yes No Yes -	● Put instructions on every page [9] ● Have a step by step wizard for complex tasks [9] ● Ensure on screen help is available [9] ● Provide an example round [11] ● Use clues [11] ● Show how many questions/tasks are left [11] ● Instructions should be kept brief and concise [31] ● Let a caregiver give instructions on how to use the technical equipment [31]
User interface and accessibility		
Interface design	Yes Yes Yes Yes Yes No Yes Yes Yes Yes - - No No No	● One key is for one function and one page is for one task [9, 31] ● Avoid scroll bars and typing [8, 9] ● Don't do drop down menus [9] ● Use a proper size of interface components [9] ● Keep the operation area in the centre of the page [9, 31] ● Reduce the items on the working page to 2-5 [9] ● Visual clutter and decorative fonts or background should be avoided [30,31] ● Highlight relevant information and minimise irrelevant and potentially distracting information [30] ● The placement and style of computer commands and navigation buttons should be consistent [30] ● Frequent and important actions should be readily visible and accessible [30] ● Put volume controls in an easy to find spot [7] ● Put application buttons and taskbar not too close together since accurate touches are hard enough as it is [10] ● Utilise haptic response when navigating or pressing buttons [7] ● Provide a "pause" button [11] ● Use a navigation bar or menu [9]
Accessibility	Yes Yes Yes	● To keep cognitive requirements to a minimum and to foster intuitive use, gesture control is preferred over remote control input devices and PC keyboard and mouse [31] ● Make sure people with different backgrounds, abilities, etc. can make use of the application [11] ● It is recommended that motor games should be designed in a way that they could be performed while standing or seated in order to include individuals that get easily physically fatigued or show balance problems [31]
Visual and auditory	Yes -	● For buttons, feedback should be visible within 50 milliseconds [9] ● For actions that take 1-2 seconds, use an hourglass icon. When it takes longer, use a message and animated progress bar [9]

elements	Yes Yes No Yes Yes No - - - -	● Use high contrast on screen and in print, so white text on a black background. Also use colours in the long-wavelength of the spectrum, so warm colours. [9,30,31] ● Important information should be large (at least 12) and in the central visual field. Uppercase is for highlighting key material but can be tiring if it is used for large pieces of text [30] ● Use voice output software to read texts aloud [30] ● Be consistent with brightness and volume [29,7] ● Pop-ups allocated to a specific part of the screen so they are not overwhelming [7] ● Use sounds but be aware that it may confuse patients [10, 11] ● Sound signals should be at least 60dB with adjustable volumes [30] ● For announcements, a male voice (in the range of 500-2000 Hz) is preferred over a high female voice [30] ● Auditory signals can be reinforced by other sensory channels, like vibrations or flashing lights. [30] ● Verbal information should have a predictable linguistic pattern with expected pauses at grammatical boundaries. A slower pace is preferred and the tone and pace should be respectful, not robotic or synthesised [30]
Text and graphic presentation	Yes Yes Yes Yes No	● Maximise readability by making the text big, but not too big to have a scroll bar [8] ● Use icons with text description [9] ● Present text in the simplest way (size, font), so no fancy text. ● Use short sentences [30] ● Let the text and graphics be adjustable in size [30]
Game design and functionality		
Difficulty	Yes Yes Yes Yes Yes	● Involve challenge, but don't make it too difficult [11] ● Reduce the need for memory of past actions [11] ● Avoid complex scoring [11] ● Keep cognitive requirements to a minimum, and adjust difficulty levels depending on the player's current cognitive and physical condition [31] ● Use different levels and difficulties [9]
Game mechanics	Yes - Yes Yes - No Yes No Yes	● Avoid complex interactions [9] ● Support synonyms in word games [11] ● Make things work the way they work in real life [11] ● Procedures should consist of simple, discrete steps [30] ● Games should be played from a first person perspective to prevent confusion with avatars [31] ● High recoverability: provide an undo function [9] ● Minimise the number of steps, and offer a "back" button [11] ● Games should not rely on prior steps being correct [11] ● The input should support the natural movements to execute game tasks [31]
Repetition and personalisation	Yes Yes Yes	● Consider repetition [11] ● Include a variety of content that pertains to different interests [11] ● Game content should be personalised and match personal interests and previous hobbies or activities to create a fun atmosphere [9,31]
User experience and enjoyment		
Engagement	Yes Yes	● The game should ensure the possibility of early success to foster motivation and prevent frustration [31] ● The game will probably used for longer period of time, so it has to stay interesting [9]

	No Yes	● Don't put the focus on challenges associated with dementia [11] ● Use dementia friendly questions [11]
Social interaction and competition	No Yes	● Use games that encourage collaboration between people [11] ● A summary screen showing scores, errors or time is recommended to foster competition and social interaction [31]

B PROTOTYPE SCREENSHOTS

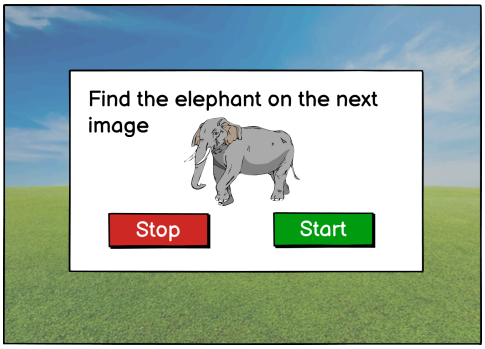

Fig. 6. Level 1 instruction

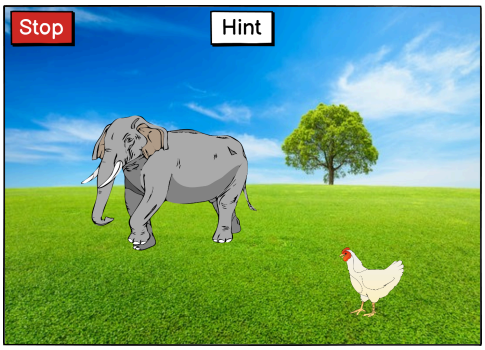

Fig. 7 Level 1

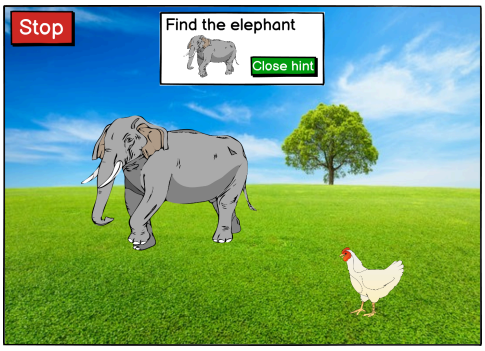

Fig. 8. Level 1 with hint

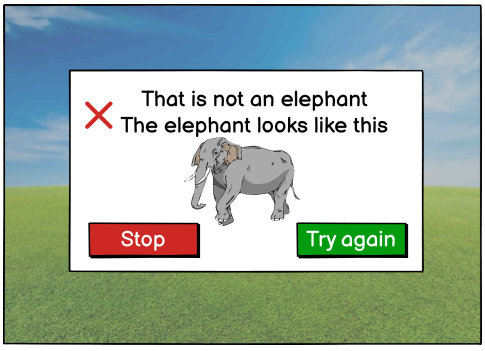

Fig. 9. Level 1 wrong animal

Fig. 10. Level 1 right animal

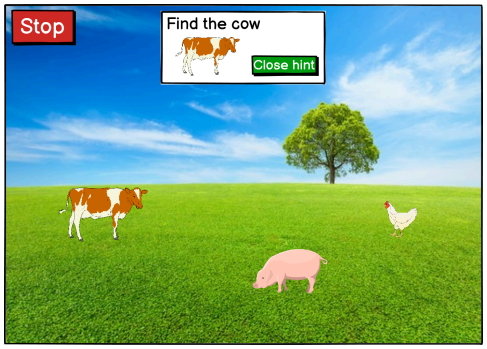

Fig. 11. Level 2 with hint

Fig. 12. End of the game

C INTERVIEW QUESTIONS

Game Design and Functionality

- How do you feel about the difficulty level of the game?
- Do you think it is important to be able to change the difficulty level?
- Do you think the prototype adapts to personal preferences?
- Would you say this game is cognitively stimulating?

User Interface and Accessibility

- Was it easy to navigate through the game?
- Are the buttons placed in logical places?
- Are there any elements that you find distracting or confusing?
- Do you think someone with moderate Alzheimer's could use the game easily?

Instructions and Guidance

- Were the instructions in the game clear and easy to follow?
- Did you ever feel unsure about what to do next?
- Do you think the messages you received during the game are helpful?

User Experience and Enjoyment

- Did you enjoy playing the game from start to finish?
- How likely are you to play this game again in the future?
- Is there any suggestion to make the game more enjoyable?