DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics

# Emotion-driven Card Game Design for Cognitive Training of the Elderly

Maximilian Stark

DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics

# Emotion-driven Card Game Design for Cognitive Training of the Elderly

# Emotion-basiertes Kartenspiel-Design für kognitives Training von Senioren



| | |
|---|---|
| Author: | Maximilian Stark |
| Supervisor: | Prof. Gudrun Klinker |
| Advisor: | Christian Eichhorn, M.Sc. |
| Submission Date: | 15.08.2019 |

I confirm that this bachelor's thesis in informatics is my own work and I have documented all sources and material used.

Munich, 15.08.2019 Maximilian Stark

# Acknowledgments

I am highly indebted to Prof. Klinker for her openness and for forwarding my project ideas to her scientific staff. I would also like to express my gratitude to my advisor Christian Eichhorn for his guidance and helpful comments as well as the building materials for the physical prototype. He helped me greatly with setting goals and staying on the right path for this bachelor's thesis. Furthermore, I'd like to thank Pierre Suchacek for managing and hosting the two evaluations at the nursing home. Having someone with experience treating Alzheimer's patients properly and with due respect helped the evaluation rounds to be as successful and smooth as they were. Many thanks as well to the Tertianum Premium Residenz München and their care manager Matthias Schiertz who helped us find appropriate times and settings to perform the evaluations. Without the ability to assess the software's performance with the target audience, this project would not have been as insightful.

# Abstract

With increasingly aging societies in the western countries, an ever-growing prevalence of dementia and its most common subset, Alzheimer's disease, can be observed. As this neurodegenerative disease is still incurable, its destructive effects can only be slowed down. One promising approach to this end is the application of serious games. These digital applications help elders train their cognitive abilities in a pleasant environment to mitigate the decline caused by the natural aging process and dementia. In this thesis, a serious card game is designed and implemented, with special attention paid to emotional factors for increasing intrinsic motivation and encouraging prolonged play. In order to assess the influence of different interaction schemes, a comparison between a touch-based digital and a physical tactile game-mode will be drawn. Social aspects will be explored by using a shared-screen multi-player mode. In an evaluation at a senior citizen nursing home using a custom questionnaire, the qualities of the aforementioned modes are assessed. Results suggest higher potential in a purely digital approach with many quality-decreasing factors in the physical alternative, due to the degraded motor control and precision of the target group. The importance of large dedicated user interfaces is validated as input errors are the predominant issue in the shared-screen approach. Emotional factors such as reminiscence and scene familiarity prove to be a helpful tool to engage the elderly.

# Contents

# 1 Introduction

"Go directly to Jail. Do not pass GO, do not collect $200." - Almost everybody knows this phrase, as it comes from one of the most successful board games in the world: Monopoly. The goal in the popular gaming classic is to build up a real estate empire, maximizing one's profits and ruthlessly driving the opponents to bankruptcy. It speaks for itself that the game has been sold in over 100 countries and spawned dozens of special editions (Doepker & Terrel, 2009). Apart from Monopoly there are several other popular community games like Ludo and UNO. After all, playing games is one of the earliest forms of entertainment and cognitive competition for mankind. Ancient games like Go or Backgammon date back thousands of years and are still actively played today, even at the scale of world championships (Fairbairn, 1995; Wilkinson, 1943).

In the modern age with the invention of the computer, new possibilities for games enabled vast market growth and popularity. Using screens and user interfaces instead of playing boards enabled new forms of presentation, modes of interaction (like mouse and keyboard or touch controls), and of course game-play design. Today, the video game industry has advanced to be the biggest entertainment industry with over $130bn total market value in 2018, surpassing the movie and music industries combined (Newzoo, 2018). Almost half of this market value stems from the mobile sector, with an average of over 1,000 new mobile games being released every single day (42matters, 2018).

However, most video games are targeting a very specific user group: young adults (Ledbury, Woolhead, Thomas, Carpenter, & Stott, 2017). There are economic factors behind this, as developing the game for a single type of user with clearly identified needs and properties shaves off development time and costs for adding customization functionality. This demographic also shows a higher interest and time-commitment to playing games (Bitkom Research, 2018). Therefore, it can be observed that the popular types of games are flashy and fast-paced, and their user interfaces are oftentimes colorful and complex.

But gaming is not all about entertainment as the primary incentive. The field of serious games focuses on utilizing the fun and entertaining aspects of gaming to convey a serious message or serve as a means of education or training (Zyda, 2005), like flight simulators, for example. While not as commercially booming as pure entertainment games, it still is a well-established market with several niche audiences (Sonawane, 2017). Greatly profiting from training in the form of such applications is the demographic of senior citizens and dementia patients. Declines in cognitive abilities due to aging and forms of dementia like Alzheimer's disease can be slowed down in this playful environment by tailoring challenges to this user group (Robert et al., 2014).

A big advantage of the digital game design over regular board games is the aspect of adaptiveness and configuration. This in turn can be utilized to change game rules, opponent behavior and interface design to suit the individual needs of the respective player. Consequentially, the training component of this gaming activity is enhanced as the system can account for the potential cognitive or stimulus-related deficits a player might face and provide assistance where needed. Common examples are adjusting for color blindness or increasing contrast to help with depth perception and object recognition. Additional measures include generally increasing the size of interactive objects, especially in the context of touch-based interaction to improve accuracy and accessibility.

As with the earlier example of Monopoly, board games can easily become very complex, especially when playing together in a group. Oftentimes the manual will be consulted multiple times over the course of a playing session, even more so when not having played for a while. In order to remove this from the gaming experience to improve flow, the feeling of being fully immersed in the activity at the right balance of difficulty and personal skill, serious games should feature simple and intuitive rules. Moreover, offering assistance by adding visual aids or guidance communication via text or audio instructions is crucial, especially for players who are struggling with the rather simplified rules of a serious game, which most certainly applies to applications for dementia patients.

Playing alone or as a group makes a big difference for the subjective qualities of playing as well. On the one hand some players might prefer honing their skills in a fully controlled environment and thus choose to play alone, for instance against an artificial intelligence (AI) agent. The advantage of that is not having to schedule common times for playing together and being able to play at any time and for any amount of time. Additionally, playing alone is arguably more efficient as rounds tend to be shorter since the AI opponent executes actions immediately.

Many casual or infrequent players on the other hand enjoy playing in a group more since the group dynamics of leadership and cooperation often bring the skill levels closer together and enable symbiotic play by implicitly assigning member roles. Support can then not only come through the game assistance system but also by other players helping one another. Since most board or card games are of competitive nature however, playing in a group can bring along increased levels of pressure and ambition. Easing those tensions through the game design and rule framework is necessary to make the players feel comfortable and have the game be a fun activity with the benefit of serious game elements.

While the digital adaptation of board games proves to be quite difficult as the digital screen size limits available board space and multi-player interactivity (Henkelmann, 2019), card games offer a great alternative. Since no board is needed and the only interactive game elements are the playing cards, the game rules are often the only thing that proves difficult for serious game adaption. Popular card games like *Schafkopfen* or

*Skat* have many complicated and intertwined rules that are difficult to master. Therefore a game with an originally small and easy rule-set should be utilized with the possibility of lowering that difficulty even further.

Unlike young users focusing on clear objective benefits and traits of a system when considering its usefulness, elders are generally more concerned with subjective qualities an application or device might offer (Ijsselsteijn, Nap, de Kort, & Poels, 2007), even if advertised as being beneficial to their cognitive abilities. This approach goes hand in hand with facilitating a familiar environment within the game world, so as to create a scene known by the users from experience. Moreover, utilizing reminiscence is a strong tool for achieving both emotional attachment and increased personal performance, as memories are brought to the conscious mind and flow increases due to parallels to remembered activities.

Reminiscence and scene familiarity can be further employed using tactile elements like "smart" playing cards, in principle going slightly back towards the original physical card game. For most elders, using motor control is more intuitive than touch-screen interaction, therefore increased ease of use should be observed as well. Bringing together the best of both worlds for this application, the physical, smart playing cards play tandem with the digital device offering assistance and guiding the player through their turns. An additional emotional element can then be provided on top of that by using the device display.

In this thesis, a serious card game for cognitive training of the elderly is designed and implemented, following state of the art design guidelines and strategies. The latter of which are outlines as related work, along with the characteristics and traits of the target group and the difficulties elders with dementia are facing. For a comparison of the effectiveness and emotional effects of different input modalities, two different input schemes will be developed: one purely digital on the touch-based handheld device, and the other one using physical game elements in the form of smart playing cards accompanying the digital display. Intermediate feedback after a first test and the results of the game's evaluation in a real nursing home scenario using a questionnaire are presented. Insights gained and the shortcomings of the implementation will be discussed, closely analyzing the up- and downsides of the two major game-modes. Ideas of future work point towards aspects that can be improved or added on top of both designs, as the project practically consists of two separate approaches that can each be developed in more detail.

# 2 Related work

There already have been several studies conducted and games designed in the field of cognitive training for senior citizens and dementia patients. After first getting familiar with the target audience, their characteristics and the issues they face, guidelines and game design rules to suit this particular user group will be elaborated on, along with related serious games and cognitive assessment methods. Various opportunities to induce motivation will be discussed with the focus on emotional and social aspects. Lastly, the fusion of physical and digital game elements will be highlighted, as the familiarity and tactile aspects could potentially increase a game's acceptability with the elder demographic drastically.

## 2.1 The effects of aging and dementia

The senior demographic encompasses people starting at about 65 years of age. In the coming years this group will grow drastically, as the sizable generation of "Baby Boomers", people born in the years between 1946 and 1964, goes into retirement (Light, 1988). By 2020, 25% of the European population will be considered Elderly (Ijsselsteijn et al., 2007).

The natural process of aging brings along with it certain declines in various abilities. Vision for one, is most likely to worsen over time. Common is the condition of Presbyopia, the inability to focus clearly on close objects due to loss of the eye's accommodative amplitude (Glasser & Campbell, 1998), which is detrimental to playing a handheld game in close proximity. Another typical aspect of vision degradation is the loss of depth perception and color sensitivity, as well as increased difficulty of adjusting to glare or darker environments.

The hearing abilities are also affected negatively by aging. A general decline in auditory acuity is common, specifically pure tones and high frequency tones become hard to recognize. Similarly, synthetic speech or high pitched sounds are difficult to understand for seniors. (Ijsselsteijn et al., 2007). Additionally, reaction times, general motor skills and the precision of voluntary movements worsen with age. The range of motion becomes ever more constrained and exhaustion is reached faster.

Most important for a game about cognitive training of course are the cognitive abilities. Typical age-related declines in cognition include attention processes, working memory and problem solving. The game's design therefore has to account for these shortcomings by being manageable and intuitive as well as always offering an overview and keeping the cognitive load at a comfortable level.

Even more significant negative effects however, occur due to the syndrome of dementia. Dementia is an umbrella term for neurodegenerative diseases that cause irreversible loss of cognitive functions and eventually lead to death. The estimated prevalence of dementia in the elderly is five to eight percent with the most common form being Alzheimer's disease (AD) in about 60-70% of cases. As it gradually deteriorates memory and abilities required for everyday living, dementia is one of the predominant causes of elderly disability and the need for assistance and nursing.

The course of the disease can be separated into three stages. In the early stages its symptoms are mild forgetfulness and losing orientation or track of the time. As the decline progresses, loss of cognitive functions becomes more noticeable for others: forgetting names, becoming lost at home, starting to need assistance in daily activities. In the final stage dementia patients become fully dependent on others. Common symptoms include loss of physical and language abilities, as well as the recognition of relatives. Emotional changes and an increase in aggression are also typical. Since it is an irreversible disease, current treatment is only able to slow down the progression using various cognitively stimulating activities (World Health Organization, 2019). Moreover, Coppola, Kowtko, Yamagata, and Joyce (2013) highlight the effect of "Sundowning" in dementia, wherein the behavior and cognitive abilities of affected patients worsen as the sun sets. Patients exert greater confusion and even increased aggressiveness towards family members and care personnel.

The various age-related declines in motivation, physical performance and perception, as well as cognitive impairments caused by AD are well researched and documented (Eichhorn et al., 2019; National Institute of Aging, 2016; Vasconcelos, Silva, Caseiro, Nunes, & Teixeira, 2012). For instance, Lapointe, Bouchard, Bouchard, Potvin, and Bouzouane (2012) categorize the symptoms of Alzheimer's into six major groups: Memory impairments, Deficits in executive functions, Aphasia (language disorders), Agnosia (disorder of recognition by sensory input), Apraxia (movement disorder) and Sensory problems. For each of these groups, different design choices have to be made in order to account for their respective shortcomings in regards to sensory input in the form of visual or auditory cues. Playback of spoken instructions for example is not suited to patients suffering from Comprehensive aphasia, whereas bright visual indicators are a bad choice for players with severe sensory problems.

The most detrimental factor overall though is cognitive complexity and the issues that arise from it. Due to the users' unfamiliarity with the digital medium, the baseline complexity for serious video games is higher than that of a board game.

The complexity of an interactive application can be formally analyzed using the Cognitive Complexity Theory by Kieras and Polson (1985), which quantifies user understanding about the system's usage so that cognitive load and the amount of required knowledge for use may be determined. Furthermore, it has been found that reducing the usage complexity of tasks brings cognitively impaired users up to par with young adults in task performance due to the implicit learning ability not being affected by aging-related declines (Holzinger, Searle, & Nischelwitzer, 2007).

## 2.2 Game design for the elderly and dementia patients

Various guidelines for game-play, user interface, and assistance component design of video games tuned to the needs of elderly and dementia patients have been established by Bouchard, Imbeault, Bouzouane, and Menelas (2012). They advise keeping the player in the "flow" zone, a psychological state of high concentration and full focus leading to absorption into the activity and great fulfillment (Csikszentmihalyi, 1975). In games, this state is achieved by immersive game-play and finding a balance between level of challenge and player abilities (Cowley, Charles, Black, & Hickey, 2008).

For their study in the field of Activities of Daily Living (ADL), Bouchard et al. (2012) built a cooking process planning game that has the player prepare meals with increasing difficulty. The authors recommend employing artificial intelligence for user-profile building and dynamic difficulty adjustments (DDA) using a HMM (Hidden Markov Model). This has inarguable benefits over statically preselected difficulty settings because in the more casual context of a serious game, the player might not fit into the predetermined difficulty settings and also the selection occurs before any game-play, so an initial choice can be overwhelming. Additionally, maintaining the flow state becomes easier as the level of challenge is tweaked over the course of the playing session. Their in-game evaluation of cognitive abilities is based on the Naturalistic Action Test (Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002), from which they conclude the guideline of limiting challenge steps to eight to twelve steps. They couple this with the Elo rating system (Elo, 1978), which was originally used for chess but is also popular in competitive video games (Blizzard Entertainment, 2016), to quantify the player performance. Thus the game is able to adapt to the individual player in terms of both game difficulty and guidance.

"Ecological interactions", interaction gestures mimicking real-life, and simple but concise high contrast visuals enhance the approachability of the game. The former drastically reduce the learning time due to their intuitive nature whereas the latter help players with visual troubles and aid in depth perception. Employing assistance and attention prompts using a combination of various approaches (acoustic, vibrotactile, visual) according to the respective user-profile covers individual patients' shortcomings in particular sensory aspects.

For their rhythm game targeted at elderly users, Park (2009) developed an AI driven self-adapting user interface in terms of feedback modalities and difficulty setting. The authors conceived a custom built game controller analogous to the real life equivalent of a wooden drumstick to play the drums the game features. This leverages familiarity and accessibility, as this element is traditional and well-known with the target audience of Korean elders.

Eichhorn et al. (2019) suggest using a "2 - or 3 for any" design approach instead of the commonly used "1 solution fits all" approach to address the differences in usability and design demands of various user groups. In order to achieve positive behavior change through the medium of serious games, self-monitoring and goal-setting are very successful design concepts. The wanted outcomes of a serious game for behavioral change are defined as reinforcement, change and pattern-shaping.

Taking the multi-design approach one step further, Foukarakis, Leonidis, Adami, Antona, and Stephanidis (2011) developed an adaptive user interface infrastructure for their poker game tailored to the senior demographic. Tied to user profile building and player analysis, components and the general look of the whole interface can be changed by the system itself to adapt itself to the current user. This includes different interactive element sizes, colors and shapes, to address motor impairments or color blindness. Depending on familiarity with the game the interface also redacts certain advanced features like a more granular betting selection. They furthermore offer different card designs, depending on user preference or familiarity. The authors built and integrated their Adaptive Widget Library into the NetBeans IDE to offer novice developers a fast and intuitive way to develop adaptive user interfaces that can be controlled by various adaptability parameters. As their game is a multi-player game, they facilitated online play with the adaptability service being a self-contained networked unit, talking to the various game clients and adapting them according to the user data collected. In their development they made use of iterative paper prototyping with expert evaluations.

Even predating the modern touch-based control scheme, it has been observed that elders with impaired vision are able to play drag-and-drop based card games on a small screen using a stylus (Leonard, Jacko, & Pizzimenti, 2005). However, as the elderly are generally not very experienced users of touch technology, the ease of use for these devices in this audience has to be examined.

Motti, Vigouroux, and Gorce (2015) compared the performance of novice versus experienced senior users at drag-and-drop tasks in a puzzle game. They measured mean time of movement and accuracy to evaluate ease of use on both a small smartphone and a larger tablet device. According to the authors, drag-and-drop is preferred by the elderly over tapping due to its more intuitive usage, despite slower execution times. Results showed that novice users spent significantly more time executing the tasks and that accuracy did not change significantly with bigger screen size, only for already experienced users. Highest precision was achieved when using a stylus instead of finger tips.

Similarly, the study conducted by Kobayashi et al. (2011) suggests that elderly users prefer drag and pinch gestures over tapping, despite being less accurate in those actions, even after some time to practice. The participants often were confused when a single application featured several similarly behaving modes (like different keyboard layouts) without an explicit textual label of the current mode. Iconography is not suited to this demographic, as seen by the fact that the users struggled to find the Shift and Backspace key on the software keyboard, despite being familiar with a PC keyboard layout. Likewise, Coppola et al. (2013) observed users' difficulties with the touch technology in that the elderly would primarily use their fingernails to tap and also tend to drag across the screen, lowering accuracy and even invoking unwanted functions.

Andersen, Gudmundsson, Achiche, Boelskifte, et al. (2011) faced comparable problems while conducting their emotion-driven questionnaire survey with elderly users. Their evaluation scale, based on the Likert scale (Likert, 1932), featured pictograms of emotional facial expressions or common gestures indicating certain attitude. They observed many challenges when surveying the elderly. Shorter concentration spans, task and scale misinterpretation as well as perceived lack of benefit all contributed to the difficulty of questionnaire design. The survey was based on the fundamental emotions of the Product Measurement Instrument (PrEmo) that are commonly elicited by product appearance.

During the development process of their cognitive gaming platform, Vasconcelos et al. (2012) designed and evaluated their prototype with seniors at several stages and fidelity levels. This user-centered design is a valuable tool in designing applications where users are more hurt by poor game and interface design and would be repelled more easily from commercially available games. Mobility and direct input devices are key factors to enable physically impaired users to play the game and also reduce potential anxiety towards using the system. Games should incorporate a social component to connect elders more and keep the experience engaging. Playing together also enables some group dynamics, helping to overcome individual potential barriers or limits. To help elders keep track of their actions in the game and personal progress, instant feedback and immediate rewards should be facilitated. Rewards also offer the social component of being a topic of discussion and exchange.

The assistance system is a crucial component of serious games for dementia patients, as the disease causes the players to lose track of the objective or the state and rules of the game. Aside from the general rule of large font size and a minimum of used symbolic icons (Kobayashi et al., 2011), many games also combine the assistance prompts with a companion character. These are often either cute animals or friendly looking persons relevant to the game or its scenario, as shown in the selection offered to users by Oosterom-Calo and López (2016). According to their user feedback, none of the aforementioned types of avatars is preferred significantly, the preferences were highly subjective and varied. Furthermore it was found that the tone and manner of communication with the user should be worded in a formal and encouraging yet not patronizing way, as not to belittle the player's progress and achievements. Elders preferred being rewarded or congratulated for major successes and to just be shown an indication of completion for smaller sub-tasks.

Serious games can also serve as a "gamified" assessment method, where mental training is not the primary focus but instead the measurement of the user's current cognitive abilities as a way to estimate dementia progression or detect early symptoms. In their study, Tong, Chan, and Chignell (2017) built a game in the fashion of the arcade game "whack-a-mole". By measuring reaction times they were able to deduce cognitive abilities which were then compared to results obtained using the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975), a standardized form-based test. They found high correlation of both scores and furthermore observed that their game was closely related to the Stroop task, another psychological tool to evaluate inhibitory executive function, where performance of reading a color's name written in a different font color is measured (Stroop, 1935). Performance in this task degrades with age, as it correlated with loss of white matter in the brain.

## 2.3 Intrinsic and extrinsic factors for motivation

"Motivation is essential for learning." (Holzinger et al., 2007, p. 925), therefore achieving prolonged motivation is essential for the positive effects on cognitive health using serious games and also maintaining flow. But as found by Ijsselsteijn et al. (2007), senior citizens often don't see any real benefits in playing those games, which even outweighs their reservations about the technology in general. Elders are furthermore often characterized as reluctant to use modern technology, partly due to insecurities and also because of their fear of damaging the device caused by their inexperience (Chen, 2013; Holzinger et al., 2007). Players therefore have to be motivated by the game design to start and keep playing while feeling secure and joyous throughout. Usability plays a fundamental role in that effort. Since most elders can be considered novice users of modern technology, usage can be difficult and unintuitive for them, leading to a lack of motivation. To mitigate this, Holzinger, Searle, Kleinberger, Seffah, and Javahery (2008) propose three levels of encouragement through design: adapting the game to the end user's physical impairments, leveraging the elders' partial familiarity with the technology to overcome hesitancy and presenting a subjective benefit while keeping a fun vs. learning ratio appreciable by the players. During their investigation of usability metrics, the authors formulate an extension to the standard QUIM usability model: *acceptability*. This factor captures subjective concerns and anxieties users might experience interacting with technology, like safety, discretion and trustworthiness. Maximizing acceptability during serious game design can be achieved by employing user-centered development. Hirsch et al. (2000) state that usability only clarifies *that* users can use a product, whereas the emotional, social and environmental factors decide *whether* a product will be used by the elderly, and that this is often overlooked.

Eichhorn et al. (2019) summarize the key influences for motivation with the four elements *Connection*, *Emotional*, *Social* and *Goals*. *Connection* can be interpreted as a tether to both memory and the outside world, by still recalling their own past and having social relationships. Together with the *Emotional* component it is considered *intrinsic*, meaning originating from within the person, whereas the aspects of *Social* and *Goals* are defined as *extrinsic*, coming from the outside environment. Since reaching *Goals* can be driven by emotions and resolve, and *Connections* are quite often of *Social* form, *intrinsic* and *extrinsic* elements are closely intertwined. Similarly, West et al. (2012) define motivation using the three components *predisposing factors*, *reinforcing factors* and *enabling factors*. While rewards can serve as reinforcing factors in an extrinsic manner (*Goals*), serious games focus primarily on utilizing enabling factors like emotions to transform the point of view of "playing the game *to get* a reward" to "playing the game, because playing *is* the reward", drawing parallels to the definition of flow by Csikszentmihalyi (1975). Adjusting the game design to fit the user's predisposing factors also covers the first level of motivation through design established by Holzinger et al. (2008).

Eichhorn et al. (2018) also conclude that elders are best reached by emotional concepts and therefore intrinsic change, due to their attitude of "try[ing] to see the world more positive[ly]" (Eichhorn et al., 2018, p. 8).

In order to convey an emotional message and build intrinsic motivation, the introduction of a virtual agent or companion is deemed useful. The design, presentation and behavior of such companions is a field of study on its own due to the multitude of factors to be incorporated, such as visual appearance, text modalities and facial expressions. Communicating emotions "felt" by the virtual agent is especially challenging, since the interpretation of faces is highly subjective and varies with cultural differences (Yu, in press). In an attempt to mitigate this, Ortiz et al. (2007) designed the facial expressions of their virtual companion based on the model of six basic emotions of anger, fear, disgust, surprise, sadness and joy by Ekman, Friesen, and Ellsworth (1972). In their evaluation with seniors and dementia patients, Ortiz et al. (2007) observed that the emotions anger, fear and disgust could not be recognized by the participants. It was also noted that despite increasing likability and enjoyment, the avatar was distracting to some extent, which made following the tutorial instructions somewhat more challenging. Overall, elders don't seem to have a clear favorite regarding visual appearance, but professional, yet emphatic looking characters fitting the application context, or on the other hand cute animals are generally preferred, according to the user feedback received by Oosterom-Calo and López (2016), when evaluating the avatar-assisted tutorial sequence for their health management application. Another great way of stimulating intrinsic motivation is by enabling the players to be reminiscent of the past and reconnect with their memories. This can be accomplished by rewarding the players with soothing music from their youth or pretty pictures of scenery or familiar scenes, again showing the strong interconnectedness of extrinsic and intrinsic factors. In their Virtual Reality application, Castilla et al. (2013) implemented such systems, referring to them as *psychological tools*, where users could explore nature with all its relaxing sounds and imagery to induce positive emotions and well-being. Serious games in the field of Activities of Daily Living also take advantage of such scenarios by setting the game-play in an activity familiar to the audience which allows them to draw from experiences and memory, like in the cooking process planning game by Bouchard et al. (2012).

Nevertheless, the power of extrinsic factors and especially social interaction, are not to be underestimated. As elders are increasingly feeling isolated due to aging-related depression or their inability to physically maintain friendships (Chen, 2013), taking part in a community activity helps them regain *Connections* and also support each other during play. A study by Gajadhar, Nap, de Kort, and IJsselsteijn (2010) revealed that although elders might prefer single-player activities over scheduling meetings for co-op play for more independence, performance and flow are higher for local human versus human play than when playing against the computer. Online multi-player however is very detrimental to the elders' enjoyment of the activity, as they feel both less immersed and pressured by the more competitive environment. That elders aren't primarily driven by success in a competitive way has also been observed by Astell et al. (2016).

In their systematic review, Cota and Ishitani (2015) found that aside from games with elements from Activities of Daily Living like gardening or cooking, elders also enjoy games that they used to play when they were younger, notably card games and board games. This in turn utilizes reminiscence, as these digitized games could use assets to re-establish the look and feel of their analogue counterparts and therefore have a positive effect on the elders when remembering and recognizing. While assessing whether familiarity was a primary factor for enjoyment for the elderly, they found that even though players were less skilled in playing the rather challenging, yet familiar card game of Solitaire, they reported higher enjoyment than when playing the simpler yet unfamiliar game offered to them. In their evaluation on the feasibility of computer-based entertainment activities in nursing homes, Tak, Beck, and Hong (2013), found that elders with even moderate dementia still like to play cognitively challenging games such as Solitaire.

## 2.4 Mixing digital and physical game elements using RFID

In order to overcome elders' reservations about technology and to also help maintain their motor skills, combining digital and physical components is a promising approach. Radio-Frequency Identification (RFID) tags on interactive elements and handheld dedicated reader devices are useful tools to create such physical-digital applications. Most modern smartphones and tablets also come with a Near Field Communication (NFC) reader-writer, a high frequency subset of RFID that also allows bidirectional data transmission (IDATE DigiWorld, n.d.). Many studies use this technology merely for player identification, so that the game can save and load data collected about the player and also display information or content relevant to the current user (Kang, Choi, & Lee, 2016; Koivisto, Lindstedt, Merilampi, & Kiili, 2016).

Integrating the technology more thoroughly with the game-play, Römer and Domnitcheva (2002) equip regular playing cards with RFID tags for their smart playing card game. As a base, they use the card game Whist, which offers them useful properties for their digital component, like cheat detection and score keeping. As Whist is a game about playing cards out onto a heap, a big central RFID antenna was used to determine the cards played out on the table. Aside from their playing cards, every player carried a handheld device (PDA) informing the player about their moves' quality through a smile or frown emoticon. A community screen for score keeping and display of game state was also used. During play testing they discovered that users who were not quite familiar with the game rules used trial and error using the cheat detection to figure out how to play. Technical difficulties arose in the form of erroneous detection of hand cards kept too closely to the antenna range and with sudden disconnects of PDAs as players would move out of range. They therefore recommended developing software architectures for this application in an event driven manner so that the system could dynamically react to unforeseen events. Furthermore, usage of multiple short range or surface antennas is deemed advantageous over one long range antenna since detection range only needs to spread in the plane when playing on a table. To avoid shadowing of tags lying directly on top of each other, multiple randomly arranged tags should be placed on every card. This way the chance of transmission interference between multiple tags is decreased.

Floerkemeier and Mattern (2006) expand on the research done by Römer and Domnitcheva (2002) by using high frequency RFID tags specifically out of tune with the receiver so that upon stacking of cards they would resonate together bringing them down to the receiver's frequency. They also highlight the importance of the "smart" card game to maintain the key properties of the traditional card game. This includes ease of setup, low costs and high level of social interaction. For their game they built a simple table mat containing five antennas, at the four edges' centers for the player hand detection and one in the middle for the heap. A multiplexer coupled to a single RFID reader would then control which antenna would be polled at what game state, to initially read player hands and then during game-play keep track of the heap. Utilizing the players' readily available mobile phones supporting the Bluetooth technology, the game mat could communicate with the phones without the latter holding any game state, protecting from system confusion upon sudden disconnect. The phone screen would offer assistance to novice players and display game scores. Extensive user testing could verify the system's reliability and speed, taking just a split second to read physical game state and update the digital counterpart.

The former two studies belong to the field of Ubiquitous Computing (Weiser, 1991), where traditionally physical elements are enhanced with computer technology, providing assistance or adding new functionality while staying mostly unnoticed by the user in terms of usage.

A different approach to engage users in a physical-digital way, offers the technique of Tangible User Interfaces (Ishii & Ullmer, 1997). Here an originally purely digital game or application is made partly physical, for example by employing physical "smart" interface elements equipped with RFID tags. Häikiö et al. (2007) utilize this approach in their meal ordering service for home-dwelling elders. By touching the smart ordering menu with a NFC-enabled mobile phone, the seniors are able to choose and cancel food orders. Aside from intuitive use by just "pointing" at the preferred choice using the handheld device, simplicity and robustness are strengths of this application. The author noted however, that users who did not own a suitable mobile phone previously were reluctant to adopt the technology and still preferred the conventional way of food ordering of calling the provider by land line.

For cognitive rehabilitation and social engagement of Alzheimer patients, de la Guía, Lozano, and Penichet (2013) developed their serious game based on Tangible User Interface. They incorporated multiple input devices in a Distributed User Interface manner, combining touch screen devices, projector screens and smart materials equipped with RFID tags interacted with using a handheld reader. They therefore implemented the tapping metaphor using two approaches, by tapping on the touch screen and alternatively by bringing the reader close to the desired tag. The selection of tags featured everyday objects easily identified and also combined with a textual label. This form of interaction reduces cognitive load as no memorizing of complex input schemes or motor processes has to be employed, but instead just pointing or tapping. The authors present various advantages of the system including flexibility in both game content and space required, as well as intuitive collaborative use when assigning different roles to players.

Similarly de la Guía, Lozano, and Penichet (2014) developed a serious game for cognitive stimulation in the elderly by equipping everyday objects like coins or images with RFID tags. They conceived their game highlighting the four primary design components challenge, control, feedback and social interaction. One mini-game of their application is a word spelling application using physical letter cards that have to be scanned using the reader device in the correct order after the word to be spelled has only temporarily been displayed on the screen. The authors furthermore highlight the importance of complementing the player on successful interaction to make them feel confident, especially when dealing with this kind of novel technology. As with the other projects, this game too is built using a client-server architecture, having the main game systems run on the primary display with the reader device acting as a client communicating scan events.

## 2.5 Questionnaire design suited to the elder demographic

To formally assess the performance of the developed application, a questionnaire with questions regarding the subjective qualities of the serious game has to be designed. When trying to simplify existing scale systems like the Likert scale (Likert, 1932) to be more intuitive and associated with emotional opposites or common gestures, Andersen et al. (2011) faced difficulties as users where often unable to correctly interpret the scale or understand the task at hand. Even without the additions of iconography to the scale, which has shown to be not a successful communication tool for this audience (Kobayashi et al., 2011), participants of the study still were not sure on how to approach the scale. Evaluating their first session, Andersen et al. (2011) found misinterpretations of the free scale. Originally it allowed for arbitrary selection in the range between "no" (thumbs down) and "yes" (thumbs up), but it was reported that some participants saw the scale as rigid selection between three steps (left, middle, right) or even as only 2-steps for the extremes with some participants not even able to understand the given gesture iconography at all and not filling out the form. Furthermore, it was noted that survey segments could not continue over long periods of time as concentration problems arose after just a few minutes. The authors concluded that the offered introductory text consisting of 5 pages with large fonts was deemed overwhelming and the number of items should stay low.

For the qualitative assessment of their working memory game, Koivisto et al. (2016) gathered data both by observing users while playing and by conducting interviews. They handed out questionnaires to both nursing staff and participants of the study, with different items on each, asking for subjective qualities of their part of the system. Participants were asked to evaluate the playing device, effectiveness of the game, game feedback and clarity. Personnel members were asked questions regarding the feel and perceived effectiveness of serious games in the context of a rehabilitation process.

Additionally, they assessed the cognitive abilities of the participants using the standard Mini-Mental State Examination (MMSE) test before and after the study. The MMSE is a test featuring questions that should be easy to answer for people without cognitive impairments (Tombaugh & McIntyre, 1992), for instance asking forn f the current date, time or location. For measuring the cognitive abilities of their serious game participants, Tong et al. (2017) employed the MMSE as well.

IJsselsteijn, de Kort, and Poels (2013) specifically developed a questionnaire for assessing the subjective quality of a gaming experience, called the Game Experience Questionnaire (GEQ). Split into three modular components, the questionnaire measures the core game experience, psychological and social involvement with others and emotional state after finishing the play session. The core component includes seven components: Immersion, Flow, Competence, Positive and Negative Affect, Tension and Challenge - each of which features five items.

As question translation can have severe impacts on the effectiveness of items, a slight surplus of questions per section is available to be pruned after evaluation of a translation's performance. Each question in the GEQ uses a five point unidirectional verbal rating scale (Pospeschill, 2010), ranging from 0, "not at all", to 4, "extremely". Several spin-offs of the GEQ have been developed, for example the In-Game GEQ, a subset of items from the original test to be used while playing.

Similarly, in the context of the Eldergames Project, Gamberini et al. (2009) developed an extensive questionnaire with over 250 items to assess acceptability. The test is split into seven motivational areas: playability / immersion, challenge / skills, feedback, control, clear goals, concentration, and social interaction. They use a four point Likert scale, omitting the neutral option so every decision creates an either positive or negative bias (Lavrakas, 2008).

In their study on questionnaire design for the elderly, Jobe and Mingay (1990) found that senior citizens often struggle with interpreting questions that tend to be rather general or ambiguous. Furthermore, a common pattern was narrative answers as participants would elaborate their disposition instead of responding according to the categories offered for selection. The authors therefore conclude that transformation of those narrative answers into the appropriate survey category should be done by the interviewers. It was also discovered that when responding, the elderly tend to overestimate their own abilities or give an outdated answer. When asked how high above their head they could raise their arms, participants gave answers that clashed with their responses after thorough probing. Using further questions depending on the initial answer to a questionnaire item, the interviewers were able to detect various misinterpretations or misjudgments by the participants, as well as memory and functional problems.

# 3 Emotion-driven card game design

In this section, the game design and implementation process is documented. First the basic game rules will be introduced. Secondly the initial prototype implementation and the improvements made according to first evaluation feedback are presented. The design and structure of the assistance system are shown thereafter, along with the implementation of the multi-player mode. Next, the development of the mixed input game mode will be elaborated on. Lastly, the design of the questionnaire employed in the evaluation will be discussed

## 3.1 Rules of the underlying card game, *Thirty One*

The digital card game implemented in this thesis is based on the traditional card game *Thirty One*. The goal of the game is to collect 31 points, hence the name of the game. Each of the two to eight players gets dealt three cards and three extra cards are placed face up on the table as the "exchange". Players take turns either exchanging a single card with the middle or finishing the game, leading to a single last turn for all other players. In the original version of the game, there is another option for players on their turn: They can swap out all their three cards for the cards in the middle, which also ends the game. This mechanic was excluded for this implementation to remove complexity. Another component was removed right from the start, namely the obligation to immediately show one's cards once hitting 31 points with the round being over at that instant due to being stress-inducing and confusing.

At the end of the round a winner is determined by the highest combined card score, calculated as described in the following (McLeod, 1995). Before elaborating the score calculation however, the specific cards in play have to be touched on. To increase familiarity with the game elements for the elderly, instead of the globally popular French card deck, the local German card deck is used.

(a) French (b) German

Figure 3.1: Comparison of French and German card suits

The deck consists of 36 cards, ranging from the numerical values six to ten, followed by four next higher ranked cards, namely "(U)nter", "(O)ber", "(K)önig" and "(A)ss", the equivalents of the French cards "Jack", "Queen", "King" and "Ace".

As shown in Figure 3.1, the decks additionally differ in terms of suits. While the French deck features (from left to right, top to bottom) "Clubs", "Hearts", "Diamonds" and "Spades", the German deck has "Gras" (Grass), "Herz" (Heart), "Schellen" (Bells) and "Eichel" (Acorn).

In the context of *Thirty One*, every numerical card has the scoring value of its numerical value, meaning the card 8 has a scoring value of eight. "Ober", "Unter" and "König" are worth ten points each with only "Ass" scoring in at eleven points. To reach the maximum number of points one therefore needs two cards valued ten points and an "Ass". However, scores can only be combined when the respective cards are of the same suit.

Additionally, all combinations of "3-of-a-kind", meaning three cards with the same value or name but from different suits are scored higher than 30, but below the maximum of 31. In the event of competing "3-of-a-kinds" the higher valued cards beat lower values ones.

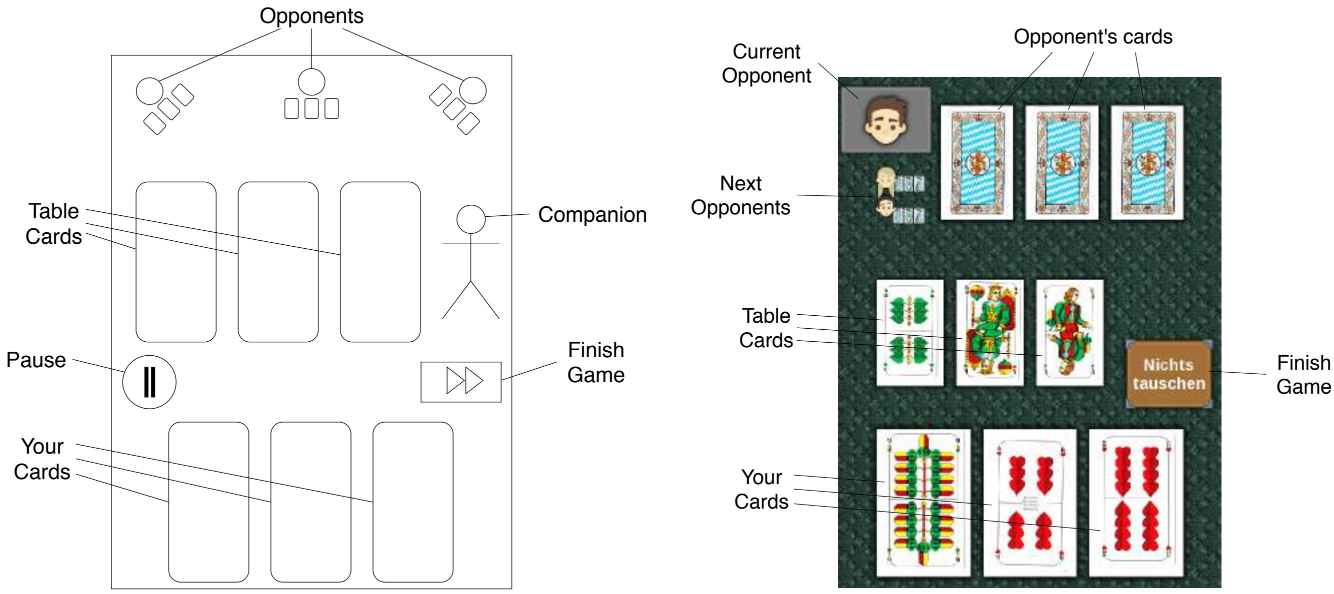
In summary, the highest regular hand could be 10, O, K. It would be beat by any "3-of-a-kind", for example 7, 7, 7, which would also lose to the maximum of 31 points, obtained by a combination like 10, K, A.

## 3.2 Design fundamentals and initial prototype

The game designed in this thesis, called *Einunddreißig-Plus* (ThirtyOne-Plus), is developed for Tablets running the Android platform and is written in Java. The cross-platform framework libGDX was used to develop on PC and deploy to Android effortlessly.


Figure 3.2: Application icon for ThirtyOne-Plus

The name picked for the application is a reference to both the underlying card game and the common way of addressing demographic groups using an age statement and a plus to encompass people at and above that age. That reference was chosen to hint at the goal of the game, to cognitively train elders, "lowering" their (mental) age. The application icon, shown in figure 3.2, depicts a simplified playing card with strong contrast and thick borders, hinting at the game's high degree of accessibility. The game's title is featured on the card in the aforementioned notation. The initial user interface design was done on paper (compare figure 3.3a) and followed several design guidelines. The visible screen was divided horizontally into three sections: the player's section, the table section and the opponent section. The player's section features their three current cards, the same for the table section. The opponent section initially featured a table-like arrangement where the opponents would sit in a circle around the table, to increase situation familiarity. In the actual implementation however, this has been changed to increase the size of the opponents' cards and their portrait while also better highlighting activity and the order of play (see figure 3.3b).




(a) Initial prototype

(b) Game implementation

Figure 3.3: From mock-up to actual interface

Furthermore, the concept of pausing, as indicated in the paper prototype, has been dropped completely from the implementation, because time-based difficulty is beyond the difficulty scope suitable to the target audience, which was also observed by Wittland, Brauner, and Ziefle (2015). The game has thus been made entirely turn based.

Following the recommendations of Kobayashi et al. (2011), no interactive element subceeds a side length of 1 cm. Since iconography is not a powerful tool for the senior demographic due to ambiguity or unfamiliarity, every button is labeled with large text which additionally increases target size.

As they are the most important game element, playing cards cover a big portion of the screen with the player's cards occupying a third of the total space. Large gaps between different interactive elements increase precision for touch controls as elderly users are less accurate when tapping and even less when dragging elements when compared to younger users.

To compensate for the various and well-known vision related declines both due to aging and Alzheimer's disease (Jones & van der Eerden, 2008), all interactive elements clearly separate themselves from the background by both high contrast and sharp edges as well as a drop shadow to aid in depth perception. Any change of game state is communicated by animation to not have the player guessing what's happening.

Successes in interaction (touching cards, moving cards, touching buttons) are visually communicated through color and size changes, along with a short vibrotactile feedback.

To execute the action of card swapping, the player has to press down on either their or the table's card they want to trade and then drag the card to the respective other card. After letting go of the card, an animation will show the exchange and return of the newly obtained card into the player's hand.

| **Game rule or property** | **Variability** |
|---|---|
| **Opponents** | |
| Number of opponents | • 1 - 4 AI opponents<br>• Multi-player: human opponent |
| Opponent strength | • Random action agent<br>• Decision tree and planning (not implemented) |
| **Cards in play** | |
| Number of suits | 1 - 4 |
| Type of cards | Portrait cards vs. number cards |
| Number of hand cards | 1 - 3 |

Table 3.4: The different adjustable difficulty settings

Despite being a card game with usually fixed rules and cards in play, for this serious game the rules had to be flexible and offer the possibility for various difficulty settings, in order to be playable at all stages of cognitive function. In the implementation, the number of cards in play and the strength and number of opponents can be configured (see Table 3.4). From this set of configurations two UI screens were built, one with slider control over each setting, and one with preselected difficulty settings in the form of levels. The initial presets of these settings can be seen in Table 3.5.

These modifications of course change the scoring of the game, as the original high score of 31 points can only be reached with three cards. In the stripped down versions

| Setting | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|
| no. of opponents | 1 | 1 | 1 | 2 | 4 |
| no. of suits | 1 | 2 | 4 | 4 | 4 |
| card types | portrait only | numbers only | all | all | all |
| no. of hand cards | 1 | 2 | 2 | 3 | 3 |

Table 3.5: The initial single-player difficulty level presets

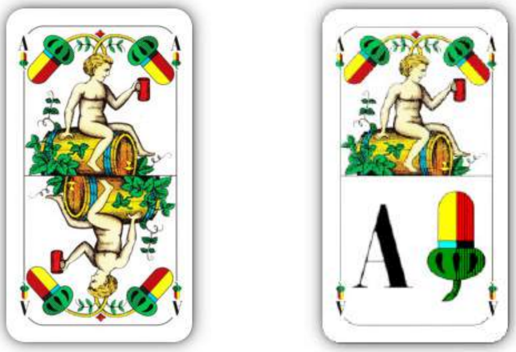
with just one or two cards, and possibly also from only one suit, the game just calculates the highest score in this smaller possibility space. The game-play changes from trying to find matching cards with maximum value to just trying to improve the score of the one current card in the player's hand. Rounds in the simpler modes are considerably shorter due to this as well, as there are only three cards in total in play (one per player, one in the middle).

## 3.3 Insights gained from the first evaluation

In the early stages of development the first evaluation took place at a nursing home in Munich, Germany. All three elderly players, two women and one man, suffered from varying degrees of Alzheimer's disease. Due to their cognitive limitations, the game was only played on its two lowest difficulty settings with reduced deck size, only a single opponent and only one or two cards in play. The predominant issue was uncertainty about the game's rules and the action they had to execute every turn, as they were not, or not anymore, familiar with the game's rules. Extensive in-game assistance had not been facilitated at that point in time.

Another issue for one participant in particular was recognizing the cards' values, due to the small size of the letters on the cards. The complexity of the card images has therefore been reduced to free up space for bigger letters on the bottom half of the card (see figure 3.6). It also has been observed that the users faced some difficulties executing the card swap action. Dragging seemed very unintuitive to them and prior to explaining or simply intuitively, they would just tap on the two cards they would like to exchange, contrary to the results by Kobayashi et al. (2011). The action of dragging and not letting go after tapping had to be explained every turn. In order to explore this further, a game setting has been introduced to enable switching between drag-and-drop and tapping-based interaction.

An issue that was already known, was the unsatisfying reveal animation at the end of a game, where all cards are turned over to determine the winner. In the early prototype,



(a) Initial (b) Improved

Figure 3.6: Changes to the card sprites for better visibility

the opponents' cards would not increase in size to be better visible. Since the evaluation made clear that the game would be way too difficult for Alzheimer's patients beyond Level 2, the difficulty settings have been drastically toned down (compare Table 3.7) to the point where all five modes feature only a single opponent.

This enabled the UI design to change in that the opponent's cards could now be present all the time in their bigger layout at the top of the screen. Thus the reveal event should be more satisfying. In the initial configuration, Level 1 only featured portrait cards in order to reduce the amount of cards to recognize to a minimum. However the players could not recall the ordinal ordering of these portrait cards hindering their ability to intuitively know whether to trade cards or not. It has therefore been changed to number cards only at Level 1. As the difficulty of all levels has been decreased, a sixth level has been added featuring the full range of cards and suits, as the original card game would be like.

| Setting | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Level 6 |
|---|---|---|---|---|---|---|
| no. of opponents | 1 | 1 | 1 | 1 | 1 | 1 |
| no. of suits | 1 | 1 | 2 | 2 | 2 | 4 |
| card types | numbers only | all | all | all | all | all |
| no. of hand cards | 1 | 1 | 1 | 2 | 3 | 3 |

Table 3.7: The revisited single-player difficulty level presets after the first evaluation

## 3.4 Assistance systems and interface design

In the first implementation iteration, the decision was made to only use a modal full-width text pop-up instead of the always-present companion shown in the paper prototype. Being modal is referring to the property of catching all user input, meaning nothing else is interactive. This banner features large font size text for important yet short notifications and spans across the whole width of the screen (see figure 3.8a). Tapping the screen dismisses the notification. Otherwise it fades out after a delay of a few seconds to release the player into playing the game. However, when the tutorial and mid-game-play assistance were added, this modal, view-blocking way of text communication did not fit the purpose.


(a) The full width assistance prompt


(b) Josef's tutorial speech bubble

Figure 3.8: The two ways of text-based communication

Since the opponent count has been reduced to always just one, instead of introducing another entity as companion, the artificial opponent has been given that role. Initially, the displayed opponent appeared relatively lifeless, only executing their turn's action. This has been changed so that they would have a personality and chat with the player, greeting them and being talkative about their actions, introducing another layer of assistance aside from the animations. Complementing the player on successful task execution is also provided by the assistant. In the game's tutorial, the opponent, named "Josef", introduces the player to the game's rules step by step with simple and short sentences and small "bites" of information at a time (see figure 3.8b). Interaction is encouraged and first touch controls are executed since the progression of the explanation is done exclusively by tapping Josef's speech bubble. During the explanations of the various interface elements, those elements play an animation growing and shrinking in size, to catch the player's attention. The game difficulty for the tutorial sequence is set to the minimum and also configured to use predefined cards to have a constant environment for learning and going back to the basics.

For communication outside of the tutorial, the banner is used for important yet short explanations due to the large text and prominent appearance. One application is telling the player that it's their turn. The text in Josef's speech bubble on the other hand is smaller and tailored for longer sentence-based explanations. The speech bubble can be dismissed by tapping on it, not disappearing on its own. Josef mentions his turn and the beginning of new rounds, reacts to the player ending the game and also explains the situation after ending the game himself. Lastly he will either congratulate or comfort the player, depending on the round's outcome.

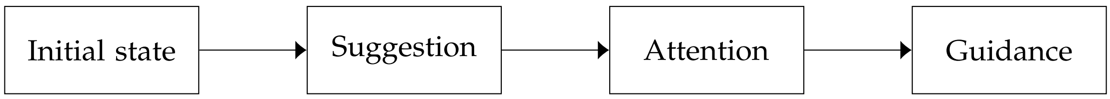



Figure 3.9: The stages of assistance

The assistance system has been designed using a Finite State Machine (FSM), with state transitions controlled by time. The longer a user takes for their turn, the further the system progresses in its level of assistance.

After a few seconds Josef makes a suggestion - using the speech bubble - to the player, for what would be the best thing to do. This is determined by simply checking all possible immediate options and comparing the player's score before and after, and maximizing this effect. Then, again after some time the game elements in question start playing animations to draw player attention and prompt interaction. The animations scale the respective element up and down in size in a repeating motion. This is the same animation as used in the tutorial to steer player attention to the explained components. In the third stage, Josef's instructions become more granular to guide the player step by step through their turn (see figure 3.9).

This way, the cognitive abilities are assisted in order of decreasing complexity, according to the taxonomy of higher and basic cognitive skills by Rojas R. and Castillo M. (2016). *Suggestion* aids in the higher cognitive skill of planning, *Attention* in recognition, and *Guidance* in basic interaction by motion execution.

## 3.5 Enabling social interaction with local multi-player

Aside from the single-player mode of playing against the computer, *ThirtyOne-Plus* also features a multi-player mode, allowing human versus human play. Social interaction and engaging in an entertainment activity together can help elders enjoy the experience and also benefit from support from within their user group (Gajadhar et al., 2010). Designing for local multi-player on a rather small screen is challenging, because space is limited and simplicity and overview have to be maintained in multi-player mode. Furthermore, the general look and structure should not deviate too much from the single-player mode, so players could bring their experience over to the multi-player after playing through the tutorial.

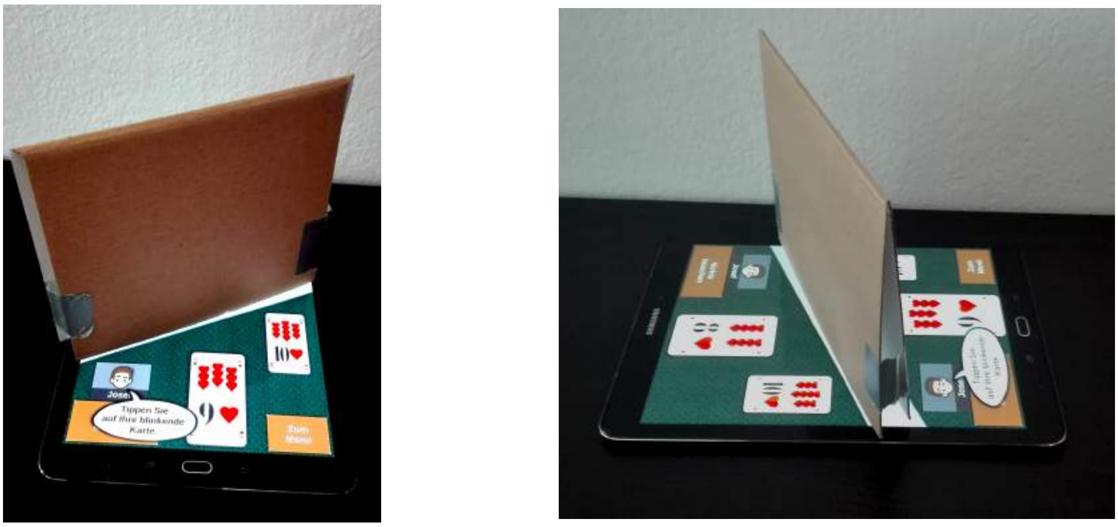
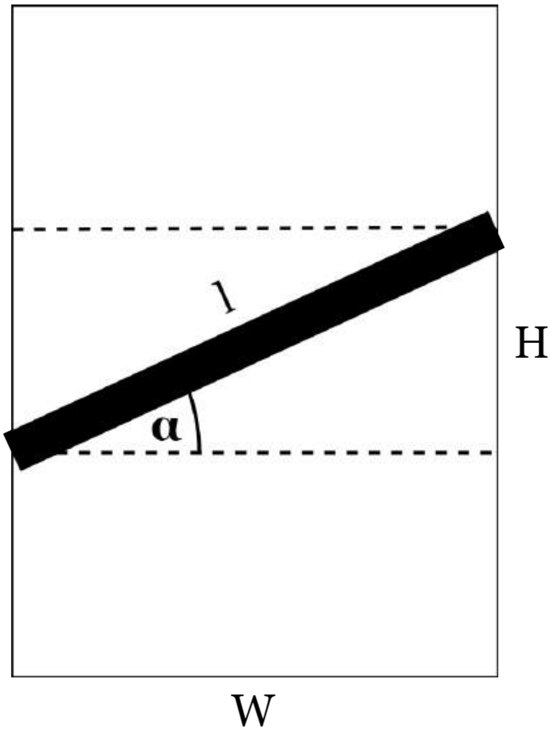



Figure 3.10: Physical view blocker placed on the screen

However the design should feature some characteristic differences in order to be easily distinguishable from the single-player mode (Kobayashi et al., 2011). The initial approach to this challenge was just to mirror the single-player game layout, so that players could play facing each other, interacting with opposite halves of the touch screen device. Some game elements that were previously located on the respective other half of the screen, like the assistant or the finish turn button, had to be moved to new locations. To prevent players from seeing the opponents cards, a physical, rudimentary cardboard view blocker has been conceived to be placed on top of the tablet screen (see figure 3.10).

Its proper position is also indicated by the interface design with a diagonal strip spanning across the screen (see figure 3.11b). It was considered to furthermore conceal




(a) View blocker length calculation


(b) Implemented multi-player interface

Figure 3.11: Multi-player screen design and implementation

the spectating player's card during the opponent's turn, by turning them over. But this would lead to uncertainty for the users about their own cards and confusion as to why their cards disappeared. In order to maximize both players share of the device screen, the view blocker is placed diagonally, to give the players more "vertical" screen space on the tablet axes instead of just horizontally cutting the screen in half.

As with the single-player layout design, the tablet screen is vertically cut into three slices, one solely for each player and the middle as shared ground. Diagonally through this middle section, the view blocker is placed (see figure 3.11a). Since the indicator texture is rectangular, setting its length to just the length of the diagonal would cause two of the four corners to remain on screen. Therefore, in order for the texture to fill the whole diagonal while still staying as small as possible, the formula 3.1 has been devised to calculate the texture's dimensions:

$$l = \sqrt{\left(\frac{H}{3}\right)^2 + W^2} + \frac{l * r}{\tan \alpha} \tag{3.1}$$

Its variables being $l$ the texture's length, $H$ and $W$ the screen's height and width respectively, $r$ the aspect ratio of the given texture and $\alpha$ the angle of the view blocker to the screen's x-axis. As the value of $l$ is self-dependent, the result had to be estimated by iterative convergence and for this purpose five iterations seemed plentiful.

To offer help to both players, the assistant has been duplicated and placed on both players' side. The speech bubble had to be modified in order to not cover the elements referenced by the assistance. Therefore two speech bubble positions have been set up, one below the portrait, covering the finish turn button, and one covering parts of the player's card. Depending on the message, the bubble will appear in either of those locations. As with the single-player mode, the modal banner is used to inform players of their turn, but also of the opponent's turn, so that they know why their game elements are not interactive. Since the middle section is no longer available to both players, the table cards to swap with had to be duplicated and now appear on both player sides simultaneously. Each player only interacts with their version of the table. On the other player's turn, their version of the table updates by playing the card turning-over animation. Due to the shared screen, no animation for the spectating player can be played showing the card-swapping as it occurs, because that could in turn be confusing for the executing player.

The game-play takes place as usual with alternating turns and end of the game once someone does not want to swap anymore. The assistant functions just like in single-player with the exception of no communication about the opponent's action, since the opponent is no longer the virtual assistant. Once the round is over, the view blocker can be lifted to reveal both players' cards. Difficulty settings also apply to the multi-player mode, therefore adjustments to deck size and variety can be made. Only the setting for card interaction had to be expanded to allow different input schemes for the two players.

## 3.6 Physical game augmentation using smart playing cards

For the second part of the comparison of input schemes for this thesis, *ThirtyOne-Plus* also features a physical-digital game mode. This multi-modal approach was conceived in order to overcome elders' potential hesitance towards touch screen interaction and engage them more in the game-play. Tactile interaction and physical aspects of originally digital serious games have shown to be quite effective means to engage this particular audience beyond the mere digital version (Henkelmann, 2019).

For this card game, "smart" playing cards have been implemented, using RFID tags at the back of the physical cards. To read the tags, wooden card holders, originally used for players struggling to hold their fan of cards, have been combined with a

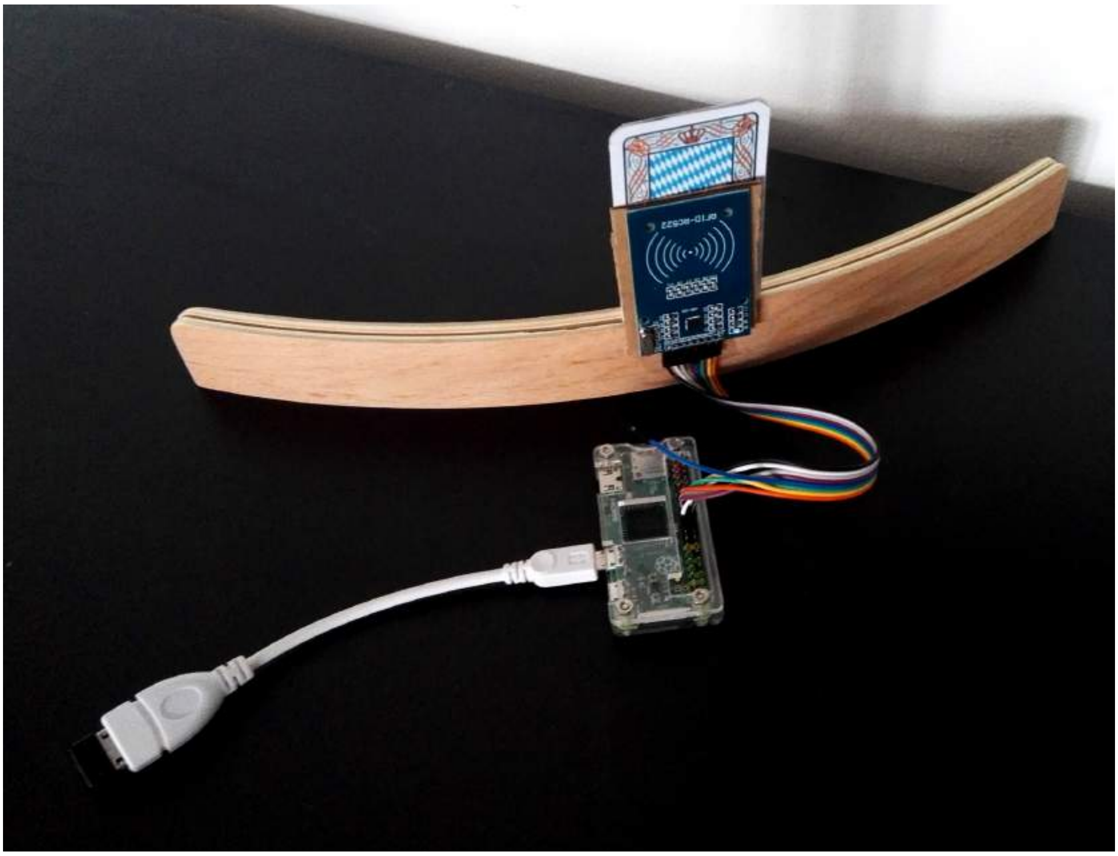


Figure 3.12: Wooden card holder fitted with a RFID tag reader, connected to a Raspberry Pi Zero

dedicated close range RFID reader, the MFRC522 board, connected to a Raspberry Pi Zero microcomputer via the GPIO pins (see figure 3.12). The decision to use such wooden holders was made to increase card reading precision as the card has to be placed exactly over the sensor in this setup, and to not have issues with the other player seeing one's cards as opposed to when they would lie on their back on top of a sensor casing. For this proof of concept, only one card holder equipped with a single reader device has been built. This can be expanded on in future work. The card reader's player-facing surface has been obscured using a piece of cardboard, so that players would not get uncomfortable being confronted with that much exposed technology.

Using a Bluetooth connection to the hand-held device, the Raspberry Pi is able to send the read data from the identified RFID chips placed on the reader. As the Raspberry Pi Zero model does not come with on-board Bluetooth capabilities, an external USB dongle had to be used. Separate software in the programming language Python was written to run on the microcomputer to both drive the MFRC522 using a driver library, and also establish and communicate over the Bluetooth channel with the hand-held game device (see figure 3.13). The tablet acts as a Bluetooth server and continues to run the game core. When starting the game, the device starts looking for Bluetooth clients, i.e the Raspberry Pi.

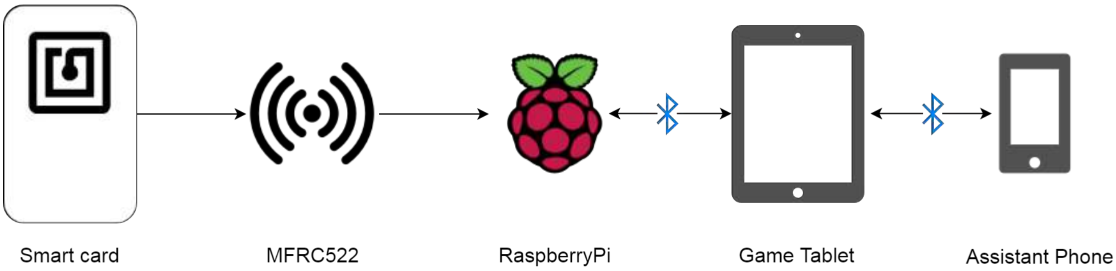



Figure 3.13: Hardware setup for reading smart playing cards

Due to the comparatively long time needed (a couple of seconds) to establish the connection, this process is started right away when the application starts and not just when the appropriate game mode is selected. Upon sudden disconnects, both parties restart their connection systems to re-establish their link. The connection then proceeds to be mostly unidirectional as the microcomputer only sends information when a card has been scanned. The only exception is the regular keep-alive transmissions from all parties involved, to ensure that the connection still holds. For that each device sends a "ping" message to their connected counterpart at a regular interval. The message is ignored, only errors on the sender side are of importance. Icons have been added to the top left corner of the game main screen to inform of connection issues with either device. The transmitted data of the actual communication is the payload of the RFID tags read.

Vibrotactile feedback is provided by the tablet upon scanning cards, vibrating twice on error and once on success. As the card is present all the time in front of the sensor during play, the software keeps track of the unique tag identifiers and only transmits data once the recognized tag differs from the previously seen one. This reading interval is however used for the "pinging" from the Raspberry Pi side.

The information on the tags is stored in plain text form, using a custom notation for quick identification and uniqueness, so that other randomly scanned tags wouldn't be misinterpreted as playing cards. For instance the card ♥ O would be encoded as `$Herz;Ober$`. The RFID tags used are the 888 byte NTAG216 tags and the data is written to the tags encoded in the NDEF format, using a smartphone equipped with a NFC reader/writer. As the driver setup is very low-level, reading the specific data

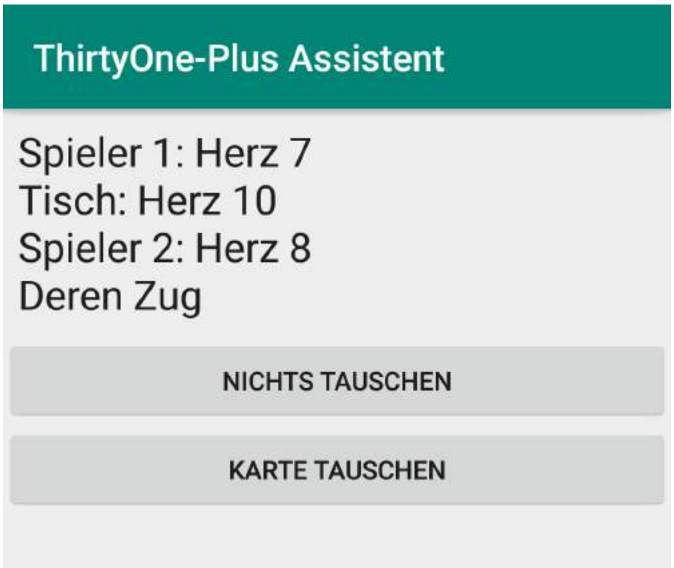



Figure 3.14: Assistant app displaying game state

structure of this tag type had to be custom written as well and then handed over to a NDEF library for parsing and extracting the payload.

To keep the physical and digital game world in sync and to assist the elderly players, an assistant (the author) is present in the game session as well. As in the ideal setup both players in the multi-player match would have their own screen for digital game representation and assistance, the assistant needs to have their own screen to be omniscient of the game state. Another separate software application was therefore written, this time for the Android platform, to run on the assistant's phone. This simple app would establish another Bluetooth connection to the game host (see figure 3.13) and plainly display any sent data on the screen (see figure 3.14).

The tablet running the game sends the details about both players' hands and the table cards for the assistant to prepare the physical counterparts. The sorted deck of physical cards is in the possession of the assistant, who is then dealing them to the players. As mentioned before, in this proof of concept only one player is interacting with smart playing cards. In this instance the assistant also serves as the opponent player. Therefore the assistant's application features two buttons, for the two possible actions on one's turn. This physical game mode also wants to emphasize social interaction, thus the button to not swap a card on a turn is only present on the assistant's application. Players have to verbally declare that they would not like to swap anything on their turn, which is again more similar to the traditional way of playing cards, alongside the physical playing cards. The assistance system has therefore been adjusted in the

*Guidance* stage to explain this behavior.

For this physical game mode, naturally, physical playing cards had to be made or acquired. Usage of commercially available cards would re-introduce accessibility issues due to unreadable small iconography on the cards, therefore the cards already present in the digital version of the game were used. This is also done to not introduce anything new but instead keep things consistent and recognizable, reducing redundant mental workload. The front and back designs were printed out and glued onto cardboard. Between the back print and the cardboard, the RFID tags were placed centered on the card. To increase stability and durability, all edges were then secured with transparent tape, making the cards grippier in the process. The decision to hide RFID tag was made to still have the cards look and feel as normal and familiar as possible. Also this way the cards are more durable as the tag can neither be peeled off nor loosen and fall off the cardboard if the glue does not hold up well.

## 3.7 Interface design for the assistant device screen in Ubiquitous Computing

As the physical game mode freed up a lot of screen space on the tablet and moved the mode of interaction away from the touch screen, the user interface could be used for other purposes, to enhance and complement the physical game-play. This approach generally falls under the field of Ubiquitous Computing, similarly to the games by Floerkemeier and Mattern (2006) and Römer and Domnitcheva (2002), in that an originally physical game is improved using a digital component for assistance and overview.

For that purpose, half of the available screen space is still used for a digital representation of the game state and the player's cards. The display is arranged in such a way as to maximize familiarity, as a digital version of the card holder is depicted on the screen, just like the player would see the physical counterpart in front of them. The virtual assistant is present and prominent on the side of the screen, as the screen is vertically and diagonally split in half. The left half features a table-surface-like background texture for scene familiarity, fading over to transparency as the right half of the screen displays the emotional component (see figure 3.15). The diagonal arrangement was chosen to still be able to have the player's cards be centered on the screen.

Since touch gesture related assistance is no longer applicable, the assistant's messages have been changed for this game mode. Furthermore, due to the removal of the player's ability to directly select the "don't swap" option, when this is the preferable option, the assistant will explain that the player has to tell the assistant member of staff (the author) their wish to not swap anything. In the *Attention* stage of the assistance engine for that


Figure 3.15: User interface for tablet screen in physical game mode. Top left displays connection icons with assistant and card reader device. The left screen half is showing game state, the right half the emotional component, the *Tourney*.

particular case, nothing can be highlighted as there is no more button or interactive element for this action.

The *Guidance* text for the action of card swapping tells the player to pick up the table card and exchange it with their current one. Further detailed step by step instructions could be possible in the future using separate antenna technology for the table cards. Once the player correctly executes the card swap the RFID tag reader will notice the different tag identifier and the payload will be extracted and sent to the tablet over Bluetooth. Along with the vibrotactile feedback according to the scanned tag, the game also plays an animation showing the card exchange upon success. This animation is the same as for AI opponents in the single-player mode. On the other hand, when the opponent executes a card swap, no moving card swap is shown on the screen. The opponent's card is not displayed on the tablet to give the important player and table cards more space, therefore introducing a new card sprite just for the sake of this one animation, appearing from out of the screen would be confusing. It has therefore been decided to just flip over the table card twice in an animation, changing its value when the back-side is turned up.

## 3.8 Emotional components to increase motivation and playtime

As stated by Eichhorn et al. (2018), elders are best reached by means of emotional motivation. Therefore the second half of the device screen in the physical game mode is used for a mini-game of sorts, running parallel to the actual game-play, without any explicit user interaction.

The mini-game titled the *Tourney* has the player participate in a country-wide tournament for the underlying card game, Thirty One. As shown in figure 3.15, the screen features a map of the German mainland with its state borders and biggest cities. The map is always centered on one of the biggest cities across the country, where the tournament is currently taking place. For increased accessibility, the current city's name is additionally displayed in large font at the bottom of the screen. To minimize visual noise, the map selected for this use-case only shows borders and the biggest cities of the various German states. No information about elevation or terrain is present as it also would not prove beneficial to this application.

Every time the player using the tablet wins against their opponent, they are proclaimed winner of the location and move to the next city. This emotional component focuses on travel and perhaps the reminiscence of some journeys in the past. Recalling fond memories and recognizing familiar places is a heartwarming emotional experience. This is stimulated further by showing iconic imagery of the current city at the top right of the screen. The selected cities for the *Tourney* are, in order: Munich, Stuttgart, Frankfurt, Cologne, Hannover, Bremen, Hamburg, Berlin and Dresden. This covers the entire German mainland and is ordered in a proximity based manner. Once reaching Dresden, it goes back to Munich and the cycle continues. This could be a potential trigger for increasing the game's difficulty and should be investigated in the future.

To keep the experience rewarding and about positive emotions, there are no consequences of defeat. The game just starts another round with new cards and this continues until the player is able to win a round.

The decision to use a mini-game like this was made because of its ease of implementation and ease of use. There is no additional input required, therefore the device functions purely as a display for this game mode, as it was designed to be by also removing the "don't swap" button as previously discussed. The focus should lie entirely on playing the physical cards and only looking to the screen for help or in this instance confidence boosts or reminiscence. It was also important to find a mini-game that would not cause the player to neglect the goal of winning the game in favor of progression in the mini-game. For example an earlier idea for the mini-game was a turn-based journey, but instead of advancement by winning, the progression would be controlled by card swapping. Therefore the emphasis would not lie on trying to achieve victory anymore, but instead trying to always swap cards in order to travel in the journey mini-game.

Another important aspect is connectedness to the game-play. It was also considered to show imagery of cute or beautiful animals in a rewarding fashion, say upon victory. But this has no real link to the game-play and would lack a sense of credibility and purpose. It would further introduce a lot of visual noise as there would have been the need for several images to not exhaust the feature too quickly.

## 3.9 Questionnaire design for the second evaluation

In order to gain some statistical insights into the acceptability and subjective performance of the game, a questionnaire needed to be designed. As the participants at the nursing home all suffer from moderate degrees of Alzheimer's, it was decided to use an indirect way of questionnaire answering. Similar to the evaluation done by Vasconcelos et al. (2012), instead of having the participants fill out the survey, the author fills out the questionnaire. This circumvents the possibility that filling out the form could prove too difficult for the participants, especially after playing the game for some time and being exhausted.

In a rather informal conversation, the participants are verbally asked the questions from the survey and the free-form responses are then interpreted and filled out on the form by the author. This way data collection can occur both during and after game-play as error rate, visible emotional responses as well as any feedback while playing can be documented immediately. This is crucial since the number of participants is heavily limited and in the worst case they might not even recall their experience due to their dementia. In the first evaluation, only three senior citizens were interested in playing the game.

It was decided to use a forced-choice approach with a five-point unidirectional verbal rating scale (Pospeschill, 2010) for the answers, similarly to the GEQ by IJsselsteijn et al. (2013), as it has proven to be a suitable scale for this target audience (Jobe & Mingay, 1990). Forced-choice is advantageous over free-form answers in this instance as it reduces mental workload for the participants and it makes evaluation and calculations easier, especially with the small sample size the evaluation would yield. The size of five-point was chosen to include the important neutral option, avoiding the forced tendency towards either extreme. This comes with the downside of a slight statistical bias towards the middle of the scale, but this is worth the ethical concerns of otherwise making users pick a disposition.

The possible answers range from "not at all" up to "completely", indicating agreeableness of the statement or question at hand. Special care went into ensuring that the answers remained disjunctive, meaning forming no possibly semantic overlaps and also exhaustive, covering the whole spectrum of possible attitudes towards the

Hatten Sie Spaß?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Wie schwer war das Spiel?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Haben Sie die Regeln verstanden?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

[Tut] Hat Ihnen die Einführung geholfen?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Fanden Sie "Josef", den Begleiter hilfreich?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Konnten Sie die Spielelemente erkennen?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Kamen Sie mit der Bedienung zurecht?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

[Phys] Wie kamen Sie mit den physischen Karten zurecht?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

[Phys] Hat das Turnier sie motiviert?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Würden Sie gerne wann anders noch einmal spielen?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Finden Sie das Spiel so besser als normales Kartenspielen?

☐ gar nicht ☐ wenig ☐ mittelmäßig ☐ überwiegend ☐ völlig

Welchen Spielmodus fanden Sie am besten?

☐ Alleine ☐ Mehrspieler ☐ Physisch

Figure 3.16: The questionnaire designed and used for the second evaluation

question. The questionnaire features 12 questions, a number deemed small enough to be not overwhelming or tedious for the elderly when interviewing the participants. The questions assess enjoyment, acceptability and usability, as well possible preferences between the three game modes of single-player, multi-player and digital-physical mode (see figure 3.16). Furthermore, understanding of the rules and performance of the assistance system are investigated.

# 4 Evaluation

After work on the project had concluded and with the questionnaire designed, the final evaluation took place, again at the same nursing home as with the intermediate evaluation. A total of $n = 5$ residents tested the game and all features and game-modes were played (see table 4.1). Notes and comments were collected as well as scores for the various questionnaire items. To preserve anonymity and still provide specificity, participants are now labeled P1 to P5. All of which are suffering from moderate dementia, with two female (P2, P4) and three male (P1, P3, P5) testers.

| **Game-mode** | **Players** |
|---|---|
| Tutorial | P1, P3 |
| Single-player | P1, P2, P3 |
| Multi-player | P4, P5 |
| Physical | P2 |

Table 4.1: Tester distribution over the various game-modes

Play-time per session varied greatly and ranged from just a few minutes (P3) to almost half an hour (P2). The evaluation was set-up on a small table with two chairs facing each other in a rather quiet corner of the entertainment room. The author would introduce himself and the presented activity, inviting the participants to play.

The procedure for P1 and P3 was the same as both played the tutorial first and then the single-player mode for a few rounds, with P1 playing considerably longer than P3. This was most likely due to the participants' predispositions, as P1 was more intrigued and captivated by the game-play than P3, who seemed eager to swiftly complete the game and return to the others at the big table.

The tutorial had very different effects on the two players. While P1 was struggling to identify the assistant at first and had problems reading the text, P3 quickly picked up on the instructions and proceeded through the sequence. A major source of confusion was the usage of game-rule terminology, as the "table card", the neutral card up for swapping, was not presented as being on a table, differing from the players' cards only in positioning (compare figure 3.3b). Eventually with both players, the tutorial was skipped through until the end and an explanation by the author followed instead.

All players played only at the lowest difficulty settings and while P1 wasn't sure on what to do on some turns, P3 played most turns by himself or at least after the first prompt of the assistance-engine, the *Suggestion* stage. It was noted however, that the controls remained a difficulty throughout. Players had to be reminded almost every turn on how to execute the card swapping if applicable. Thus lowering the timeout for the *Guidance* step could be a future improvement. Moreover, the change to the tapping-based control scheme for card swapping proved successful as the users did not execute any intuitive dragging and instead only tapped on interactive elements.

Regarding the text-based instructions it was observed with P1 and P2 that the center-aligned text combined with the line-wrapping led to worsened reading performance. Participants were often only identifying a subset of the displayed text, reading only the first or the first few lines. The confined space and odd proportions of the speech bubble only increased those difficulties.

Even though almost all players voiced their uncertainty about the rules and on what to do, with assistance from either the author or the virtual assistant, most turns were executed correctly. One consistent observation was the natural understanding of the ordering of the playing cards. As the lowest difficulty setting only featured the number cards of a single suit (compare table 3.7), players were able to identify whether to swap or not and were just not sure how to execute the preferred action. The selection of the "don't swap" choice was more often successful as the button seemed more intuitive to interact with.

The physical game-mode was tested by P2. After introduction of the game elements and the *Tourney* as well as the rules, by the author, several rounds were played until a full cycle of the city locations was completed. Right from the start it was noted that the physical game elements were so captivating that P2 did not pay any attention to the screen which had been positioned to the side, upright against its protective cover. Only when pointed out by the author upon city change, was focus shifted onto the device. The presence and interaction of the assistant was not recognized at all. The progression in the *Tourney* proved to be a great motivator and the targeted emotional stimuli were achieved when entering various cities as P2 talked about previous experiences and fond memories seeing the imagery of the respective locations.

The physical game elements proved to be very difficult to play with as well. The biggest source of confusion stemmed from P2 confusing her own card in the card holder with the table card lying flat on the table behind and to the side of the card holder, in the middle of the playing table. When asked to swap, the process of putting the newly acquired card back into the slim slot of the card holder was very difficult as motor precision had declined and P2's hand was shaking slightly. This was also arguably worsened by the thickness of the cards, as they were hand made using cardboard in the middle, instead of just one sturdy piece of printed paper like with regular playing cards. This also showed during attempts to pick up the table card for swapping, which proved difficult at times as the card was not as flexible as probably expected. Oftentimes it was observed that a more intuitive location for her own card might be the table surface in front of the card holder, as P2 placed the swapped card there instead of in the card holder. Another issue seemed to be the opponent implementation. As the author was facing P2 and playing as the opponent, the sight of the hidden card held by the author had P2 puzzled. Many rounds the question arose: "What card do you have?".

After the conclusion of the physical play-through, P2 also played the purely digital single-player, in order to make a comparison. As she was already familiar with the rules, the tutorial was skipped and it went straight into the game. Immediately observed was the fact that here the ownership of the cards seemed much more clear. There was no more confusion about which card was hers and which was the table card. Furthermore, as the game was now played against the artificial intelligence, no more questions about the opponent's card came up. Controls also seemed to be more intuitive as less guidance had to be provided by the author. The in-game assistant however remained unutilized or unnoticed. After play had concluded, P2 stated when asked which game-mode was the preferred one, that the digital one was more too her liking, and she was very confused by the physical mode.

For the last test, two participants were needed as the feature left was the shared-screen multi-player mode. It was arranged so that P4 and P5 were seated opposite of another, with the screen on the table surface between them. After verbal explanation of the game and the rules by the author, playing commenced. Difficulties were almost immediately noticed. The social aspect combined with the shared screen caused many involuntary inputs when P4 was helping P5 and touched things on her portion of the screen by accident.

Multiple occurrences of triggering the wrong action were observed as well, as the user interface was just too cramped and elements too close together. Furthermore, P4 had the habit of resting her hand on the screen which led to more accidental inputs and even return to the main menu. The lack of proper instructions for both players clearly showed as confusion was considerably higher than in the single-player sessions. Both players could profit from the help provided by Josef as well as from the social interaction between each other. More fun and enjoyment was observed even though performance was very low which must be attributed to that social component, as P4 and P5 were close friends.

| | **Item** | **Samples** | **Mean** | **Std. dev.** |
|---|---|---|---|---|
| 1 | Hatten Sie Spaß? | 5 | 4.20 | 0.40 |
| 2 | Wie schwer war das Spiel? | 5 | 3.20 | 0.75 |
| 3 | Haben Sie die Regeln verstanden? | 5 | 3.80 | 0.98 |
| 4 | Hat Ihnen die Einführung geholfen? | 2 | 3.00 | 0.00 |
| 5 | Fanden Sie "Josef", den Begleiter, hilfreich? | 5 | 4.20 | 1.17 |
| 6 | Konnten Sie die Spielelemente erkennen? | 5 | 4.40 | 0.49 |
| 7 | Kamen Sie mit der Bedienung zurecht | 5 | 3.40 | 0.80 |
| 8 | Wie kamen Sie mit den physischen Karten zurecht? | 1 | 4.00 | 0.00 |
| 9 | Hat das Turnier Sie motiviert? | 1 | 5.00 | 0.00 |
| 10 | Würden Sie gerne wann anders noch einmal spielen? | 5 | 3.80 | 0.40 |
| 11 | Finden Sie das Spiel so besser als normales Kartenspielen? | 5 | 2.80 | 0.40 |

Table 4.2: Questionnaire evaluation, choices transformed to cardinal values:
1 (not at all) - 5 (completely)

In the evaluation of the questionnaire (see table 4.2) most noticeable is the high standard deviation of $\sigma = 1.17$ for item no. 5, regarding the helpfulness of the digital assistant "Josef". This can attributed to the various amounts participants noticed the assistant and could profit from the written instructions and help. The mean of $\mu = 3.2$ for item no. 2 indicates that the difficulty at the bottom most level was challenging enough or even slightly too much so. General participant enjoyment can be concluded from the moderately high values of item 1 and 10; however no real preference over playing cards normally has to be noted, seeing the low mean value of item no. 11.

# 5 Discussion

The evaluation proved to be very insightful. Clear improvements since the first evaluations could be identified, such as the user preference of tapping, clearly confirming a standpoint opposite to the literature, as well as the need for an assistance engine. However it also showed that even with a digital companion, the guidance by and interaction with assistant staff members or in this case the author remains necessary and important, as players tend to neglect or miss the instructions given by the game.

The physical approach showed many difficulties regarding the prototype-level implementation, but promises future improvements with even just smalls steps leading to great enhancement, such as industrial-grade playing cards, which are more familiar to the players in tactile aspects. The usage of a card holder, intended as an improvement for accessibility and usage accuracy, established the need for an alternative approach using a table mat for instance, as the table surface remains the intuitive place for users' playing cards. The technological setup, especially in the physical game-mode, demonstrated robustness and showed flexibility as expansion with multiple card readers would be straightforward using the Serial protocol. The Bluetooth connections were stable and no issues with reconnecting or lost data were observed.

The purely digital single-player mode demonstrated the highest base potential in the present state, as players enjoyed this game-mode the most and due to the combined usage of opponent and assistant with "Josef", much more attention was paid to the game's own assistance, than in the physical game-mode where the screen was easily neglected in favor of the physical elements more important for the actual game-play. With difficulty adjustments and some learning algorithms building user-profiles this single-player mode could become very captivating and maximize flow.

The shared-screen multi-player showed the most issues as the comparatively big tablet screen still proved way too small for two player interaction, with unintentional touches and increased confusion. The clear improvement here would be to separate the game into one device per player.

Overall, players seemed to enjoy the game and for the most part quickly understood the simplified rules, the achievement of which in and of itself was a big hurdle to overcome at the beginning. Finally it has to be noted that due to the small sample size, the given evaluation metrics should be further investigated using larger participant groups with more intra-participant variety as to game-modes played. Similarly, the indirect questionnaire answering by the author from interpreted feedback leads to a clear decrease in answer accuracy, showing only tendencies. The difficulty of conducting a survey with dementia patients has led to this decision as research in this field progresses slowly (Andersen et al., 2011).

# 6 Future work

The prototype application and hardware solution developed for this thesis offers many possibilities of extending or building upon and serves as a solid foundation for future developments. Due to this work being a comparison between the two modalities of purely touch based and a physical-digital approach, neither versions could be explored to their fullest potential. Future projects might also try this comparison with different card games to test or determine whether the game rules this serious game was designed with were particularly well suited to the audience or if a different, maybe more well-known yet greatly simplified game could lead to even higher acceptability.

The rules of the game implemented, Thirty One, and the simplifications added, caused the matches to be very short, as in the most basic setting only three cards were in play. Facilitating flow over the course of such a short play session is rather difficult so captivating players in longer, and yet not too difficult tasks could help the overall cognitive training goal this serious game tries to achieve. In this project, the game just immediately starts another round to keep the user playing and enjoying the game, without returning to a menu or game selection. Another aspect that can be expanded upon for this is adding mechanisms to dynamically adapt the difficulty setting to the player while building a player profile. This could be done by monitoring error rate and interaction delays after the prompting by the various stages of the assistance engine. The system could also adjust the timings between the different steps of the assistance using this information about the player. This would follow the system Bouchard et al. (2012) conceived for their cooking process planning game.

In this implementation the difficulty settings are discrete settings in terms of number of cards in play and their variety. Changing difficulty means going back to a menu in order to select a harder or easier difficulty. Having the game automatically adjust various settings appropriate to the current player is another great expansion of the concept. Players who might struggle recognizing certain cards but have no problem with say, two cards in their hand would in the current system not be able to play on higher difficulties due to their rigid definition. A more flexible and user-centered system could therefore allow for more flow and possibly longer play sessions.

As this game was tailored to the evaluation environment of a rather noisy senior citizen home's entertainment room, the game's usage of sound effects and voice-recordings for assistance and feedback should be more thoroughly investigated in the future, when the focus would lie more on usage by an individual in their own quarters and free time. Multi-modal feedback and assistance is crucial to ensure success in communication and attention grabbing. The current prototype relied on vibrotactile feedback and animations.

Due to resource limitations both on hardware and software programming side, the touch-based multi-player was implemented on a single shared tablet screen. Using a prototype cardboard-based view blocker to prevent players from seeing the opponent's cards was a result of those limitations. Screen space was heavily limited and it proved difficult to maintain ease of overview regarding the user interface. In future projects a different approach with dedicated devices per player should be investigated. Apart from the straightforward advantage of more user interface space per player, more user centered assistance could occur. For instance, restructuring the user interface to the user's needs and displaying animations about the opponent's turn, which was not possible in the shared screen version as it would be confusing to the player executing the turn could be facilitated. A system like this would need to use wireless communication to share game state just like in the physical version.

The latter offers by far the most potential for future expansion. The current architecture only allows for a single player using the modality and an assistant acting both as opponent and cards dealer. This can be altered with the use of more hardware so that every player has their own smart card reader and assistance tablet screen. For the time being, an assistant is still needed to hand out cards and troubleshoot potential system issues.

The software design would also need a central device to run the definite game simulation on, to have a consistent game state across all participant devices. This central game server would then keep the clients updated and react to potential inputs. Of course the benefit of enabling true physical multi-player is the social component. Real interaction on top of physical game elements ought to improve the subjective experience significantly. The emotional component, in this case the players' journey through the major German cities on a tourney of sorts, could be coupled with a collaborative rather than competitive aspect, as this would better fit the elder demographic's general mindset (Gajadhar et al., 2010).

As with the digital version, the physical version is bound to the underlying game rules and simplifications. In this instance, the smart card holder is only equipped with a single RFID reader chip, connected to a Raspberry Pi microcomputer. With different games or higher difficulty this will not suffice, which would lead to interesting solutions regarding driving multiple chip readers with a single microcomputer and transmitting that information.

Another approach could follow the solution by Floerkemeier and Mattern (2006) by manufacturing a table mat fitted with increased range antennas, connected to just a single reader chip. The challenge then would lie in the sampling of the correct antenna at the right time and ensuring data correctness and reliability. This system could also be used to fully automate and control the physical-digital game state correspondence, as the table's cards could also be registered by a well-placed antenna. This could also benefit the assistance engine as the registration of changes on either the table's or the player's cards could be used in the *Guidance* stage of helping the player step by step through their turn's preferable action.

# 7 Conclusion

In this thesis a serious game was conceived and implemented to help senior citizens and dementia patients train their cognitive abilities and be motivated to play through emotional factors in the game design. Two evaluations, one early in development and one after completion, guided the project in a user-centered design approach. In order to compare different input schemes and modalities, two major sub-projects were implemented, one game-mode entirely digital on a touch screen device, and another mode mixing digital and physical elements. Here, cardboard smart playing cards with RFID tags were combined with a digital display for emotional elements and assistance. A digital companion and guide was implemented following a state machine pattern for assisting and guiding players at various levels. Furthermore, to explore social aspects and levels of engagement, a shared-screen multi-player mode using a cardboard view-blocker placed on top of the screen was devised.

The evaluations clearly showed the strengths and weaknesses of the present design, particularly the need for dedicated screens per player in a multi-player environment and the difficulty of dealing with degraded motor precision when utilizing physical game elements. Furthermore it was found that it is important to focus on familiarity when developing metaphorical game components, such as the right material composition for tactile playing cards and proper textures for digital interfaces.

The prototypes showed stability and acceptability with the target group as the users generally enjoyed playing and understood the rules, even showing natural understanding of the core rule, the ordinal sequence of the playing cards. The visual presentation proved to be clear and high in usability as little to no accidental invocations of functions were observed in the single-player mode. The usage of animations and vibrotactile feedback worked well for accessibility, particularly for attention-grabbing in the stages of assistance.

From this it can be concluded that the most promising approach explored in this thesis was the purely digital one, showing highest player engagement and action success rate, along with little to no uncertainty about game elements or interaction.

# List of figures



# List of tables

# Bibliography

42matters. (2018). Average number of new android app releases per day from 3rd quarter 2016 to 1st quarter 2018. Retrieved April 9, 2019, from https://www.statista.com/statistics/276703/android-app-releases-worldwide/

Andersen, C. L., Gudmundsson, H. P., Achiche, S., Boelskifte, P., et al. (2011). Challenges and limitations of applying an emotion-driven design approach on elderly users. In *Ds 68-7: Proceedings of the 18th international conference on engineering design (iced 11), impacting society through engineering design, vol. 7: Human behaviour in design, lyngby/copenhagen, denmark, 15.-19.08. 2011* (pp. 74–84).

Astell, A. J., Joddrell, P., Groenewoud, H., de Lange, J., Goumans, M., Cordia, A., & Schikhof, Y. (2016). Does familiarity affect the enjoyment of touchscreen games for people with dementia? *International Journal of Medical Informatics*, *91*, e1–e8. doi:https://doi.org/10.1016/j.ijmedinf.2016.02.001

Bitkom Research. (2018). Anteil der computer- und videospieler in verschiedenen altersgruppen in deutschland im jahr 2018. Retrieved August 8, 2019, from https://de.statista.com/statistik/daten/studie/315924/umfrage/anteil-der-computerspieler-in-deutschland-nach-alter/

Blizzard Entertainment. (2016). Welcome to competitive play. Retrieved May 26, 2019, from https://playoverwatch.com/en-us/news/20167051

Bouchard, B., Imbeault, F., Bouzouane, A., & Menelas, B.-A. J. (2012). Developing serious games specifically adapted to people suffering from alzheimer. In M. Ma, M. F. Oliveira, J. B. Hauge, H. Duin, & K.-D. Thoben (Eds.), *Serious games development and applications* (pp. 243–254). Berlin, Heidelberg: Springer Berlin Heidelberg.

Castilla, D., Garcia-Palacios, A., Bretón-López, J., Miralles, I., Baños, R. M., Etchemendy, E., . . . Botella, C. (2013). Process of design and usability evaluation of a telepsychology web and virtual reality system for the elderly: Butler. *International Journal of Human-Computer Studies*, *71*(3), 350–362. doi:https://doi.org/10.1016/j.ijhcs.2012.10.017

Chen, W. (2013). Gesture-based applications for elderly people. In M. Kurosu (Ed.), *Human-computer interaction. interaction modalities and techniques* (pp. 186–195). Berlin, Heidelberg: Springer Berlin Heidelberg.

Coppola, J. F., Kowtko, M. A., Yamagata, C., & Joyce, S. (2013). Applying mobile application development to help dementia and alzheimer patients. *Proceedings of Student-Faculty Research Day, CSIS, Pace University*.

Cota, T. T., & Ishitani, L. (2015). Motivation and benefits of digital games for the elderly: A systematic literature review. *Revista Brasileira de Computação Aplicada*, *7*(1), 2–16.

Cowley, B., Charles, D., Black, M., & Hickey, R. (2008). Toward an understanding of flow in video games. *Comput. Entertain. 6*(2), 20:1–20:27. doi:10.1145/1371216.1371223

Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety*. San Francisco, CA, USA: Jossey-Bass Publishers.

de la Guía, E., Lozano, M. D., & Penichet, V. R. (2013). Cognitive rehabilitation based on collaborative and tangible computer games. In *2013 7th international conference on pervasive computing technologies for healthcare and workshops* (pp. 389–392). doi:10.4108/icst.pervasivehealth.2013.252375

de la Guía, E., Lozano, M. D., & Penichet, V. M. R. (2014). Increasing engagement in elderly people through tangible and distributed user interfaces. In *Proceedings of the 8th international conference on pervasive computing technologies for healthcare* (pp. 390–393). PervasiveHealth '14. doi:10.4108/icst.pervasivehealth.2014.255361

Doepker, R., & Terrel, E. (2009). Monopoly patented. Retrieved July 21, 2019, from https://www.loc.gov/rr/business/businesshistory/December/monopoly.html

Eichhorn, C., Plecher, D. A., Klinker, G., Lurz, M., Leipold, N., Böhm, M., ... Hiyama, A. (2018). Innovative game concepts for alzheimer patients. In J. Zhou & G. Salvendy (Eds.), *Human aspects of it for the aged population. applications in health, assistance, and entertainment* (pp. 526–545). Cham: Springer International Publishing.

Eichhorn, C., Plecher, D. A., Lurz, M., Leipold, N., Böhm, M., Krcmar, H., ... Klinker, G. (2019). Motivation and design guidelines focusing on mobile app development for elderly and alzheimer patients in the area of healthcare management. *ACM Transactions on Graphics*.

Ekman, P., Friesen, W. V., & Ellsworth, P. (1972). *Emotion in the human face: Guidelines for research and an integration of findings (general psychology)*. New York, NY, USA: Pergamon Press.

Elo, A. E. (1978). *The rating of chess players, past and present*. Arco Pub.

Fairbairn, J. (1995). History of go – china. Retrieved May 25, 2019, from http://gobase.org/reading/history/china/

Floerkemeier, C., & Mattern, F. (2006). Smart playing cards–enhancing the gaming experience with rfid. In *Proceedings of the third international workshop on pervasive gaming applications-pergames* (pp. 27–36).

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. doi:https://doi.org/10.1016/0022-3956(75)90026-6

Foukarakis, M., Leonidis, A., Adami, I., Antona, M., & Stephanidis, C. (2011). An adaptable card game for older users. (p. 27). doi:10.1145/2141622.2141655

Gajadhar, B. J., Nap, H. H., de Kort, Y. A. W., & IJsselsteijn, W. A. (2010). Out of sight, out of mind: Co-player effects on seniors' player experience. In *Proceedings of* *the 3rd international conference on fun and games* (pp. 74–83). Fun and Games '10. doi:10.1145/1823818.1823826

Gamberini, L., Martino, F., Seraglia, B., Spagnolli, A., Fabregat, M., Ibanez, F., ... Andres, J. M. (2009). Eldergames project: An innovative mixed reality table-top solution to preserve cognitive functions in elderly people. In *2009 2nd conference on human system interactions* (pp. 164–169). doi:10.1109/HSI.2009.5090973

Glasser, A., & Campbell, M. C. (1998). Presbyopia and the optical changes in the human crystalline lens with age. *Vision Research*, *38*(2), 209–229. doi:https://doi.org/10.1016/S0042-6989(97)00102-8

Häikiö, J., Wallin, A., Isomursu, M., Ailisto, H., Matinmikko, T., & Huomo, T. (2007). Touch-based user interface for elderly users. In *Proceedings of the 9th international conference on human computer interaction with mobile devices and services* (pp. 289–296). MobileHCI '07. doi:10.1145/1377999.1378021

Henkelmann, T. (2019). *Combining a drinking gadget with a board game to improve the quality of life of alzheimer's patients* (Master's thesis, Technische Universität München, Deutschland).

Hirsch, T., Forlizzi, J., Hyder, E., Goetz, J., Kurtz, C., & Stroback, J. (2000). The elder project: Social, emotional, and environmental factors in the design of eldercare technologies. In *Proceedings on the 2000 conference on universal usability* (pp. 72–79). CUU '00. doi:10.1145/355460.355476

Holzinger, A., Searle, G., Kleinberger, T., Seffah, A., & Javahery, H. (2008). Investigating usability metrics for the design and development of applications for the elderly. In K. Miesenberger, J. Klaus, W. Zagler, & A. Karshmer (Eds.), *Computers helping people with special needs* (pp. 98–105). Berlin, Heidelberg: Springer Berlin Heidelberg.

Holzinger, A., Searle, G., & Nischelwitzer, A. (2007). On some aspects of improving mobile applications for the elderly. In C. Stephanidis (Ed.), *Universal acess in human computer interaction. coping with diversity* (pp. 923–932). Berlin, Heidelberg: Springer Berlin Heidelberg.

IDATE DigiWorld. (n.d.). Number of nfc-enabled mobile devices worldwide from 2012 to 2018 (in million units). Retrieved June 22, 2019, from https://www.statista.com/statistics/461494/nfc-enabled-mobile-devices-worldwide/

IJsselsteijn, W., de Kort, Y., & Poels, K. (2013). *The game experience questionnaire*. Technische Universiteit Eindhoven.

Ijsselsteijn, W., Nap, H. H., de Kort, Y., & Poels, K. (2007). Digital game design for elderly users. In *Proceedings of the 2007 conference on future play* (pp. 17–22). Future Play '07. doi:10.1145/1328202.1328206

Ishii, H., & Ullmer, B. (1997). Tangible bits: Towards seamless interfaces between people, bits and atoms. In *Proceedings of the acm sigchi conference on human factors in computing systems* (pp. 234–241). ACM.

Jobe, J. B., & Mingay, D. J. (1990). Cognitive laboratory approach to designing questionnaires for surveys of the elderly. *Public health reports (Washington, D.C. : 1974)*, *105*(5), 518–524. 2120731[pmid]. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/2120731

Jones, G. M., & van der Eerden, W. J. (2008). Designing care environments for persons with alzheimer's disease: Visuoperceptual considerations. *Reviews in Clinical Gerontology*, *18*(1), 13–37. doi:10.1017/S0959259808002645

Kang, K., Choi, E.-J., & Lee, Y.-S. (2016). Proposal of a serious game to help prevent dementia. In R. Bottino, J. Jeuring, & R. C. Veltkamp (Eds.), *Games and learning alliance* (pp. 415–424). Cham: Springer International Publishing.

Kieras, D., & Polson, P. G. (1985). An approach to the formal analysis of user complexity. *International journal of man-machine studies*, *22*(4), 365–394.

Kobayashi, M., Hiyama, A., Miura, T., Asakawa, C., Hirose, M., & Ifukube, T. (2011). Elderly user evaluation of mobile touchscreen interactions. In P. Campos, N. Graham, J. Jorge, N. Nunes, P. Palanque, & M. Winckler (Eds.), *Human-computer interaction – interact 2011* (pp. 83–99). Berlin, Heidelberg: Springer Berlin Heidelberg.

Koivisto, A., Lindstedt, A., Merilampi, S., & Kiili, K. (2016). Designing working memory games for elderly. In R. Bottino, J. Jeuring, & R. C. Veltkamp (Eds.), *Games and learning alliance* (pp. 311–320). Cham: Springer International Publishing.

Lapointe, J., Bouchard, B., Bouchard, J., Potvin, A., & Bouzouane, A. (2012). Smart homes for people with alzheimer's disease: Adapting prompting strategies to the patient's cognitive profile. In *Proceedings of the 5th international conference on pervasive technologies related to assistive environments* (30:1–30:8). PETRA '12. doi:10.1145/2413097.2413135

Lavrakas, P. (2008). *Encyclopedia of survey research methods*. doi:10.4135/9781412963947

Ledbury, C., Woolhead, L., Thomas, F., Carpenter, R., & Stott, H. (2017). *Something for everyone - why the growth of mobile apps is good news for brands*. Ipsos MORI.

Leonard, V. K., Jacko, J. A., & Pizzimenti, J. J. (2005). An exploratory investigation of handheld computer interaction for older adults with visual impairments. In *Proceedings of the 7th international acm sigaccess conference on computers and accessibility* (pp. 12–19). Assets '05. doi:10.1145/1090785.1090791

Light, P. C. (1988). Baby boomers.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, *22 140*, 55–55.

McLeod, J. (1995). Schwimmen (31). Retrieved April 11, 2019, from https://www.pagat.com/commerce/schwim.html

Motti, L. G., Vigouroux, N., & Gorce, P. (2015). Ease-of-use of tactile interaction for novice older adults. In J. Zhou & G. Salvendy (Eds.), *Human aspects of it for the aged population. design for aging* (pp. 463–474). Cham: Springer International Publishing.

National Institute of Aging. (2016). Alzheimer's disease fact sheet. Retrieved April 10, 2019, from https://www.nia.nih.gov/health/alzheimers-disease-fact-sheet

Newzoo. (2018). Global games market report. Retrieved April 9, 2019, from https://newzoo.com/insights/articles/global-games-market-reaches-137-9-billion-in-2018-mobile-games-take-half/

Oosterom-Calo, R., & López, B. (2016). Teaching older adults with multiple chronic conditions to use a tablet and patient application for health management. In *International conference on human aspects of it for the aged population* (pp. 342–351). Springer.

Ortiz, A., del Puy Carretero, M., Oyarzun, D., Yanguas, J. J., Buiza, C., Gonzalez, M. F., & Etxeberria, I. (2007). Elderly users in ambient intelligence: Does an avatar improve the interaction? In C. Stephanidis & M. Pieper (Eds.), *Universal access in ambient intelligence environments* (pp. 99–114). Berlin, Heidelberg: Springer Berlin Heidelberg.

Park, C. (2009). Intelligent interface for elderly games. In C. Stephanidis (Ed.), *Universal access in human-computer interaction. intelligent and ubiquitous interaction environments* (pp. 704–710). Berlin, Heidelberg: Springer Berlin Heidelberg.

Pospeschill, M. (2010). *Testtheorie, Testkonstruktion, Testevaluation*. München: Reinhardt.

Robert, P., König, A., Amieva, H., Andrieu, S., Bremond, F., Bullock, R., … Manera, V. (2014). Recommendations for the use of serious games in people with alzheimer's disease, related disorders and frailty. *Frontiers in Aging Neuroscience*, *6*, 54. doi:10.3389/fnagi.2014.00054

Rojas R., C. I., & Castillo M., J. A. (2016). Tests of cognitive training as archetypes in elderly people. In J. Zhou & G. Salvendy (Eds.), *Human aspects of it for the aged population. design for aging* (pp. 371–377). Cham: Springer International Publishing.

Römer, K., & Domnitcheva, S. (2002). Smart playing cards: A ubiquitous computing game. *Personal and Ubiquitous Computing*, *6*(5), 371–377. doi:10.1007/s007790200042

Schwartz, M. F., Segal, M., Veramonti, T., Ferraro, M., & Buxbaum, L. J. (2002). The naturalistic action test: A standardised assessment for everyday action impairment. *Neuropsychological rehabilitation*, *12*(4), 311–339.

Sonawane, K. (2017). *Serious games market by user type (enterprises and consumers), application (advertising & marketing, simulation training, research & planning, human resources, and others), and industry vertical (healthcare, aerospace & defense, government,* *education, retail, media & entertainment, and others) - global opportunity analysis and industry forecast, 2016-2023*. Allied Market Research.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. doi:10.1037/h0054651

Tak, S. H., Beck, C., & Hong, S. H. (2013). Feasibility of providing computer activities for nursing home residents with dementia. *Non-pharmacological therapies in dementia*, *3*(1), 1–10. PMC4204016[pmcid]. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25343006

Tombaugh, T. N., & McIntyre, N. J. (1992). The mini-mental state examination: A comprehensive review. *Journal of the American Geriatrics Society*, *40*(9), 922–935. doi:10.1111/j.1532-5415.1992.tb01992.x. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1532-5415.1992.tb01992.x

Tong, T., Chan, J. H., & Chignell, M. (2017). Serious games for dementia. In *Proceedings of the 26th international conference on world wide web companion* (pp. 1111–1115). WWW '17 Companion. doi:10.1145/3041021.3054930

Vasconcelos, A., Silva, P. A., Caseiro, J., Nunes, F., & Teixeira, L. F. (2012). Designing tablet-based games for seniors: The example of cogniplay, a cognitive gaming platform. In *Proceedings of the 4th international conference on fun and games* (pp. 1–10). FnG '12. doi:10.1145/2367616.2367617

Weiser, M. (1991). The computer for the 21 st century. *Scientific american*, *265*(3), 94–105.

West, J. H., Hall, P. C., Hanson, C. L., Barnes, M. D., Giraud-Carrier, C., & Barrett, J. (2012). There's an app for that: Content analysis of paid health and fitness apps. *Journal of medical Internet research*, *14*(3), e72.

Wilkinson, C. K. (1943). Chessmen and chess. *The Metropolitan Museum of Art Bulletin*, *1*(9), 271–279. Retrieved from http://www.jstor.org/stable/3257111

Wittland, J., Brauner, P., & Ziefle, M. (2015). Serious games for cognitive training in ambient assisted living environments – a technology acceptance perspective. In J. Abascal, S. Barbosa, M. Fetter, T. Gross, P. Palanque, & M. Winckler (Eds.), *Human-computer interaction – interact 2015* (pp. 453–471). Cham: Springer International Publishing.

World Health Organization. (2019). Dementia. Retrieved May 26, 2019, from https://www.who.int/news-room/fact-sheets/detail/dementia

Yu, X. (in press). *Emotional interaction between artificial companion agents and the elderly*. Singapore: Interdisciplinary Graduate School of the Nanyang Technological University.

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer*, *38*, 25–32. doi:10.1109/MC.2005.297