DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Master's Thesis in Informatics

Combining a drinking gadget with a board game to improve the quality of life of Alzheimer's patients

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Kombination eines Trinkmessgerätes mit einem Brettspiel um die Lebensqualität von Alzheimer's Patienten zu verbessern.

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

Munich, 15.05.2019 Tim Henkelmann

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Abstract

The number of people suffering from Alzheimer's disease, the most common form of dementia, is rising from year to year. With the ongoing demographic change in western countries and no cure in sight, this problem will only increase in relevance. The illness puts a tough toll on caregivers, patients and their friends and family. Due to impairment of the short term memory and a decreased thirst, the affected persons forget to drink which in turn affects their overall health. The course of the disease can be slowed down if they are mentally and physically challenged and at the same time socially integrated. To keep up the quality of life of the patients for as long as possible, efforts need to be made.
Therefore, a virtual version of the board game classic "Ludo" was developed that is specifically adjusted for users suffering from Alzheimer's disease. Combining physical pieces with virtual computing functionality creates a captivating gaming experience that aims to increase socialization and hydration as well as challenge the patients cognitively and physically. The application was evaluated in a retirement home to identify not only the benefits and shortcomings of the game but also particularities when developing for Alzheimer's patients.

Kurzfassung

Die Anzahl der Leute, welche an Alzheimer, der häufigsten Form von Demenz, erkranken, nimmt von Jahr zu Jahr zu. Angesichts des anhaltenden demografischen Wandels in den westlichen Ländern und keiner Heilungsmöglichkeit in Sicht wird dieses Problem immer mehr an Relevanz gewinnen. Die Krankheit stellt eine hohe Belastungen für Pflegekräfte, Patienten und deren Freunde und Familie dar. Durch die Beeinträchtigung des Kurzzeitgedächtnisses und einen verminderten Durst vergessen die Betroffenen oft, ausreichend zu trinken, was wiederum ihre allgemeine Gesundheit beeinträchtigt. Der Krankheitsverlauf kann verlangsamt werden, wenn sie geistig und körperlich gefordert sind und gleichzeitig sozial integriert werden. Um die Lebensqualität der Patienten so lange wie möglich aufrechtzuerhalten, müssen zusätzliche Anstrengungen unternommen werden.
Deshalb wurde eine virtuelle Version des Brettspielklassikers "Mensch Ärgere Dich Nichtëntwickelt, die speziell auf an Alzheimer leidende Personen zugeschnitten wurde. Die Kombination von haptischen Gegenständen mit virtuellen Computerfunktionen schafft ein einnehmendes Spielerlebnis, welches darauf abzielt, die Sozialisierung und Hydration zu verbessern, sowie die Patienten kognitiv und physisch herauszufordern. Die Applikation wurde in einem deutschen Seniorenheim getestet, um nicht nur die Vor- und Nachteile des Spiels, sondern auch die Besonderheiten bei der Entwicklung für Alzheimerpatienten zu identifizieren.

Contents

1. Introduction

This first chapter gives an overview about the motivation and necessity of this master's thesis. Following, the concrete goals as well as the chosen approach are presented. Finally, the structure of the thesis is outlined.

1.1. Background

Alzheimer's disease is the most common form (60-70%) of dementia among elderly people [1]. It is estimated that more than one million people in Germany are currently suffering from this illness [2]. With the ongoing demographic change in western countries [3], this number is most likely going to rise in the future. Therefore, the total costs to take adequate care of the patients will drastically increase while due to lower birth rates, the number of care personnel is going to decrease [4]. Initiatives by the government need to be made to help support the people who work in these challenging conditions and new therapy approaches have to be developed as up to this day, there is no medical cure for Alzheimer's disease.

1.2. Problem

While in the early stages of the disease, patients can still participate in their everyday life, this is getting harder and harder as the illness progresses. The symptoms are quite diverse, ranging from a gradual loss of short-term memory to sensory problems like visual identification or physical problems, e.g. walking and talking difficulties, to only name a few. As a result, the affected individuals often isolate themselves more and more, making it tough for their relatives and care-givers to get in contact with them. Another consequence in that regard is the decline of self-care and motivation to live a healthy lifestyle, often leading to dehydration, which also results in various other health problems. Therefore, it is vital to improve the quality of life for patients as much and as long as possible.

1.3. Aim

The aim of this thesis is to develop a new approach that improves the quality of life of Alzheimer's patients. The focus should be on creating social connectedness, improving hydration and increasing cognitive and physical activity. This should be done by engaging them in a playful way.

1.4. Approach

In order to achieve the above-mentioned goals, a comprehensive interdisciplinary literature review is done at first. With the identified strategies and guidelines, a board game is developed on a tablet that increases social interaction between the players and challenges them cognitively and physically. It is specially designed for seniors as well as Alzheimer's patients and therefore offers multiple options for adjustments to best fit their individual needs. The board game can be connected to other peripherals like a Bluetooth dice or a device, that measures the drinking amount[1]. In-game incentives are implemented to motivate the patients to improve their hydration.

1.5. Outline

The first part of this thesis is focusing on the related work by providing the necessary background information as well as giving an overview of the previous work that was done in associated fields. Subsequently, the implementation of the board game is presented. This covers the development process of the game in general and the key concepts that were taken into account from the related work section. Afterwards, a practical evaluation of the game and the results obtained are examined. In the final part, a conclusion of the thesis and an outlook on the future research is provided.

[1]previously developed on the university chair [5]

2. Related work

In this chapter of the thesis, a comprehensive literature review is carried out in all areas that benefit the development of the application. Hence, an overview about the Alzheimer's disease (AD) is given first to inform the reader about the origin, impact and particularities of this illness. Afterwards, the topics of age related decline and hydration are discussed. Furthermore, the importance of cognitive stimulation for AD patients and related work about the application development for this user group are presented. In the final sections of this chapter, we focus on the topic of hybrid tabletop games and evaluation methods.

2.1. Alzheimer's disease

Alzheimer's disease is a slowly progressing, neurodegenerative illness and the most common form of dementia, accounting for roughly 2/3 of all cases [1]. Dementia is an umbrella term for a number of symptoms. Affected patients suffer from impairment of memory as well as other cognitive domains (see section 2.1.4) [6]. In 2017, more than 50 million people worldwide were diagnosed with dementia. It is therefore one of the major causes of dependency and disability among the elderly [7].
While dementia describes the symptoms, Alzheimer's disease is their cause. Some forms of dementia, e.g. caused by drug interaction, may be reversible but Alzheimer's is not. Starting slowly, the symptoms gradually get worse over time, making it harder and harder for the affected people to take part in the activities of their daily life [8].

2.1.1. Cause

Up until this day, the direct cause for Alzheimer's has not been found. In only 1-5% of all cases, genetic differences have been identified [9]. Furthermore, different hypotheses exist that might explain the cause but have not yet been proven, with genetic [10], cholinergic (reduced synthesis of the neurotransmitter acetylcholine) [11], amyloid (extracellular amyloid beta deposits) [12] and the tau-hypothese (tau protein abnormalities initiate the disease cascade) [13] being the most popular ones.
Even though the cause remains unclear, it is certain that the disease leads to a progressive loss of nerve cells. This results in a size reduction of specific brain regions, destroying up to 20% of the total brain size. The typical feature of Alzheimer's disease is that the death of nerve cells is accompanied by the formation of abnormally altered protein fragments, which are deposited in the brain in the form of fibrils. These are the neurofibril bundles that were first described by Alois Alzheimer [14] in 1907. These clusters, which can be detected within many nerve cells, consist of tau proteins, a normal component of the cytoskeleton.

The second pathological protein deposit characteristic of Alzheimer's disease is the plaque found between the nerve cells. They consist of a central amyloid nucleus surrounded by pathologically altered nerve cell processes and supporting cells [15].

2.1.2. Diagnose

A diagnose of Alzheimer's is not as definite as compared to other illnesses because it shares a lot of symptoms with other forms of dementia. Medical imaging methods like CT (computer tomography) or MRI (magnetic resonance imaging) can help to exclude other diseases. But an unambiguous diagnosis can only be conducted post-mortem, when the brain tissue is examined.

A common diagnose tool is the use of neuropsychological tests such as the mini–mental state examination [16]. To unify the criteria, the Alzheimer's Disease and Related Disorders Association (ADRDA, now called Alzheimer's Association) and the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) created a common set for diagnosis in 1984. The so called *NINCDS-ADRDA Alzheimer's Criteria* has proven to be reliable and valid as Blacker et al. could show [17]. It was updated in 2007 to account for the recent scientific knowledge and medical improvements [18].

Often, persons suffering from Alzheimer's disease are not aware of their deficits [19]. Interviews with family members and care-givers can therefore be helpful in classifying the disease. These may, however, not always be reliable as other research has shown [20].

2.1.3. Stages of Alzheimer's disease

There is no delimiting distinction between the different stages of the Alzheimer's disease, the transition is rather gradual. Due to the irreversible nature of the disease, the progression through the stages is one-way, from *pre-dementia* to *advanced*, as described by Förstl et al. [21].

Pre-dementia

Only mild cognitive impairment like difficulties to learn new information can be observed. The ability to plan ahead can be reduced or memory problems occur. But in general, the person is still able to perform Activities of Daily Living (ADL). While the reported problems may be the first signs of Alzheimer's disease, this might also be caused by mere age-related decline or other, often reversible, diseases.

In addition to the aforementioned symptoms, "non-cognitive alterations of behavior, including social withdrawal and depressive dysphoria, may be present five years before a clinical diagnosis is made" [21, p. 1].

Early

In contrast to the *pre-dementia* state, significant impairment of memory and cognitive functions exist. During this early stage, also called *mild dementia* stage, the person is struggling to perform complex tasks that require the ability to plan, judge and organize. As perceptional

problems and spatial disorientation occur, driving a vehicle becomes a high risk situation. The first difficulties in communication arise and ADL become increasingly harder to handle. This is often the first time the Alzheimer's disease is diagnosed. Regarding the physical abilities, subtle impairment "may remain unnoticed on standard neurological experiments" [21, p. 2]. Non-cognitive alterations as described in the *pre-dementia* stage can increase, ranging from short phases of emotional disturbances to full-blown depressive episodes.
At this stage, most of the patients are still able to live a relatively independent life, but more and more assistance is needed as the disease progresses. Support can often be provided by family members and a clinical stay is not necessary.

Moderate

This stage is often the longest of all AD stages and can last for many years. The short-term memory is now severely impaired, which creates the impression that the patients are living in the past. The ability to process new information decreases further as well as logical reasoning, speaking, writing and reading skills. Patients tend to lose focus and basic tasks like dressing, eating or ADL in general cannot be performed reliably. Due to cognitive and perceptual impairment, familiar faces are hard to recognize. At this stage, one third of the patients develop illusionary misidentifications and other delusional symptoms. For 20%, this even worsens to hallucinations, often of visual form. Patients also develop activities of restlessness like wandering and hoarding [21].
As patients get more and more confused, they also tend to lose control of their emotions. Sudden outbursts of anger occur, often accompanied by physical and verbal aggression. This puts a high strain on the relationship to family members and/or caregivers. When restlessness, disorientation and incontinence occur frequently, families, who took care of their relative, often decide that professional care in a clinical stay is necessary.

Advanced

At this stage, also called *severe dementia stage*, cognitive functions are almost completely destroyed. Patients cannot express their needs because communication is reduced to simple phrases and words. They are, however, still able to receive and return emotional signals. Prolonging episodes of restlessness, aggression and complete apathy take turn. The patients now need assistance in basic motor functions like chewing and swallowing. Primitive reactions like grasping can interfere with caring activities of the medical staff. In the end, the patients are completely bedridden and barely any signs of brain activity can be observed. "Pneumonia followed by myocardial infarction and septicaemia are the most frequent causes of death in AD" [21, p. 3].

2.1.4. Classification of symptoms

According to Lapointe et al. [22], Alzheimer's disease symptoms can be classified into the following categories: Memory impairments, Deficits in executive functions, Aphasia, Agnosia,

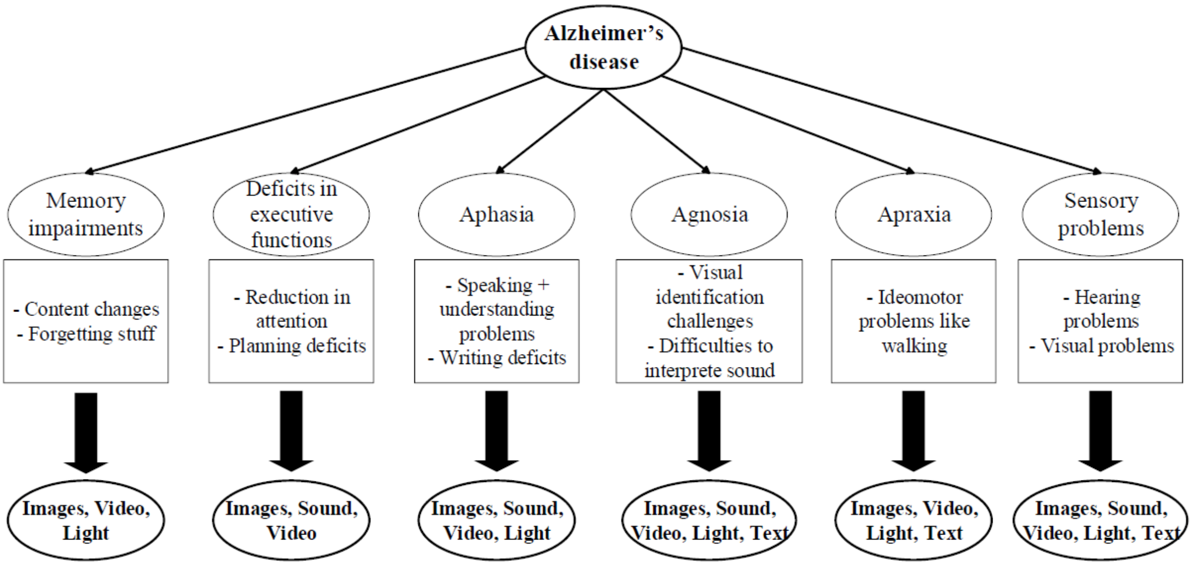

Figure 2.1.: Alzheimer symptom classification as summary

Source: [22, p. 4]

Apraxia and Sensory problems (See Figure 2.1). The individual levels of impairment differ from patient to patient, but can also depend on the day form. Therefore, it makes sense to use different ways to communicate with the patients, e.g. sound, images, text, video, and light patterns (recommended by Lapointe et al. [22]). It can also be useful to use these concurrently. But one needs to ensure that this does not confuse or overtax the patients.
Another problem identified by [23] in this context is the segmentation of the symptom categories. If a person has difficulties to identify objects visually, this symptom would be mapped to the Agnosia class. In this particular case, it could make sense to use sounds or music to counter the visual deficits. If however it is only known that the person is suffering from Agnosia, this could also imply an auditory decline where the interpretation of sounds is impaired. Here, it is obviously not very helpful to make excessive use of sounds or music.
Going one level lower, visual impairment could mean difficulties in identifying objects. Replacing complex objects with written words would aid the patient in this case. But if difficulties in identifying letters arise, images can a helpful alternative.

2.1.5. Treatments

Up until this day, there are no known medical or therapeutic cures for stopping or even reversing the progression of Alzheimer's disease. Current treatments therefore focus on mitigating the symptoms and hence improving the patients' quality of life as well as assisting the caregivers [23]. These treatments can be divided into the categories pharmaceutical, psycho-social and caregiving.
Although there exist a number of prevention methods regarding medication, lifestyle and

diet that are linked to a reduced risk of AD, there is no definite evidence to support these claims [24].

2.1.6. Costs

When it comes to the total global cost of the Alzheimer's disease, this is quite difficult to estimate as there are many different costs involved and the distinction between dementia numbers and Alzheimer's numbers in the reports are not always clear. The "World Alzheimer Report 2018" published by Alzheimer's Disease International [25] predicted it to be around one trillion USD in 2018 (including the cost incurred by family members), and this is forecast to double by 2030. Even though these numbers might not be completely accurate, they emphasize on which scale this disease affects the global population.
The cost can be divided into direct medical (e.g. nursing home care), direct non-medical (e.g. in-home day care) and intangible cost (e.g. lost productivity of patient and caregiver). The long-term health care is estimated to correspond to 2/3 of the total cost [26]. Even though the global cost for informal care is difficult to quantify, it is estimated to be at about 82 billion hours per year [25].
What is even harder to estimate, but should also be taken into account, is the emotional cost to family members and caregivers. This may be in form of emotional distress or a decline of mental and physical health due to their caring effort [27].

2.1.7. Current state in Germany

In 2017, 1.7 million people in Germany suffered from dementia. It is estimated that more than two thirds of those can be attributed to the Alzheimer's disease. With the ongoing demographic change and no medical cure in sight, these numbers are most likely going to increase. Even when we take into account the people who pass away due to the disease, the total number of Alzheimer's patients increases by more than 100 every day. Predictions are that by 2050, it will hit the 3 million mark [2].

2.1.8. Communication

Due to the aforementioned impairments of people suffering from AD, a high focus should be put on communication. The capability always depends on the individual state, differing from patient to patient and from day to day. In the literature of Alzheimer's disease, numerous guidelines have been developed that try to establish general rules to facilitate communication. In this regard, Small et al. [28] identified 10 reoccurring strategies (see Figure 2.2). It should be noted that strategies 1-7 are recommended in at least 7 out of 10 researched sources, in contrast to strategies 8-10 which were only recommended 5 times or less (as can be seen in Figure 2.2). This might imply, that the first 7 strategies are of greater value.
However, literature exists which disagrees with strategy number 7 to prefer closed-ended questions over open-ended questions. To test whether this strategy is supported by empirical data, Tappen et al. [29] analyzed 35 transcribed 30-minute interviews with 23 patients

Publication	Recommended strategies* 1	2	3	4	5	6	7	8	9	10
Alzheimer's Association (1990)	X	X	X	X	X	X		X	X	
Alzheimer's Association (2000)	X	X	X	X		X		X		
Alzheimer Canada (1991)	X	X	X	X	X		X		X	
Alzheimer Canada (1996)	X	X	X	X	X	X	X		X	
ADEAR (2000)	X	X	X	X	X		X			
B.C. Ministry of Health (1992)	X	X		X		X		X		
Dippel and Hutton (1988)	X	X	X	X	X	X	X		X	
Mace and Rabins (1991)	X	X	X		X	X	X		X	
Ostuni and Santo-Pietro (1991)	X	X	X	X	X	X	X	X		X
Rau (1993)	X	X	X	X	X	X	X	X		X
Total (out of 10)	10	10	9	9	8	8	7	5	5	2

*Strategies are in rank order:

1. Use short simple sentences.
2. Speak slowly.
3. Ask one question or give one instruction at a time.
4. Approach the patient slowly and from the front; establish and maintain eye contact.
5. Eliminate distractions (e.g., TV, radio).
6. Avoid interrupting the patient; allow the patient plenty of time to respond.
7. Use "yes/no" rather than open-ended questions.
8. Encourage circumlocution (ask the patient to "talk around" or describe the word they are searching for).
9. Repeat messages using the same wording.
10. Paraphrase repeated messages.

Figure 2.2.: Strategies recommended in literature for AD caregivers

Source: [28, p. 272]

suffering from moderate to advanced Alzheimer's. They investigated what type of questions elicits longer/more relevant responses and which strategies facilitate the maintenance of a conversation and the expression of feelings by the AD patients.
Their results suggested that subjects were able to respond similarly to both open-ended and closed-ended questions. Even a trend to longer responses was obtained with open-ended ones. While closed-ended questions may be the preferred choice when asking for specifics or when aiding a patient with their ADL, open-ended questions can help to build a better relationship and talk about emotions. Therefore, both types should be used, depending on the situation.
In addition to this insight, they observed the following communication strategies which helped to facilitate the expression of feelings and concerns:

1. Broad openings: By using a general statement like "Tell me how you are feeling today" as an opener, the individuals were able to respond in a variety of ways and to the best of their abilities. This allowed the patient to share as much information as he wants and likes to. Specific questions on the other side did sometimes trigger emotions of shame or anger, as the person was made aware that she/he could not remember certain facts or memories.[1]

2. Speaking as equals: The communication should be done on eye level and as equally valued, not with a perceived hierarchy between the participants. One should be open to learn from the individuals and let them know.

3. Establishing commonalities: Discussing shared interests and perceptions helps to establish a bond between the participants and creates a feeling of connectedness and friendship.

4. Sharing oneself: Opening up and letting the patients know about the caregiver's feelings elicited emotional responses in the AD individuals as well. This is not limited to current events but can also be done via sharing of personal stories of the past.

Even though it can sometimes be difficult to follow a patient's story due to verbalization issues, imprecise articulation or cognitive errors, one should try to recognize the topic that was introduced by the patient, ask clarifying questions, encourage the other person verbally and non-verbally as well as summarize the spoken to help maintain the conversation. If the person still does not want to continue, accept it, let him/her know that you understand the situation and suggest another topic or activity.
To support the communication, one should add gestures or visual cues when communicating with a person that has Alzheimer's disease [30]. Instead of only asking a person, if he/she needs to visit the toilet, also point towards it to make your intention clear. When examining communication strategies, it is important not to forget about nonverbal methods like body language, touch and facial expressions. Sometimes an understanding smile can help where words can not.

[1] It can sometimes be helpful to introduce oneself (again) as the AD patient might have forgotten.

2.2. Age related decline

There are a variety of problems that frequently occur in the aging process. Holzinger et al. [31] are classifying them into the following categories:

- Cognition: This includes a reduced attention span, memory impairment and a reduced cognitive performance.
- Motivation: This factor can decline if there is a users distrust in his/her own capabilities or if the resulting benefits are not obvious. Another reason for a decreased motivation might be that the task to be performed is too complex, therefore overtaxing the user.
- Physical: Common effects are slower response times, impaired fine motor skills and diminished coordination.
- Perception: This includes all types of sensory impairments like reduced color vision, problems with illumination or the ability to detect and localize sound.

Apart from *motivation*, Ownby et al. [32] obtained the same categorization. The design guideline chapter 2.6.5 in this thesis will therefore mainly focus on the categories *cognition*, *perception* and *physical/motoric* while *motivation* guidelines will be discussed separately in section 2.6.6.

2.3. Color weakness/blindness

A common form of perceptive impairment is color weakness or color blindness. This describes the inability to distinguish between similar colors or even see any colors at all. In literature, color weakness and color blindness are often used interchangeably.
Males are more susceptible due to having only one X-chromosom [33]. The most common form is the green-typed colorblindness, diagnosed at roughly 8% of males and 0.5% of females, followed by red-typed and blue-typed colorblindness [34]. These types are inherited and the result of gen defects. They can however also occur or deteriorate with ongoing age [35].
Alternative color schemes, e.g. the "Colors optimized for color-blind individuals"[36, p. 441] by Wong, were developed to account for this type of impairment. While these alternative colors may be helpful for people suffering from partial color blindness, it does not assist those that cannot perceive any colors at all. It is therefore recommended to additionally use different forms or symbols for distinction.

2.4. Hydration

Mild forms of dehydration are actually quite common among the population, causing fatigue, dizziness or headaches. But as the level of dehydration increases, it can also lead to more advanced physical and mental deterioration. If not counteracted, this can ultimately lead to death [37]. The risk of not drinking sufficient water is increased for the elderly due to a variety of age-related reasons [37]:

- decreased thirst.
- changes in the water and sodium balance. This often worsens due to various impairments of the elderly and the resulting medications.
- decreased total amount of body water.

In addition to these physical factors, Lehman et al. [38] mention further psychological factors like poor initiation, lack of motivation or poor monitoring. But also other diseases and the hence needed medication influence hydration levels negatively. For people suffering from Alzheimer's disease, mood swings and distractions are an additional burden. As the disease progresses, all these effects are worsening. This also puts a high workload on the caregivers who need to ensure and keep track of adequate hydration.

2.4.1. Drinking devices

It is important to support the elderly and Alzheimer's patients to maintain healthy hydration levels. Previous research on the "Chair for Computer Aided Medical Procedures & Augmented Reality" at the TU Munich developed a *weight-based drinking detection* [5]. This device looks like a bigger version of a beer mat at first glance (see Figure 2.3). As the name suggests, it measures the drinking amount via the difference in weight with an implemented scale. The values are transmitted to a database that stores information about the users and their previously measured drinking volumes. The device is also equipped with a small LED screen as well as vibration capabilities that help to inform the user about necessary interaction. Different prototypes were tested with a high focus on hygiene, safety, expandability, interaction and daily usage. They should also be able to handle different cups as testing could show that the elderly prefer to use their own drinking cups.

To motivate the elderly in a playful way to drink more, different *serious games* (see section 2.6.3) were developed that incorporated these drinking devices in their game flow. After a certain time, a reminder is displayed to the user. The player can only continue with the game if he takes a sip from the cup. In addition to reoccurring reminders, these notification could also be triggered by in-game decision.

2.5. Cognitive stimulation and Alzheimer's disease

In the past, there have been multiple studies that examined the relation between cognitive stimulation and developing dementia. For example, the results of Wilson et al. [39] suggest that "frequent participation in cognitively stimulating activities is associated with reduced risk of AD"[39, p. 1]. When investigating the effect of crossword puzzles, playing games and reading on the risk of dementia, Doyle et al. [40] came to the same results. Furthermore, seniors in a 20 year follow-up study who regularly played board games showed less cognitive decline and less depression [41].

To summarize these findings, the statement is that "actively participating in cognitive leisure activities during mid- or late life may be beneficial in preventing the risk of Alzheimer's

Figure 2.3.: The weight-based drinking detection device

Source: [5, p. 15]

disease and other dementias in the elderly; however, the evidence is currently not strong enough to infer a direct causal relationship" [42, p. 17]. Other review-studies, e.g. the review of 52 studies regarding leisure activities, cognition and dementia that was performed by Wang et al. [43], obtained similar results. "A protective effect of mental activity on cognitive function has been consistently reported in both observational and interventional studies. The association of mental activity with the risk of dementia was robust in observational studies but inconsistent in clinical trials" [43, p. 482].
A commonly mentioned flaw is the ambiguous definition of "cognitive stimulation" and "leisure activity". There is a need to standardize these regarding "frequency, intensity, duration and the type of activity; and also that the cognitive test batteries and the definition of cognitive decline are harmonized/standardized" [43, p. 490]. Additionally, follow-up times of the studies should be prolonged to achieve more detailed results.
While most of the identified research focused on the question whether cognitive activity can prevent or delay the development of dementia, others investigated how leisure activities affects the Quality of Life (QoL) of those that are already suffering from dementia. In a pilot study, Maci et al. evaluated "the effect of cognitive stimulation, physical activity, and socialization on patients with AD and their informal caregiver's QoL and mood"[44, p. 107]. Therefore, they divided fourteen AD patients into an active treatment group and a passive control group. The passive group should simply carry out their normal activities as usual. The active group on the other hand went to the gym five days a week, participated in group discussion, engaged in cognitive training regarding orientation, memory, executive skills as well as language and were encouraged to talk and sing on their way from and to the gymnasium. When the study ended after three months, "a significant improvement in apathy, anxiety, depression, and QoL"[44, p. 110] could be observed. Additionally, the caregivers showed "a significant improvement in their mood and in their perception on patients' QoL"[44, p. 110]. In contrast, the mood and quality of life of the control group as well as their caregivers

worsened during this time. In their conclusion, Maci et al.[44] once more underlined the importance of socialization in their experiment.

2.6. Application development for seniors and Alzheimer's patients

Playing casual video games has been shown to increase the mood and decrease symptoms of stress. In their research, Russoniello et al. [45] could prove that different games affected brain waves in unique ways, however all of them were consistent with increased mood. This was supported by tracking of the *Heart Rate Variability* (to assess autonomic nervous system stress) as well as the reported feedback before and after playing each game via a *Profile of Mood States* assessment.
But applications can provide even more benefits, especially for seniors and people suffering from Alzheimer's disease, as this section will present.

2.6.1. Focus group

It should be stated that the occurrence of Alzheimer's disease does not necessarily imply an old age of the patient. However, less than 2% of all diagnosed patients are younger than 65 years [2]. Therefore, most of the research as well as this thesis mainly focuses on elderly AD patients.
Eichhorn et al. [23] distinguish the elderly into two groups: the *active* and the *passive participants*. The first group is still taking part in their activities of daily living. As they are driven by *intrinsic motivation* (see section 2.6.6), it is relatively easy to motivate them to use mobile devices. AD patients in their early stages often fall into this category of *active participants* as Zmily et al. [46] could show.
On the other hand, we have the *passive participants*. Their restraint can come from a variety of reasons like the inability to use the application, a fear of breaking the unknown devices or a simple disinterest. *Extrinsic motivation* (see section 2.6.6) is needed to address this group.
As the requirements and needs of this focus group are quite diverse, the common *One fits all* approach should be substituted with a *2- or 3 for any* approach [47]. A high focus should be put on design, usability and functionality, also taking into account the different implications of age-related and AD-related decline.

2.6.2. Types of application development

Previous research [6] [46] [48] [49] could already show that not only elderly in general but also Alzheimer's patients in particular were interested in and could benefit from electronic devices and playing video games. It is a good active alternative to the otherwise often passive and one-sided activities like watching TV. Additionally, "most of the researchers in the diverse area of application development for elderly people came to the conclusion that games or gamification of daily routines have a positive impact on cognitive abilities and can enhance social connectedness and mental health"[49, p. 2].
According to Ijsselsteijn et al. [50], there are four areas of design opportunities for games

for seniors: *Relaxation and Entertainment*, *Socialization*, *Cognitive stimulation* and *Motor skills training*. Games that target multiple of these areas are often referred to as *Serious Games* (see section 2.6.3). Due to the aforementioned diversity of the elderly, targeting all of these aspects simultaneously may be next to impossible. For an average 70-year old person, playing a simple dice game might not be very demanding cognitively and physically. But for a person suffering from Alzheimer's disease or another type of mental/motor impairment, this might very well be the case.

2.6.3. Serious Games

After reviewing the associated literature, multiple different definitions for the term *Serious Games* could be identified. This dates back as far as 1970, where Abt [51] introduced the term to describe games that improved education in and outside of the classroom. It was later redefined by Sawyer et al. [52] in 2002 as "the idea of connecting a serious purpose to knowledge and technologies from the video game industry"[53, p. 119]. Or as Michael et al. [54] define it: "Games that do not have entertainment, enjoyment or fun as their primary purpose"[54, p. 21]. Even though the definitions differ in wording, the general idea remains: video games can provide more than mere entertainment.
Serious games can be related to a variety of fields, e.g. education, healthcare, politics or communication. The multitude of these fields might explain why so many different definitions exist, because each one has a different focus. These games help to teach concepts and knowledge of the respective discipline in a playful way. Sometimes, it is not possible to directly learn from real world situations due to cost, safety and other factors. Serious games can then simulate these environments in a controlled and repeatable way.
In addition to games that facilitate learnings for the work environment, serious games can also provide benefit in other ways. For example, *Eldergames* [55] was an EU-funded project in 2006 that aimed to develop games with therapeutic value for the elderly, while improving cognitive, functional and social skills.

2.6.4. Rules of thumb for a gaming platform targeted at seniors

Vasconcelos et al. [56] studied, what aspects have to be considered when developing a gaming platform for the elderly that stimulates them cognitively and improves their well-being. In this context, they created ten general rules of thumb.

1. Usage of direct input devices. Mobile devices with touch screen, e.g. a tablet, should be the preferred tools instead of pcs with keyboard and mouse. This can reduce computer anxiety which is quite common among seniors.

2. Mobility. The elderly can use the application in a comfortable position and environment if it is deployed on a mobile device like a tablet or a mobile phone.

3. Senior adapted interface. The design should account for aspects of age-related decline (see section 2.2).

4. Expandability. This allows to integrate new games or peripherals that the user can interact with.
5. Variety. Based on their individual preferences, seniors can choose from a multitude of games.
6. Customization. The games can be customized with content from the user, e.g. by using pictures and integrating them in the game-flow.
7. Instant Feedback. This lets the user know, what impact his actions have on the game. Delaying the feedback might disguise, which action led to which result and confuse the elderly.
8. Engaging goals. The goals should be clear and challenging to keep the senior engaged.
9. Immediate rewards. As cognitive stimulation, motoric engagement and social interaction as benefits might not be recognizable at first, it is important to motivate the users with immediate rewards.
10. Social interaction promotion. Engaging with other people should be promoted by the platform as social isolation is a common problem among the elderly and highly affects their quality of life.

These suggestions are, however, of a fairly general nature. The following two sections 2.6.5 and 2.6.6 will thus take a closer look into design and motivation.

2.6.5. Design guidelines

Eichhorn et al. [23] compared and summarized the current literature and created guidelines regarding application design for seniors and Alzheimer's patients. The current section 2.6.5 will therefore be based on their work.

Current flaws in the design approach

Up until today, the common misconception still exists that the elderly are not interested in electronic mobile devices or the applications and games associated with them. This might also be one of the reasons, why there has been limited development for this user group [57]. But according to Zickuhr et al. [58], many elderly are already equipped with mobile devices, even passing the distribution of PCs.
Section 2.6.2 could also show that the elderly are in fact quite interested in new technology but often do not see the associated benefits, therefore missing motivation to use it, or the applications and devices are simply not designed for this diverse user group. There has been some focus on an adapted design for the elderly in the past, e.g. big and clunky "senior" phones. Kobayashi et al. [59] criticize that these are only of limited use as their big buttons might help with visual and haptic problems but at the same time result in a smaller screen. Another downside is the inability to install (health) applications or use common features

like cameras, excluding the elderly from communicating with the younger generation via messenger applications.
The diversity of the elderly (as discussed in section 2.6.1) creates the need for a new design approach different to the common *One fits all* approach [57]. Alternatives could be the *2- or 3 for any* approach suggested by Lorenz et al. [47] or the *Ability-based Concept* by Wobbrock et al. [60], which focuses on the individual abilities of a person.
Even though the user group is so diverse, common problems exist for a majority of them. Often, the text is too small to be readable, as older people quite often suffer from visual impairment. Besides, due to motoric problems and no/limited experience with touchscreens, a gap exists between the intended and the actual location that is clicked [59]. This allows to create some general design guidelines for the elderly in general and Alzheimer's patients in specific, following the recommendations by Eichhorn et al. [23]. These guidelines will be divided into cognition, perception and motor abilities, following the categorization from section 2.2.

Cognitive design guidelines

It is recommended to use multiple ways of communication in addition to text when giving instant feedback. For example, the user finishes a task, which results in a text box popping up that shows the result. To further get the attention from the user, the device could vibrate and omit a sound effect.
As an input method, touchscreen is recommended (see section 2.6.4). As it makes use of hand-eye-coordination, this form of direct input feels natural to even completely inexperienced users. Even multi-touch-gestures like pinching could be performed with fairly little training, but no more than two fingers should be used at a time [59].
To make the elderly feel more comfortable, "the interface should offer familiar elements and an environment that connects to known experiences"[23, p. 13]. By simplifying the flow of tasks, the cognitive workload is reduced, therefore making it easier for the elderly to participate in the game. In addition, a tutorial-like approach and continuous advice in form of a companion has proved to be helpful To further reduce the complexity (see section 2.6.7). If fitting, this advice should be given in multiple ways, e.g. audio in addition to text as it is done in the butler system created by Castilla et al. [61]. Since a butler is already associated with help, this companion connects to known experiences and "delivers the basic instructions in text form and communicates further explanations to reinforce the understanding" [23, p. 13]. Finally, an auto-pilot feature is recommended which takes control over the game if no action is done or a player gets stuck. This could also help to catch the interest of *passive participants*.

Additional cognitive guidelines for Alzheimer's patients
Zmily et al. [46] suggest the following general standards when developing an application for patients with Alzheimer's disease:

- Use simple language.
- Repeat instructions several times.

- Divide instructions into simple steps given one at a time.
- Allow ample of time to respond or react.
- The messages should be as short as possible. Split them up if necessary.

Furthermore, it is useful to integrate playful tools into the application that train the memory of the patients. As their memory is often impaired, reminding the patients about the actual use of the device restores motivation. It is recommended to not only focus on memory, but also on planning skills, initiative and perseverance, to further improve the cognitive abilities of the users.
A high emphasis should also be put on what kind of information is displayed at which time. When simply displaying the time without any additional information like morning/evening or the weekday, this could confuse patients in the case of a bright summer evening or a dark winter afternoon. Another negative example of misplaced information would be to confront the patient with a forgotten relative, which in turn could result in bad feelings and depression.
The component of in-game help was already addressed in the beginning of section 2.6.5. This becomes even more important for Alzheimer's patients. Most serious games still lack the ability to compensate for cognitive errors. As this kind of "failure" can be quite demotivating for the user, the application should assist him or her in passing the challenge, for example through a dynamic difficulty adjustment. Preparation and necessary configuration should be reduced to a minimum.
When thinking about the kind of input, natural interfaces like the Wii have also shown to be quite helpful and easy to use. They should, however, not focus on the whole body as physical impairment is quite widespread among AD patients. As already mentioned in section 2.6.5, vibro-tactile feedback should be integrated in addition to visual and audio feedback as it has been proven as an effective memory aid.

Perceptual design guidelines

One of the first problems that come to mind when thinking about the elderly using applications is that font size and interactive buttons are too small (up to 48% of study participants in [62]).Darroch, Goodman, Brewster, and Gray [63] therefore recommended to use a font size of at least 12pt to 14pt. For buttons, the font size should be at least 16pt as Caprani et al. [64] suggest. Regarding the type of font, sans-serif font types seem to be advantageous as the characters can be recognized and distinguished more easily.
Buttons should be at least the size of a 20 mm x 20 mm square, or have the length of 30mm [64]. Other touchable targets should not be smaller than 8 mm [59], but better accuracy can be achieved when they are bigger than 12mm and located in a corner [65]. They should also be clearly distinguishable from other game elements. Moving text or animations as well as colored text on colored background should be avoided as it reduces readability. Regarding the color selection, one should also address color-weakness or -blindness, as this is quite common among the elderly (see section 2.3). Choose alternative colors or models to compensate for

this.
As already proposed in section 2.6.5, multiple ways of feedback in addition to text like vibration or simple speech messages can be helpful.

Additional perceptual guidelines for Alzheimer's patients
For Alzheimer's patients, the decline of perception is often amplified. The design should account for this by using simple scenes that offer assistance to the player. Simple textures with warm and bright colors create a friendlier atmosphere and can be distinguished more easily than cold and dark colors. Combined with a well-lit display and a high contrast, this will create good luminosity and facilitate the usage.
Additionally, a 3D perspective connects to the real life experiences of the patients and should therefore be the perspective of choice. Creating a good depth perception with clear borders as well as choosing a distinctive color system helps to distinguish the in-game elements from the background. This object distinction could be supported by using different outline thickness and it should be consistent throughout the whole application.
Since the general perception is impaired, it makes sense to use the full potential of the mobile device via multi-sensory interactions for output and input, in the form of text, audio/speech and vibrations.

Motoric design guidelines

With an increasing age, the motoric accuracy often declines. This maybe due to vision difficulties, muscular problems or disease-related symptoms like shaking, to only name a few. One should account for these by providing a button spacing of 3.17 mm to 12.7 mm [64]. Values below this size reduce the accuracy while values above reduce the speed of the selection. In a user evaluation with older adults [66], 6.35 mm was the spacing preferred by the elderly that also had the highest accuracy. In addition, border detection helps to inform the user, when he or she misses a button.
Regarding the input, simple gestures like swiping and zooming were found to be easily usable. Advanced gestures like pinching with panning or tapping however are more challenging [59]. Kobayashi et al. [59] identified the following difficulties for tapping: First, tapping on small objects was difficult as the intended point of touch differed from the registered point of touch. Participants tended to touch right of the target. Second, some attendees pressed the touch for a prolonged time instead of a mere tap.

Additional motoric guidelines for Alzheimer's patients
Because of the cognitive decline combined with the fact that the Alzheimer's disease also negatively impacts the motoric capabilities of the patients, different input gestures cannot be performed precisely. Simple gestures should only be used sparsely and when needed.

Summary of all design guidelines

Taking all the aforementioned information about design into account, Eichhorn et al. [23] created the following design guidelines (see Table 2.1).

Cognitive working memory, processing speed	**Perceptual** vision and hearing decline	**Motor Abilities** shaking, decrease in muscle power
Companion/Avatar	Iconography from their world perspective	Border detection with feedback
Linear navigation like a tutorial	Clear label design and shapes to differentiate labels/buttons	Border space for buttons etc.: min. 3.17 mm and 12.7 mm
Autopilot	Connection to known experiences	Avoid gestures
Language selection	Button size: min. 20x20mm (square) or min. length: 30mm	
Simple, precise language with short and repeating instructions	Font size buttons: min. 16 pt	
Extended time information	Font size text: min. between 12 pt and 14 pt	
Avoid the need for configuration by the Alzheimer patient	Gestures (avoid tapping)	
Difficulty settings system for the individual user (flow zone)	Haptic feedback; clear distinctive sound	
Highlighted key words in instructions	High contrast between elements	
	Not all colors are useful e.g. considering colorblindness	
	Audio simple and clear speech	
	Standardized color schema	
	Feedback for a button press	
	Shader for borders	
	Special focus on depth perception	

Table 2.1.: Summary of the design guidelines sorted in three categories *Cognitive*, *Perceptual* and *Motor abilities*, ■ additional Alzheimer recommendations, ■ should not be used in the context of an advanced state of Alzheimer's disease (canceled out finding), ■ the need for future research

Source: [23, p. 16]

2.6.6. Motivation guidelines

Motivation is quite often overseen or not given the adequate importance. Developers tend to focus on the improvement of design elements like larger fonts and buttons as well as other key points mentioned in 2.6.5. But when gathering feedback from the elderly, it is quite often similar to statements like *"I'm too old for this!"* or *"Why would I use it?"*.
What good is the design of an app if the users do not see the resulting benefits of using it? What if they have no *motivation* to use it?
This section will therefore take a deeper look into the concept of motivation and how this influences application development.

Types of motivation

The topic of motivation is quite complex. We will merely discuss the general concepts introduced by Deci et al. [67], who distinguish between *intrinsic* and *extrinsic* motivation.

Intrinsic motivation
As the name already suggests, intrinsic motivation comes from within. The user is motivated because of personal interest and needs. According to Eichhorn et al., "*Connection* and *Emotional* are deeply related as *Intrinsic* motivating elements"[23, p. 11]. *Connection* in this context describes the relationship to a memory on a personal level. *Emotional* means that it triggers some kind of emotional response. This may be curiosity, because of using a new technology, or joy, due to an appealing application design.

Extrinsic motivation
Extrinsic motivation on the other side comes from outside of the individual. This might be the comparison with other human beings or *Social* influence in general. When you see people in your environment who are putting effort into a healthy lifestyle, you might reconsider some of your choices regarding nutrition and exercise. Another powerful extrinsic motivation tool is to set *Goals*. Breaking a target down into small sub goals helps to keep the user motivated. For example when losing weight, 10kg seem like a lot but when you break it down to 1kg per month which is further broken down to a certain kcal count per day, this total weight loss of 10kg becomes manageable. Goals should conform to common criteria like SMART (Specific, Measurable, Attainable, Relevant/Realistic and Time bound).
A summary of the connections between the motivating elements can be seen in Figure 2.4.

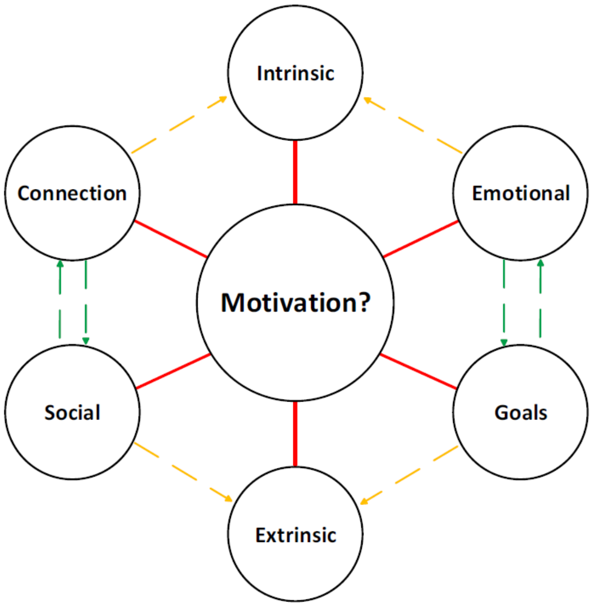

Figure 2.4.: Summary of Motivation Guidelines and connections between motivating elements

Source: [23, p. 12]

Motivating seniors to live a healthier lifestyle

After we have broken down the general concept of motivation, we take a closer look into how mobile devices can motivate the elderly to live a healthier lifestyle. To achieve behaviour change, there are three wanted outcomes as proposed by Oinas-Kukkonen et al. [68]:

1. Reinforcement of existing positive attitudes, hence preventing their change.
2. Change of a response to an issue to generate a better outcome.
3. Shaping of a pattern for an outcome, where a reaction is missing.

West et al. [69] distinguish between three factors that influence the behaviour of an individual, therefore having an effect on their health:

1. Predisposing factors: Antecedents to behaviour, such as knowledge, attitude, beliefs, values, and confidence or motivation.
2. Enabling factors: Aspects that facilitate behaviour change, such as teaching skills, providing a service or tracking progress.
3. Reinforcing factors: Factors that provide a reward or feedback for behaviour, such as interaction with family, friends (social networks), or health professionals (trainer).

Predisposing factors
Why do the elderly live an unhealthy lifestyle? This can be due to a variety of reasons. As already written in section 2.2, a general decline of capabilities can be observed. Motoric and perceptional impairment make activities of daily living harder for them, even more so when it comes to exercise or other strenuous activities. Combined with a cognitive decline that influences their eating and drinking habits, this often leads to a secluded lifestyle, therefore worsening the effects of aging. Depression is also quite common among the elderly, which further increases this tendency of self-destructive behaviour.

Enabling factors
How can we trigger a behaviour change in the individual? When doing research about advertisement for the elderly, Williams et al. [70] discovered that elderly are preferring emotional, subjective and evaluative ads. They are also highly influenced by their personal values and experiences. A product for the elderly should therefore connect to some kind of emotional goal (e.g. love, care) to be appealing.
As their experience with new technology is generally low and cognition can be impaired, elderly users are often overwhelmed by the complexity of the tasks. In an effort to not demotivate seniors, tasks should be in the so called "flow zone". This describes "the feeling of complete and energized focus in an activity, with a high level of enjoyment and fulfillment" [48, p. 245]. Challenges should hence not be too demanding but also not too easy as they would otherwise bore the user. To provide adequate assistance, B. Bouchard et al. [48] suggest artificial intelligence technologies like "*activity recognition*"[48, p. 250] or dynamic game changes like a "*dynamic difficulty adjustment*"[48, p. 250].
Building an overall positive and relaxing experience, e.g. by integrating music and pictures, will help patients with focus and motivation. By creating excitement, curiosity and joy, even passive participants can be transformed into active ones. The positive influence of music on a patient's constitution was already shown in [71] and [72]. As one patient stated: "I have problems with writing e-mails or any letters, but I can write with greater ease when I am listening to music"[72, p. 2].
Social interactions should be encouraged to further trigger behaviour change. This can either be by bringing multiple people together via the app or by implementing virtual "friends" with whom the user can interact. Section 2.6.7 takes a closer look into these virtual agents. By combining social contact with entertainment and physical activity, long-term motivation can be established.

Reinforcing factors
What kind of rewards are there to motivate for a healthier lifestyle? Often, these are very specific and differ from person to person. If the benefits of a product cannot be seen, it helps to transform these into perceived needs, therefore showing the usefulness of change to the user. Naumanen et al. [73] identified three barriers in this regard:

1. General factors, such as education or income.

2. Individual assumptions about technology and its complexity.

3. Personally discovered advantages for the new technology.

Tasks should be small and simple to generate easily achievable rewards. This will motivate the elderly to stay focused and achieve the goal. When presenting an application for the first time, all important features should be shown to spark interest in the user while not overwhelming them at the same time.

2.6.7. Virtual agents

A virtual agent, also known as artificial companion, is some kind of in-game companion character that interacts with the user. The agent can be displayed in different forms, e.g. an abstract animated animal or a realistically designed face. One should however be careful not to evoke false expectations, intentionally or unintentionally, as Albaina et al. [74] state. While a doctor companion could be intended to spark the feeling of help and trust, quite the opposite could be the case due to its association with illness and pain for some people. The companion can either be a continuous part of the app or only occur occasionally to offer advice.
In the example of *Flowie* [74], an animated flower functions as a virtual coach that encourages the elderly user to walk more. This seems to be most effective when it tries to reach the elderly via emotional concepts. Albaina et al. determined 5 strategies for individual motivation:

1. Goal setting: the process of setting concrete goals as described in section 2.6.6.

2. Self-monitoring: to monitor and visualize the behaviour of the user.

3. Conditioning: for example be positive or negative reinforcement.

4. Consistency: the desire to do what we promise to do.

5. Intrinsic motivation: see section 2.6.6, e.g. elements of challenge, curiosity and control.

Another example of a virtual agent is *Laura* [75]. This type of agent is also known as a "relational agent" as it tries to establish and maintain a long term social-emotional relationship with the user. *Laura*, the animated head of a woman, communicates face-to-face with the user through speech and non verbal behaviours such as hand-gestures. The user can then respond by selecting one of the predefined text-boxes, limiting the necessary literacy skills. With an integrated speech-recognition, this could be circumvented completely. Just like *Flowie*, *Laura* motivated elderly users every day to increase their activity, but in a more personal way through direct "human" conversation. After a two month period, the results showed that the agent was easy to use and that the users were thankful for the reminders and did indeed increase their walking steps by an average of more than 200%.

2.7. Hybrid tabletop games

The following section focuses on hybrid tabletop games that integrate physical and virtual components into a pervasive gaming experience. Hybrid tabletop games are a sub-genre of the field *pervasive games*. This umbrella-term describes all entertainment products where a real-world game is extended with computing functionality to create an improved gaming experience or a virtual game is partially brought back to the real world. Among tabletop games, it includes smart toys, affective games, location-aware games, augmented reality games and others [76]. Because these games try to establish a connection between previously separated worlds, they require interdisciplinary collaboration from different fields, including software developers, interaction designers and electronic engineers [77].

2.7.1. Benefits

After an extensive literature review [76] [77] [78] [79] [80], the following advantages in comparison to their only-virtual or only-physical counterparts were identified:

- Social interaction: Computer games still have the negative image that they decrease social face-to-face interactions and physical activities by merely focusing the player's attention on a screen. When they are integrated with classic board games, which generally provide rich social interaction [78] and, to a certain degree, physical engagement, this is reestablished.
- Pervasive gaming experience: Integrating computing functionality into board games can provide a richer experience for the players. Animations, sound and vibration engage the players in a multi-sensory way and create new ways of user-interaction. Depending on the implementation, a sophisticated hybrid tabletop game can feel like an additional player guided by artificial intelligence.
- Dynamic adjustment: All virtual parts of the game can be changed on demand, hence offering multiple games in one system. This creates numerous possibilities, e.g. customization capabilities, a dynamic information visualization and an evolving game environment as the game progresses, or a difficulty adjustment that can be initiated manually by the player or automatically by the implemented software.
- Continuity and rule enforcement. When the game flow is controlled by software, the game itself can offer available options to the players and enforce the rules. This is especially helpful in complex games where reading through a 100 page manual might rather hinder the game flow. For lengthy encounters, the game session can be saved and continued at a later point in time.
- Inclusion and support: An intelligent board can offer multiple languages and provide aid to inexperienced or impaired users. It can help to decrease computer anxiety, increase computer self-efficacy and "provide the possibility of digitally augmenting

the game area while keeping playing pieces in the player's physical environment, thus reinforcing the emotional impact of videogames [...] and making digital technology accessible to other user profiles such as very young children [...], users with disabilities [...] and senior citizens"[77, p. 426].

A recent and quite advanced product from this field is "Square One®" by Wizama [79], which won a CES Innovation Award in the category Gaming at the Consumer Electronics Show 2019[81]. It offers various features like connected cards, playing pieces, dice and board customizations that make use of Bluetooth and NFC technology. The system, however, was not designed for the elderly or Alzheimer's patients in particular.
But with the Dynamorph project, Feng et al. [82] have developed an interactive table especially designed for seniors. Evaluating the system with a pilot study showed "that the interactions with the table reduced agitation of the elderly participants and increased the instances of positive social behaviours"[82, p. 49].

2.7.2. Tangibles

Ever since the first development of touch screens, different approaches were made to interact with the virtual world via physical elements. These physical elements are called *tangibles*. One of the first known approaches was the *DigitalDesk* done by Wellner [83] in 1993. A projector transmitted the virtual content to a surface while a camera detected the user input. Many more solutions followed this example of tracking activity via a camera. Others tried to combat this problem via magnetic field detection or RFID technology. However, a main disadvantage of all these solutions is a complex hardware and/or software setup. With capacative touchscreens being widely spread in phones and tablets, a simpler approach was necessary.
Capacative touch screens work by detecting grounded electrical conductors (e.g. a human finger) near the surface. This interference with the electrical field can then be located by the device [84]. The two most common sensing techniques are self capacitance and mutual capacitance. The first technology works by measuring the capacitance of an electrode with respect to ground, therefore changing the self-capacitance. A disadvantage is that not more than one touch can be detected unambiguously. The latter one works by altering the mutual coupling between row and column electrodes. This allows for multi-touch recognition and is the preferred option [84].
Tangibles made from conductive material therefore only work if they are connected with the human body or contain some form of electric hardware. This conflicts with the common requirements for these widgets, like an easy and cheap production or continuous detection, even when untouched. When integrating active electronics, this increases the size of the tangible and leads to other issues like battery maintenance.
To combat these aforementioned problems, Voelker et al. [85] developed the concept of *Passive Untouched Capacitive Widgets (PUCs)*. These are restricted to only work for mutual capacitance touch screens, but this technology is the preferred option for multi-touch screens anyway [84]. They work by utilizing "the capacitive coupling to a second area on the display as

ground. Through several pads on each *PUC* marker that are electrically connected to each other, currently active intersections on the touch screen are coupled to other, currently inactive intersections that serve as ground" [85, p. 102]. To detect a *PUC* continuously, independent of its orientation, at least three unaligned touch points are therefore needed, e.g. a "Ring" *PUC*. The suggested minimal radius is 30 mm and the longterm detection differed between the tested devices [85] as they implement different filter algorithms that are designed to filter electrical background noise.

2.8. Evaluation

Once an application is developed, it should be evaluated, preferably with the targeted user group, to test for numerous traits, e.g. whether it fulfills the predefined requirements, has a good usability, an appealing design and meets the intended goals.
In the first part of this section, the *Technology Acceptance Model* is presented with which one can measure the acceptance of a new technology according to a restricted set of characteristics. Afterwards, different methods of gathering feedback and documenting an evaluation are discussed. Finally, a guideline for an evaluation with Alzheimer's patients is developed.

2.8.1. The *Technology Acceptance Model*

The first version of the *Technology Acceptance Model (TAM)* was developed by Davis [86] in his PHD thesis in 1985. It is an extension to the *theory of reasoned action* [87] with a focus on technology usage. *TAM* examined, which factors influence a person to accept and use a new technology in his or her job. According to this theory, the main factors are *Perceived usefulness* and *Perceived ease of use* (see Figure 2.5). While the first one describes, whether a person believes that using the technology would enhance his or her job performance, the second factor denotes, whether using the technology would be free from effort [88].
The original version of the *TAM* was modified twice [89]. At first, by Davis et al. in 1989 [88], who introduced the concept of "Behavioural Intention" (originally named "Intention to Use") that in turn leads to an actual use of the system. And subsequently, by Venkatesh et al. in 1996 [90], who eliminated the concept of "Attitude Towards Use". More information about the specific changes can be attained from [89]. The final version of *TAM* is displayed in Figure 2.5.

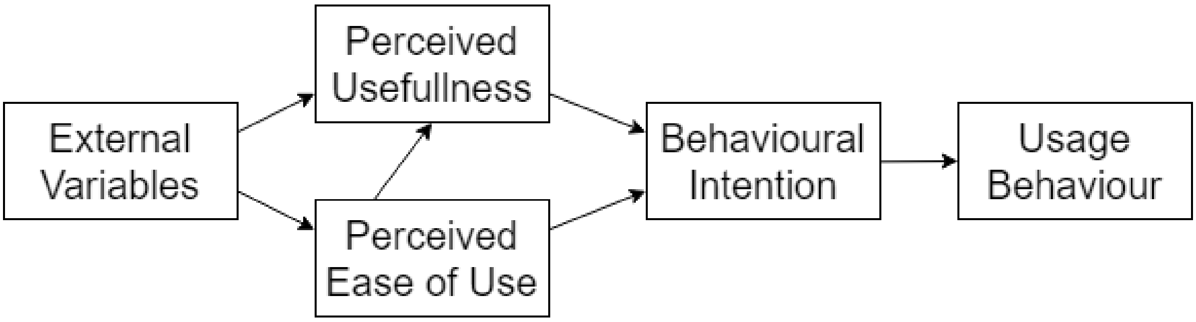

Figure 2.5.: The final version of *TAM*

Source: [89, p. 27]

Over the years, the *Technology Acceptance Model* underwent two major revisions, resulting in *TAM2* by Venkatesh et al. [91] and *TAM3* by Venkatesh et al. [92]. In contrast to the previously mentioned modifications [88] [90], both *TAM2* and *TAM3* further investigated the impact of external variables. An overview of the *TAM3* model with all external variables can be seen in Figure 2.6.
Only those external variables will be explained that will be used in the evaluation in chapter 4. For all other variables, please refer to [92].

- Job Relevance: The perception whether the target system is relevant and supporting for the individual's job.
- Computer Self-efficacy: The belief into one's own abilities to perform a task on a computer.
- Computer Anxiety: The presence of feelings of fear or similar when using a computer.
- Perceived enjoyment: The extent to which the activity is perceived as enjoyable.

The *Technology Acceptance Model* has been studied in depth and, as multiple research could provide empirical evidence, *TAM* has proved to be a valid and robust model [93]. It did, however, receive various criticism. *TAM* has been extended multiple times, introducing new variables that rather broadened than deepened the understanding. Research on how and why a particular variable influences technology adoption is rather sparse [94]. Bagozzi states that even though "*TAM* is a remarkable model and has had an incredible effect on empirical research for a long time. [...]recent extensions of *TAM* (e.g., the UAUT) have been a patchwork of many largely unintegrated and uncoordinated abridgements"[94, p. 252].

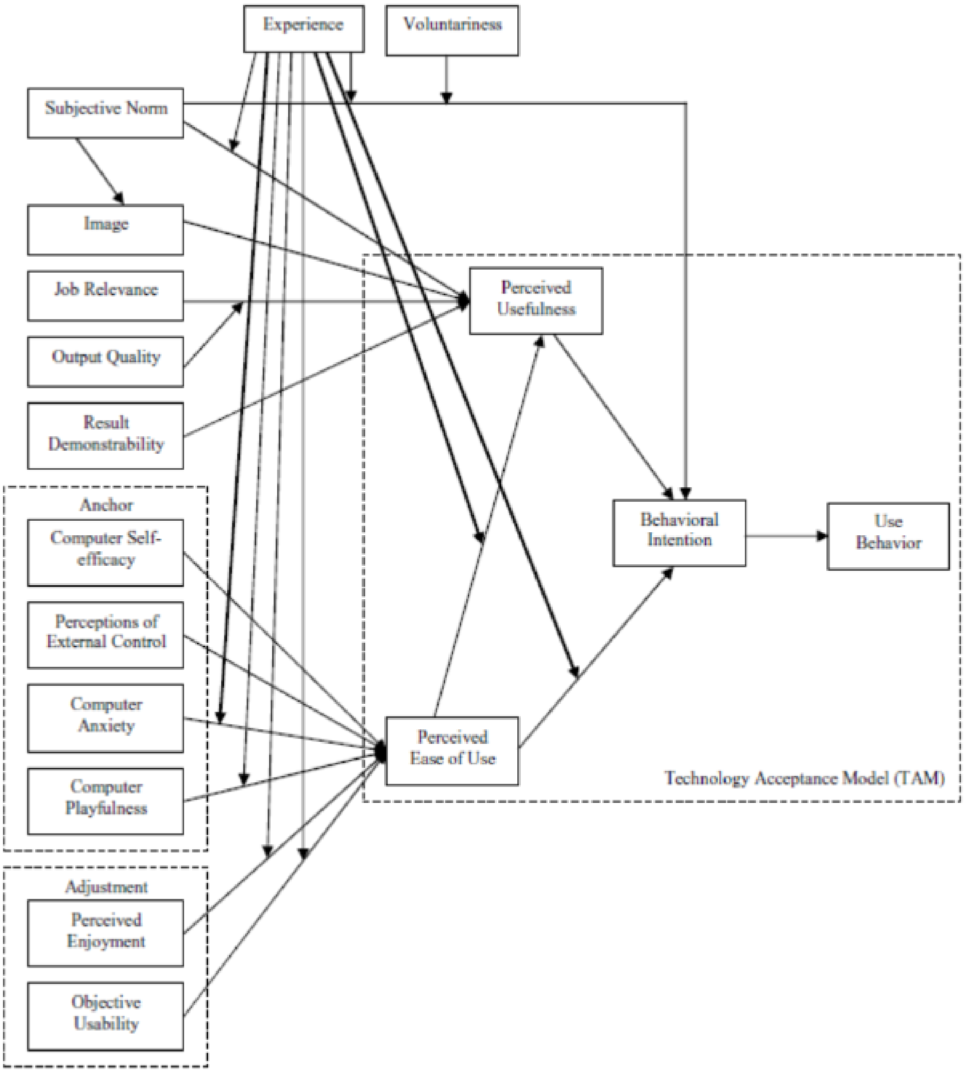

Figure 2.6.: The final version of *TAM*3

Source: [89, p. 29]

2.8.2. Survey methods

Numerous different methods exist that assess the user's attitude towards a new software and enable the structured collection of feedback. They differ in many regards, e.g. user involvement, accuracy of results or organizational effort. In their investigations into age-appropriate product development, Stöber et al. [95] identified and examined the following methods with a special focus on evaluation with seniors and all the associated peculiarities:

- Questionnaire
- Focus interview
- Group interview
- Observation
- Think Aloud
- Eye-Tracking
- Piloting

The rest of this chapter will merely focus on those methods that will be applied in the evaluation in chapter 4. Section 4.5 will explain why these methods in particular were chosen. The methods are summarized according to detailed findings of Stöber et al. [95].

Questionnaire

This descriptive method aims to gather information in a mostly passive and universal approach. In contrast to for example a focus interview, no direct contact between the questioner and the interviewee is established.
A questionnaire should fulfill the following scientific quality criteria: objectivity, reliability and validity. It is expected to include instructions on how to fill out the form and highlight, when specific focus is needed. The questions ought to be bundled by topic and the first and last section is supposed to be easy to fill out, e.g. socio-demographic questions or feedback in free text form. Prefabricated questionnaires, e.g. those provided by Jöckel et al. [96] for queries regarding sociodemography, should be used where available and applicable. In general, the questions ought be easy and precise, while at the same time avoiding error-prone constructs like double negations or generalizations. Two question formats are suggested: Those that serve to explore concrete facts (e.g. "How often do you use the Internet?"), and claims that have the goal of capturing the respondent's position or setting (e.g. "The use of a navigation device leads to dependencies."). While the latter is always answered with a closed answer format (e.g. "does not apply at all" - "fully applies"), the former can be answered with an open or closed format.
Questionnaires possess the following advantages: they are cheap, easy to organize, can be performed during the complete development cycle, have a high objectivity and can be used to interview a large number of users. This in turn can reflect the heterogeneity of the sample

and enable the use of multivariate statistical methods. On the other hand, questionnaires often only have a limited response format. Therefore, additional or in-depth information can only be collected via open questions, which can lead to incomplete answers [95].

Observation

Observation is a behavioural method that describes the study of participants in everyday life or during interaction with the system under test.
The scientific form of observation should be based on an observation plan that describes, which aspects of a subject's experience and behaviour are to be observed, the organizational framework and how the data are to be documented and evaluated. To compare results across several systems, a corresponding standardization of the test conditions is advantageous.
The test leader/coordinator should always be objective, inconspicuous and attentive. He can either take the role of a passive observer or actively participate in the observation. As the latter option has direct impact on the results, this can interfere with the objectivity of the study and disturb the other participants. The objectivity can further be compromised if the test leader took part in the development of the system. In the scientific field, the passive observer should therefore be the preferred option. Videotaping the test execution allows for a retrospective examination.
Observation is a qualitative method and hence requires a text analysis. It is often combined with other survey methods like Eye-Tracking or Think Aloud.
Overall, observation gives direct and largely objective insight into the experience and behaviour of potential users when interacting with new technical solutions. Negative and positive system properties can be detected even when they cannot be verbalized by the user. The method of observing does, however, require a high personnel and organizational effort, and therefore only allows for a limited number of participants. In the end, the quality of the results depends on the objectivity and attention of observers [95].

Think aloud

This behavioural method encourages participants to verbalize their thoughts during the test execution. It can reveal problems and preferences by the user that would not be captured by a mere observation. A user might for example finish a task in the "intended" way but by mentioning his concerns, it can be inferred that there might be room for improvement. It is therefore crucial to not externally influence the participant's thoughts.
Similar to an observation, this method is supposed be executed according to a pre-established plan. The test leader should furthermore fulfill the same requirements as previously mentioned. But in contrast to an observation, he is expected to always actively participate and is encouraged to ask short questions as well as remind the participant to express his thoughts and feelings.
Alternatively, the test execution can also be captured on tape, which enables the participant to comment on his mindset in hindsight. While this allows to additionally evaluate non-verbal information like facial expressions and gestures in greater detail, the retrospective comments

might differ from thoughts that would have been expressed during the test.
To summarize, one can measure the cognitive and emotional processes of a user with the Think Aloud method. It can and should be combined with other survey methods like observation, because it does not require a lot of additional effort for the test execution. Self-monitoring can, however, be hard for first-time participants and hence influence their experience and behaviour, which in turn can lead to flawed results [95].

2.8.3. Evaluation for the elderly and Alzheimer's patients

When conducting an evaluation with seniors and people suffering from Alzheimer's disease, all guidelines apply that were introduced previously, e.g. the communication guidelines for AD patients in section 2.1.8 or the design guidelines in section 2.6.5.
In addition to mere observation, whether an application was used correctly, the feedback should also incorporate the communication with AD patients as a vital source of information [72]. At an early to mid stage, most of the individuals are still capable of verbalizing their thoughts and emotions. When patients are integrated early, a balance can be achieved "between what scientists seek (e.g., an understanding of mechanisms) and what patients need (e.g., treatment and an improved quality of life)"[72, p. 2].
From these guidelines, the following evaluation strategies for AD patients were developed:

- A concrete plan should be established beforehand that determines the aim of the evaluation, the necessary preparations, the schedule of events and the methods of observation and documentation.
- While the plan is supposed to be adhered to as much as possible, one should be willing to deviate from the exact execution and rather go along with the patients' input. Repeatedly forcing the schedule on the participant will most likely only result in an isolation of the patient. The test leader therefore needs to demonstrate sensitivity to attain the most out of the evaluation without upsetting the attendees.
- Room for error needs to be provided. This can mean additional time for the completion of the task, an alternative/reduced schedule of events or pausing the evaluation to continue at a later stage.

Furthermore, an evaluation should preferably not be performed around late afternoon or early evening. Research has shown that AD patients can become increasingly restless around this time [97]. This phenomenon is also known as "Sundawning". Common symptoms are "disorientation, emotional stability, agitation, resistance to care, and combativeness"[6, p. 4].

3. Implementation

This thesis is part of the *enable* project. *enable* is an interdisciplinary cluster sponsored by the German Federal Ministry of Education and Research (BMBF) that develops new strategies to improve the nutrition and support a healthy lifestyle of people at different stages of their lives from birth to old age [98].
The thesis will contribute to the focus area "FA4 - Prevention of malnutrition in old age"[1].

3.1. Aim of the application

Before we take a closer look into the implementation, the goals of the application are summarized. In general, the quality of life of Alzheimer's patients should be improved. This can be divided into the following requirements:

1. Challenge the patients mentally.
2. Challenge the patients physically.
3. Engage the patients socially.
4. Improve the patients' hydration.
5. Create a playful atmosphere.

These demands are fulfilled by implementing the board game Ludo (also known as "Mensch Ärgere Dich Nicht" in Germany) on a tablet. A board game should cognitively challenge the patients while at the same time bring them together in a fun environment, therefore targeting requirement 1, 3 and 5. The reasoning why specifically this game was chosen on this device type can be retrieved from the following sections 3.2 and 3.3.
To tackle requirement 2, the game should be connected to physical elements. Therefore, physical traceable pieces and a Bluetooth dice (see section 3.5), that transmits the thrown dice result to the tablet, were developed.
And additionally, drinking devices (see 2.4.1) should be connected and integrated into the flow of the game to support the hydration of the patients (requirement 4).
An image of the final application is displayed in Figure 3.1.

[1] translated from the German term "Prävention von Mangelernährung im Alter"

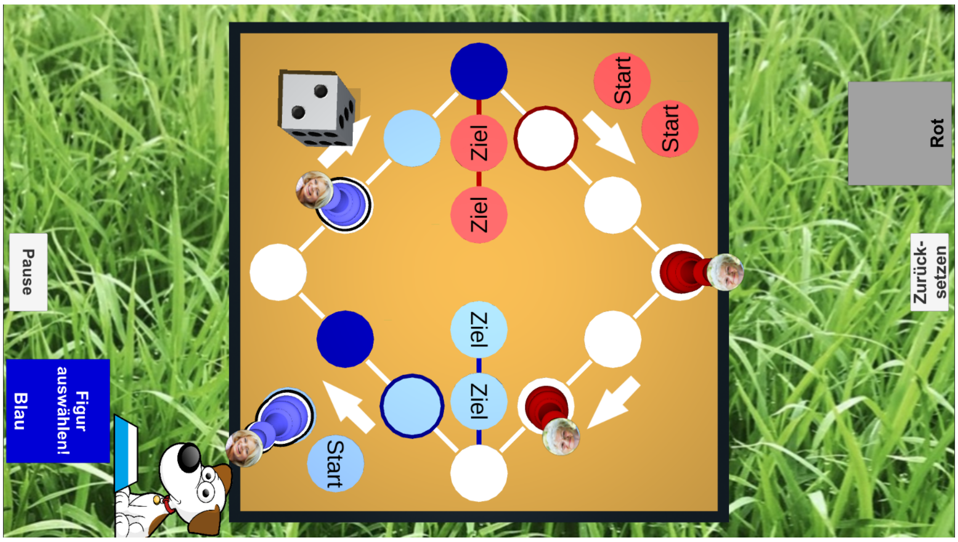

Figure 3.1.: A match between 2 players on a small board

3.2. Game choice

The benefits of games for elderly and AD patients were already discussed in section 2.6. Board games are known to most people, especially seniors, and therefore connect to familiar experiences.
There are many board games that could be developed as a game application for Alzheimer's patients. However, some are more suited than others. With the related work in mind, the following requirements were developed. The game should be:

- playable by multiple users as we want to engage the patients socially (see section 3.1, goal 3). The number of players should not be too high in order to not overtax the patients.
- relatively simple and have a consecutive game flow. Since Alzheimer's disease can affect the patients' response time as well as their cognitive abilities, fast reaction times and consecutive actions by different players should be avoided.
- known from the past. Previous research [71] [99] showed that the engagement of dementia patients increased when they were shown memories from their past like music or pictures, therefore reconnecting to the often still functioning long term memory.
- extensible in its game flow such that peripherals (Bluetooth dice, drinking devices, ...) can be integrated (see section 3.1, requirement 2 and 4).

The game Ludo (see Figure 3.2) fulfills all of these criteria. As a modified version of an Indian board game, it was patented in England at the end of the 19th century [100, p. 12] and gained a high popularity all around the globe due to its simplicity. It is still played up until today and should therefore be known to most people from western countries.

Figure 3.2.: The Ludo game board

Source: [101]

3.3. Device

As already mentioned in section 2.6, elderly people are actually quite interested in new electronic devices. Kobayashi et al. [59] could also show, that they are quite comfortable with a touch screen as an input method, even with advanced gestures likes pinching and dragging. Further research [46] [99] with Alzheimer's patients revealed that "people with early stages of AD used mobile devices successfully without any prior experience in using such devices" [46, p. 1]. Even though there are some challenges when using a touch screen [6, p. 5], it is still the "best available input technology for inexperienced users" [49, p. 5]. But as suggested in section 2.6.5, one should then only use simple input gestures, and only when necessary. The implemented game therefore makes no use of complex gestures.
As a result, a mobile device seems to be a reasonable choice of medium. When comparing the different devices, the advantages of a tablet in comparison to a mobile phone are quite obvious. Due to its larger size, it helps with reducing visual and tactile problems. This comes in handy when thinking about the design guidelines mentioned in section 2.6.5.
The benefits of using a hybrid approach in contrast to classical board games were already discussed in section 2.7. For the application of this thesis, these are:

- The flow of the game can be controlled by the tablet. As the short-term memory of AD patients is often impaired, this will help to keep the game going. Additionally, this helps to enforce the rules of the game. If physical pieces fall over, the state of the game can easily be restored.
- The pieces can be virtual or physical. Virtual pieces should be preferred when motoric abilities are slowly degrading and pieces cannot be moved adequately. If, however, you want to engage the patients motorically, trackable physical pieces should be used (see 3.7.9).
- Different customization options and the difficulty of the game can be adjusted. This

will be discussed in 3.7.6 and 3.7.7 in greater detail.

- Other peripherals like a Bluetooth dice (see 3.5) or drinking devices (see 3.4) can be integrated into the game flow.

While a tablet will not be able to fully replace human interaction [6], it can still be of great help in many regards.

3.4. Drinking devices

With the development of the drinking devices at the chair (see section 2.4.1), it is possible to measure the drinking amount of the patients. However, users are still missing the motivation to actually change their drinking habits. To improve the hydration in a playful approach, these devices could be integrated into the flow of the game.
This could be done in a reoccurring pattern (every 10 moves) or to trigger special game events like moving a piece out of the start position or giving the player a "x2" multiplier on his or her dice throw. As "elderly people should not be encouraged to consume large amounts of fluids at once but rather small amounts throughout the day"[37, p. 150], this should only be used sporadically.
Unfortunately, problems in production and maintenance of the drinking devices arose that were independent of this thesis. Even though the final version of the application therefore did not integrate these drinking devices, it provides the framework to add them at a later point in time (see section 5.5). To still combat the problem of dehydration, incentives to drink were implemented as can be seen in section 3.7.5

3.5. Bluetooth dice

In preparation for this master's thesis as well as other work done at the chair, a 3D-printed dice with Bluetooth capability was developed by the thesis supervisor Christian Eichhorn (see Figure 3.3). Multiple manuals exist online on how to create such a device, for example [102].
The dice contains a *Bluefruit Feather nRF52832* micro-controller which offers an accelerometer, a gyroscope and Bluetooth LE services. It's implemented dice algorithm can therefore detect, if the dice was thrown and which side is facing up. The result of the dice can then be transmitted to the tablet via Bluetooth.
The initially implemented algorithm had to be adjusted for efficiency and reliability reasons (see section 4.9).

3.6. Technology

The game is developed in "Unity 2018.3", the most recent stable version of the unity gaming engine. This allows for an easy and powerful creation of a 3D game and a flexible distribution on multiple platforms.

Figure 3.3.: The application, deployed on a tablet, with the developed pieces and the Bluetooth dice

3.7. Game adaptions for Alzheimer's patients

During the development of the application, a high focus was put on following the recommendations proposed by the available literature and previous research (see chapter 2). A few of these adaptations will be discussed in detail in this section.

3.7.1. Motivational elements

Motivation is an important factor in application development that decides, if a person is going to use the app (as discussed in section 2.6.6). It is therefore crucial to address all aspects of motivational elements (see Figure 2.4).
When targeting intrinsic motivation elements, these can be divided into *Connection* and *Emotional*. To *connect* to the personal memories of the user, a board game of their childhood was selected (see section 3.2). This will hopefully remind the elderly about their own childhood or the childhood of their children/grandchildren. These kind of memories can be especially helpful for people suffering from Alzheimer's disease. This goes hand in hand with the *emotional* aspect of intrinsic motivation elements. Using a new technology aims to spark curiosity in the users. Additionally, a natural game background coupled with calm background music and a playful companion design should create an atmosphere of fun and relaxation.
On the other hand, there are the extrinsic motivation elements *Social* and *Goal*. The *social* component is present in nearly all board games. We create a place where elderly, affected by AD or not, can come together and socialize. This inclusive approach could create new friendships in the retirement home. Since the game isn't too taxing for the users, it leaves place for small chats. The new experience, may it be perceived as good or bad, gives a great conversation topic for the elderly during and after their game sessions. While the main

goal for the users might simply be to compete and win the game, more subtle goals can be identified when taking a closer look. For some, it might be to socialize with others and engage with new technology. Others want to stay cognitively fit, improve their hydration or simply have fun. The goals are often personal and as diverse as the users. But what unites them is that eventually, they motivate the person to engage in the experience.

3.7.2. Reducing cognitive complexity

If a task is complex, it can be too challenging for people suffering from Alzheimer's disease. This can be quite a demotivating event, as the cognitive guidelines in section 2.6.5 pointed out. To reduce the mental workload, some measures were taken. For example, the menus were made as simple as possible while still providing enough options for customization. The layering of menus was reduced to a minimum. And at any point, the companion (see section 3.7.5) can provide useful help for the current phase of the game.
To further reduce complexity, the game will highlight all pieces, that can be legally moved by the player, in a blinking fashion. In addition, all possible routes and the respective "end tiles" (tiles where a piece will land) are highlighted (see Figure 3.4). This makes it easier to figure out, if/where a piece can move and if another player's piece could be thrown. Pieces can be moved by either clicking on them or the respective end tile in an effort to avoid "failing" actions by the user, e.g. "No, you need to click on the piece and not the tile" or vice versa.
Another common problem is the impaired short-term memory. A player could forget, whose turn it is or what color her/his pieces are. To account for this, every player has an info box at the respective side of the table (see Figure 3.4). It displays the player's name if configured (see section 3.7.7) and will be highlighted once it's his or her turn. The info box will then let the user know, what needs to be done, i.e. throw the dice or select a piece. To further create a connection between the board pieces and a player, custom faces can be added to the board pieces (see section 3.7.7).

3.7.3. Accounting for operating inaccuracy

Due to impairment in vision and fine-motor skills as well as cognitive execution, precisely targeting objects on a tablet can be a challenging task. To account for this, the design guidelines as described in section 2.6.5 were implemented where applicable. In addition to that, all interactive game elements like buttons, board pieces or the companion have an enlarged collider. This will trigger the game element even when the user clicks slightly outside of the visual boundaries.
The virtual dice is thrown and the pieces are moved, if a user taps on it. But as it can be inferred from the motoric design guidelines in section 2.6.5, tapping should be avoided for two reasons: Elderly users tend to "press" instead of "tap" and their intended touch point differs from the registered one. The implementation of the game ensures that pressing a game element for a prolonged time does not result in unexpected behaviour (e.g. "pressing" a piece would trigger the next dice throw). The second problem is solved by the aforementioned increase of the colliders of each game element.

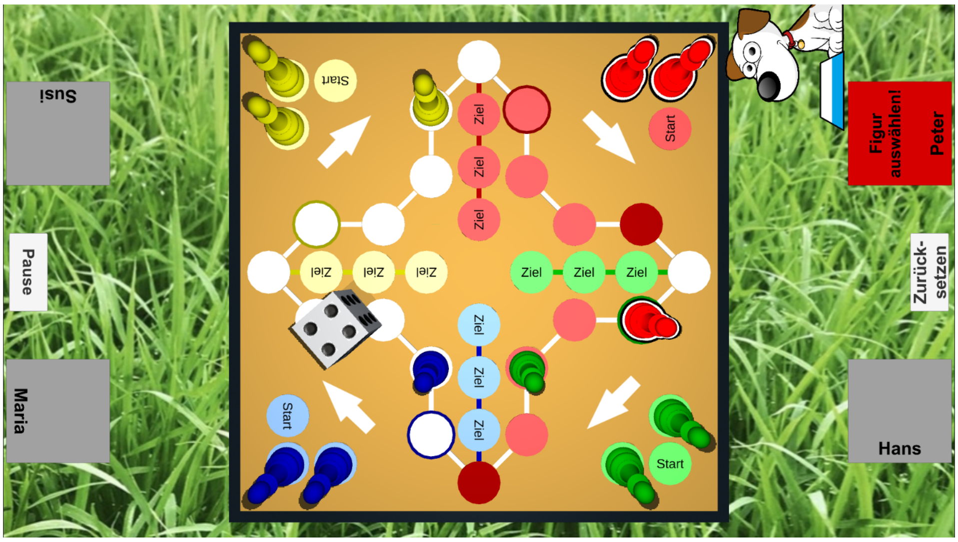

Figure 3.4.: Infoboxes and highlighted pieces/routes

Nevertheless, it can happen that a player throws the dice or moves a wrong piece by mistake. Therefore, a reset ("Zurücksetzen") button (see Figure 3.4) was implemented that revokes up to two previous user actions.

3.7.4. Feedback

Users should receive instant feedback in various ways when interacting with an application (see section 2.6.5). In the case of the Ludo application, these interactions during the game are rather simple: roll the dice, move a piece and, if physical pieces are used, drag a piece. Whenever this happens, haptic feedback is given in the form of a small vibration. Rolling the dice will emit a virtual dice rolling sound. In addition, the text and colors of the info boxes (see section 3.7.2) change accordingly. When it is the next player's turn, the companion moves to his or her position.

3.7.5. Virtual agent

As suggested in section 2.6.7, a virtual agent was added to the game to support the users in their in-game decisions. The image of a dog was chosen because this is often associated with help, e.g. rescue dogs or guide dogs. At every point in the game, the companion is either located next to the board (see Figure 3.4) or the menu (see Figure 3.6). It can be activated by the patient via a click or passively if a certain threshold time is exceeded. Based on the currently active menu or the state of the game, the virtual agent will then try to offer help (see Figure 3.5). The key words of the help message are bold to increase readability. In addition to offering help, this companion also functions as a hydration reminder for the elderly. The companion dog therefore receives a bowl filled with water when a round of Ludo is played.

Figure 3.5.: The activated virtual agent

As the game progresses, the content of this bowl will gradually decrease. Once the bowl is empty, a notification pops up which lets the user know that the dog is exhausted from running around. To refill the bowl, the user is encouraged to drink a sip of water and then continue the game. This is based on a voluntary participation of the user. This could, however, be made obligatory once the drinking devices (see section 2.4.1) are integrated into the game flow.

3.7.6. Difficulty adjustment

As we saw in section 2.1.4, the symptoms of Alzheimer's disease are quite diverse. It is therefore crucial to adapt the game to the individual needs of the users. Multiple different options, in general and player-specific, can be selected to customize the game, as can be seen in Figure 3.6 and 3.9.

Variable board size

Cognitively impaired patients are benefiting from a "smaller" board size (meaning less tiles) as this decreases the complexity of the game. This can also help users with visual problems as all the board items are enlarged. Therefore, three different board sizes were implemented (see Figure 3.7).

Color weakness/blindness mode

As described in section 2.3, different forms of color weakness or blindness are quite common among the elderly. Therefore, a *color weakness/blindness* mode was implemented that not only

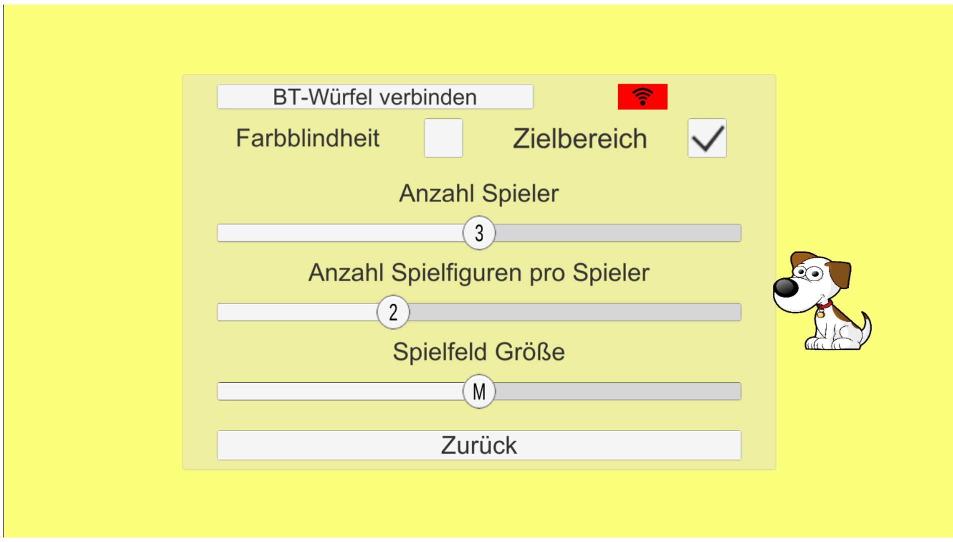

Figure 3.6.: General options

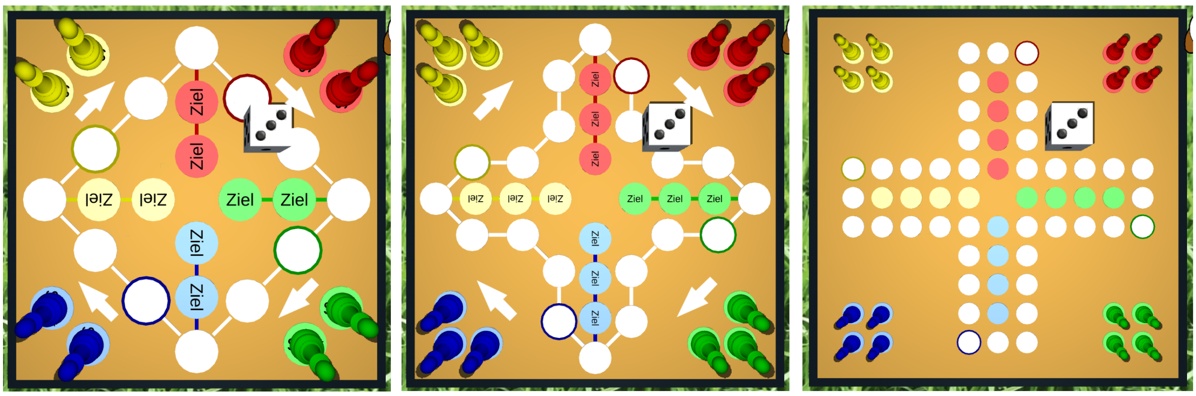

Figure 3.7.: The different board sizes small, medium and large (from left to right)

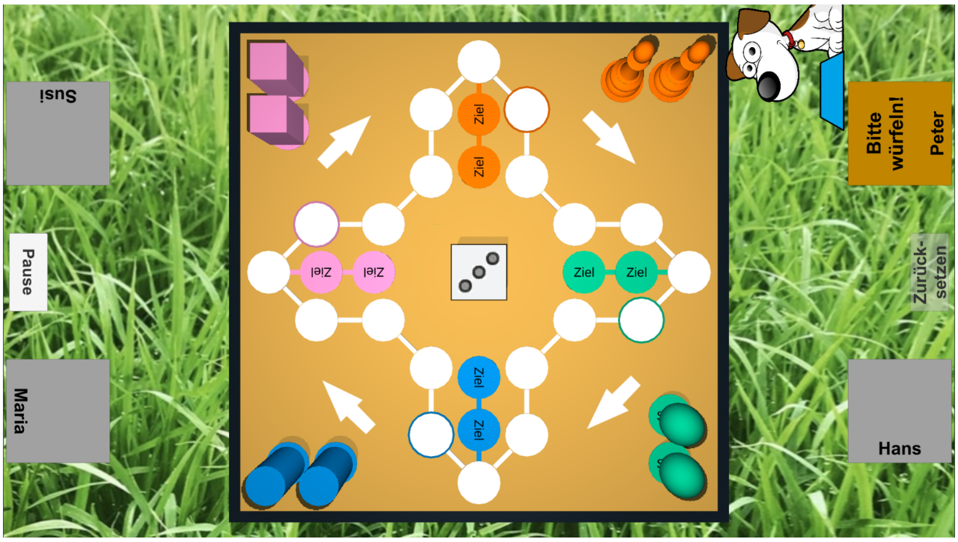

Figure 3.8.: Color blind mode

changes the colors (as suggested by [36]) but also the models of the board pieces to help distinguish between them (see Figure 3.8).

Background music

The paragraph about enabling factors in section 2.6.6 already presented how music can increase an AD patient's motivation and transform passive into active participants. For this reason, a calm background music called "Crinoline Dreams" by Kevin MacLeod[2] was implemented.

3.7.7. Personalization

Several different features were added to establish a connection with the users and make the game a more personal experience (as seen in Figure 3.9). Every player can enter his name and will then be addressed directly by the in-game help messages. When the "Choose pieces" ("Figuren auswählen") option is selected, the player selects the piece that should be moved by clicking on it. Otherwise, the game engine will select a piece for the user, giving priority to a piece that will throw another player's piece. The other check box that can be selected is the "Use Bluetooth dice" ("Bluetooth Würfel nutzen") option. This will configure, whether the connected Bluetooth dice should be used or if the person would like to throw a virtual in-game dice.

[2]licensed under Creative Commons: By Attribution 3.0 License and freely available at https://incompetech.com/music/royalty-free/index.html?isrc=USUAN1700073

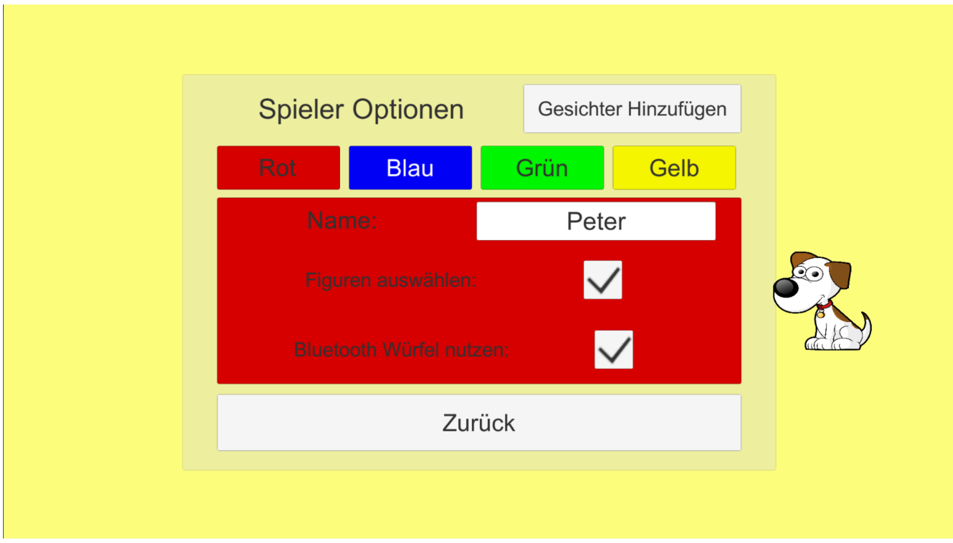

Figure 3.9.: Player options

Customize player pieces

The "Add faces" ("Gesichter hinzufügen") feature[3] in the top right corner enables the user to crop his face out of a picture, which will then placed on the in-game pieces (see Figure 3.11). This does not only give the game a more personalized look but also reminds the patients on which pieces belong to whom. A screenshot of the "Add faces" window can be seen in Figure 3.10.

3.7.8. Physical interaction

Depending on the physical impairment, the necessary interaction by the patients can be adjusted. A user can either decide to physically throw the 3D-printed Bluetooth dice or, in the case that this is too challenging, simply tap on the device for a "virtual dice throw". Regarding the selection of the pieces, one can either choose them directly or simply click the screen and the game will automatically choose a piece.

3.7.9. Tangible elements

Section 2.7.2 already described previous research as well as associated benefits regarding tangible elements. Combined with the Bluetooth device (see section 3.5, integrating tangible game pieces is intended to engage the patients physically and increase the similarity to the original Ludo game. This mix of virtual and physical game elements is aimed to spark interest in the users.
Two different types of tangibles were taken into account: tangible elements that are only tracked when the player touches them and elements that are continuously tracked. The

[3]This feature was developed in another thesis at the chair [103]

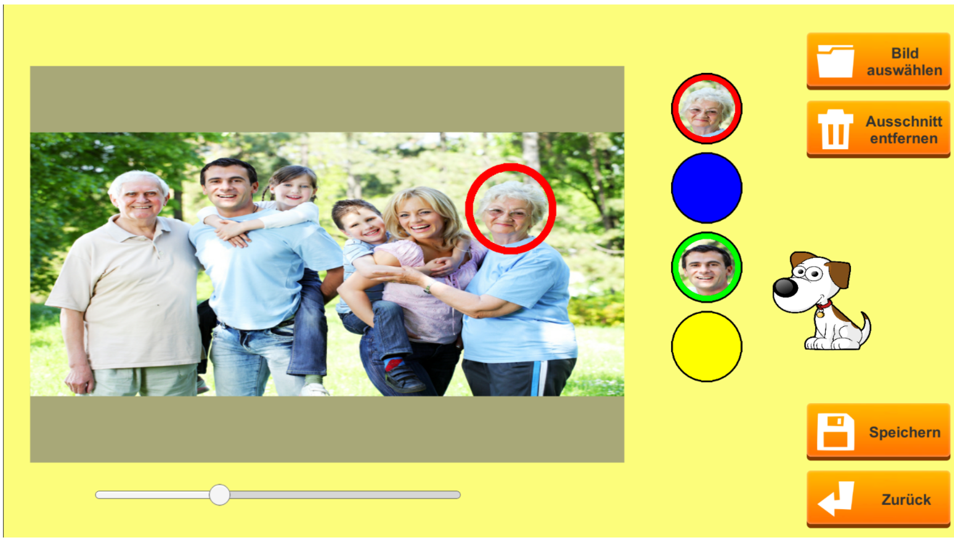

Figure 3.10.: Add faces - cropping screen

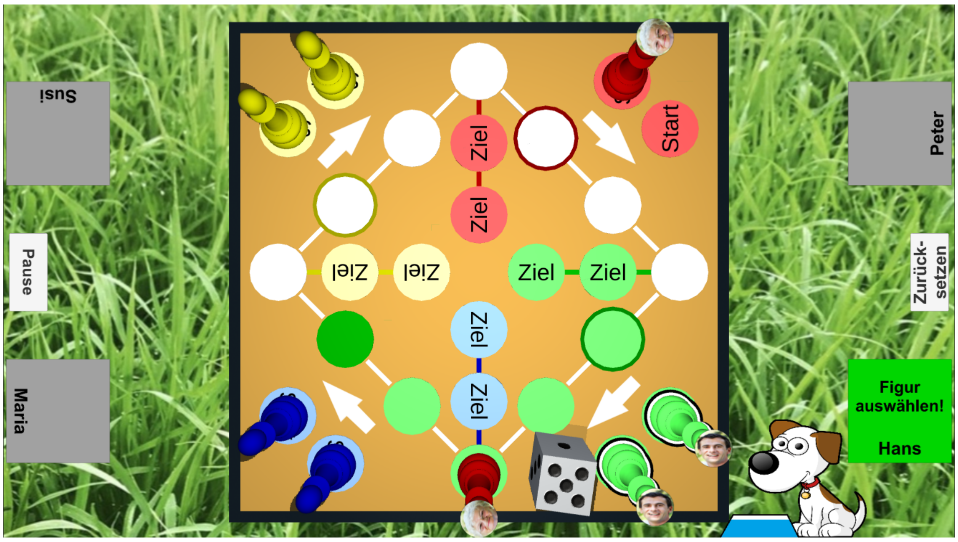

Figure 3.11.: Add faces - customized in-game pieces

advantage of the first kind is, that it allows for more pieces to be used because a piece does not block one of the tablet touch points (often limited to around 10). If a piece is, however, thrown over, this is not registered by the device.
Continuously traceable pieces on the other hand often need quite complex and large electronics. For *PUCs* (see section 2.7.2), this is not the case, but with a suggested diameter of at least 6 cm for reliable and continuous tracking, these are too big to be used on a common tablet.
It was therefore decided to go for the first approach. This can be easily achieved by wrapping 3D-printed physical pieces in tinfoil or covering them in conductive paint. The final result of the application, the connected Bluetooth dice and both types of physical pieces (tinfoil and conductive paint) can be seen in Figure 3.3.

4. Evaluation

The fourth chapter of the thesis will focus on the practical evaluation of the developed application. At first, the aim of the evaluation and the general procedure (user group, hardware, schedule, etc.) is discussed. Afterwards, a closer look into the practical part of the evaluation is done, which contains the execution of the schedule as well as the gathered insights and feedback. Finally, the results of the evaluation are analyzed.

4.1. Aim of the evaluation

The evaluation of this thesis will be conducted to test the application that was developed in chapter 3. Thus, the following sub goals were defined:

- Gather insight into the daily life of AD patients and their interaction with mobile devices.
- Evaluate the current state of the application.
- Collect feedback and suggestions for improvement.

4.2. Strategy

For the success of this evaluation, all the aforementioned insights from chapter 2 and chapter 3 will be applied where possible. A high focus is put on the evaluation guidelines of section 2.8.3 and the communication guidelines of section 2.1.8. Due to the dynamic approach of the evaluation and the limited number of test runs, a descriptive analysis of the results is done in section 4.8 and 4.10 instead of a statistical analysis.

4.3. Device

The evaluation will be performed on a Galaxy Tab S2 Tablet. It offers a 9.7" touch screen with a resolution of 2048x1536 pixels. The implemented operating system is Android 7.0. The tablet can measure up to 10 touch points simultaneously.

4.4. User group

The evaluation takes place in the Tertianum elderly home in Munich, Germany. It is done during the free time periods of the residents, which are scheduled before lunch (10:00AM until 12:00PM) and in the afternoon (3:00PM until 5:00PM). All participants(R1-R8) in the evaluation suffer from mild to moderate symptoms of Alzheimer's disease and are aged 80 and above. In total, five female and three male patients participated. At every stage, a non-resident is needed to play with the resident or guide the match between residents. Therefore, a caregiver (C1), a student assistant of the chair (S1) and the author of this thesis (T1) took part in the test runs.

4.5. Survey methods

Different methods on how to track the participants' behaviour and thoughts were already introduced in section 2.8.2.
Eye-Tracking requires the integration of a gaze tracking systems, which proved to be too much effort for this thesis. It could however provide interesting insights into the visual recognition of Alzheimer's patients in a future work.
Focus interviews and Group interviews cannot be performed due to the limited availability of the residents and their caregiver. While it might be difficult for the former to recall the test execution at a later stage and maintain a prolonged conversation, the latter was responsible for the entertainment and care of all attending residents.
Piloting describes a long-term evaluation of the product in everyday conditions. This method could be applied once the application is published and used in the retirement home.
All remaining survey methods Questionnaire (Q), Observation (O) and Think Aloud (T) did not show any flaws for this type of evaluation beforehand and will therefore be used where fitting. As the evaluation requires a dynamic approach (see Section 4.7), a diversity of the applied methods is intended but cannot be guaranteed.

4.6. Questionnaire

The questionnaire consists of three parts and is attached in section A.1 (Figure A.1 and Figure A.2). In the first part, general information like sex and age of the participants is collected.
The second part is based on the *Technology Acceptance Model* questionnaire and focuses on perceived usefulness (PU), perceived ease of use (PEOU), job relevance (REL), computer self-efficacy (CSE), computer anxiety (CANX), perceived enjoyment (PE) and behavioral intention (BI). Every question was measured on a five-point Likert scale (1 = disagree, 2 = slightly disagree, 3 = neutral, 4 = slightly agree, 5 = agree).
The last part consists of two open questions about general feedback and suggestions for improvement.

All *TAM* questions of the second part are mapped to the *TAM* categories in the following way:
Perceived usefulness
Question 4: Users are challenged mentally when they play the game.
Question 5: Users are entertained when they play the game.
Question 7: Users are in contact with other patients when they play the game.
Question 8: The supports (flashing fields, helper dog, reminder who is next, ...) in the game are helpful.
Question 9: The game is a good alternative for the classic Ludo.

Perceived ease of use
Question 3: Users find it easy to play the game.

Job relevance
Question 10: I see advantages in using the game in my profession.

Computer self-efficacy
Question 1: Users are capable of using electronic devices (e.g. tablet).

Computer anxiety
Question 2: Users are afraid of operating electronic devices (e.g. tablet).

Perceived enjoyment
Question 6: Users enjoy playing the game.

Behavioral intention
Question 12: If the game was available, I would use it with patients.

4.7. Evaluation setup

The author of this thesis will take on the role of the test leader, who coordinates the evaluation. The application is evaluated with the aforementioned user group in two phases, test phase A and test phase B (see Figure 4.1). A test phase in this regard consists of multiple test runs. A test run consists of the application testing with a subset of the user group as well as collecting feedback during and after from the involved participants (where possible). The testing itself describes the usage of the application with different settings and can consist of one or more rounds.
It was decided to go for a dynamic evaluation approach due to the following reasons:

- The number of participants that are physically available for the test phase is not known beforehand.

- Even though residents of the elderly home are present during the test phase, it does not imply that they can or want to participate. While some residents are not able to take part due to physical or cognitive impairment, others do not want to take part. This can differ depending on the residents' daily form and even as the day progresses. Residents that are not able to interact with their surroundings before lunch can sometimes improve their conditions during the afternoon and vice versa.
- If a resident decides to take part, one has to go along with the patient's mood. While most of the test runs were performed for three rounds, this cannot be scheduled beforehand.
- The settings as well as the included peripherals (Bluetooth dice) need to be adjusted for every test run, depending on the course of events. Nevertheless, efforts were made to use as many of the available options as possible.

For the majority of the test runs, the Bluetooth dice (see section 3.5) is connected to the application to create an environment familiar to the "traditional" Ludo game. At first, the board size is selected as "Small" (the simplest setup). Once the players get acquainted with the application, they are then able to try out different settings that fit their individual level. This can mean an increase/decrease (where possible) of the players, the player pieces, the board size or the adjustment of the personal options. Due to the cognitive impairment and the barely available expertise with electronic devices, this has to be done by a non-resident person.
The feedback is collected during and/or after each testing, depending on the test-leader's involvement. Adapting to the constitution of the patients and the availability of the care personnel, the questionnaire will be filled out by them and/or the test-leader.
Once test phase A is completed, the gathered feedback is incorporated. Test phase B is then performed in a similar fashion, but with an improved application.
To avoid the effects of "Sundowning" (see 2.8.3), the test runs will be performed before and after lunch time.

4.8. Test phase A

Test phase A was performed on the 16th of April, 2019. It was divided into two sessions, the first one from 10:30 AM until 12:00 PM and the second session from 3:00 PM until 3:45 PM. In between, the residents had lunch and an after-lunch nap. During the testing phase, one of the thesis' supervisors and a student assistant of the TUM chair were also present. Especially the latter proved to be extremely helpful since he has already been in contact with the caregivers and the residents of the elderly home for multiple years.
Before the evaluation began, a 30-minute conversation was held with Mr. Schiertz, head of facility and nursing services in the Tertianum elderly home, to get acquainted and discuss the application. Mr. Schiertz then introduced the aforementioned members to the residents and their main caregiver (C1), who was in charge.

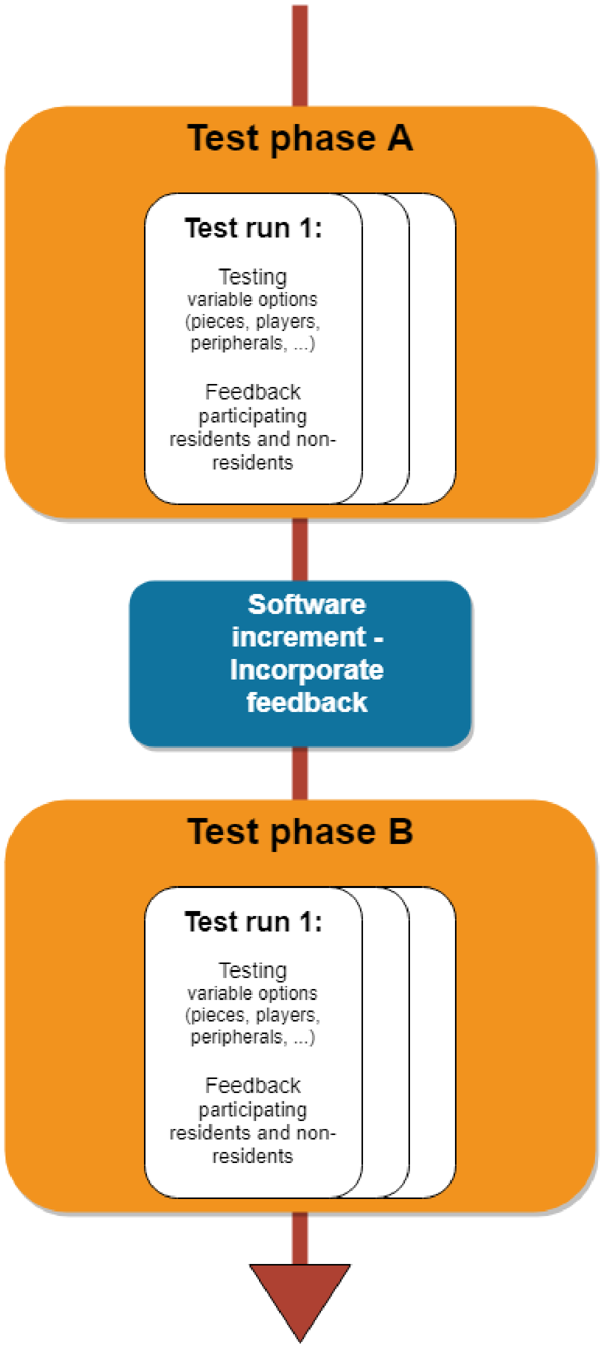

Figure 4.1.: Evaluation setup

After the introduction, informal conversations were held with the residents, leading to the following test runs (see Table 4.1):

Test run	Participants	Rounds	Survey methods	Details
1	R1 + T1	3	Q + O + T	The physical dice was used.
2	R2 + C1	3	Q + O	The physical dice was used. C1 did not get an introduction into the game.
3	R3 + S1	3	Q + O	The physical dice was used. S1 did not get an introduction into the game. The board sizes Small and Medium were tested. Normal Ludo pieces were used as support. Touch had to be done by S1.
4	R4 + R5 + S1	3	Q + O	The virtual dice was used. The first two rounds were played by R4 and R5, the third round was played with R4, R5 and S1.

Table 4.1.: Summary of the test runs in test phase A

The results of the *TAM* section in the questionnaire will be displayed in section 4.11 and compared to those of the test phase B. In addition to the test runs mentioned above, another conversation was held with one of the residents (R0) in advance. The resident started a game session but quickly lost interest. Afterwards, it was not possible to restart a chat. This could be due to a variety of reasons: e.g. the game was too overtaxing, the patient was the first of all participants and did not have time to get accustomed to the situation or simply, because the resident was not in the mood to play. For reasons of completeness this should nevertheless be mentioned.

Overall, the test runs provided many great insights not only regarding the application but also in regard to the communication with people suffering from Alzheimer's disease. Due to limited availability, no direct feedback could be received from C1. All questionnaire had to be filled out by the test leader[1] during the test run or in retrospective. The main points of the findings and feedback were the following:

General usage

- The application seemed to be intuitive for the non-resident players C1 and S1 as they did not get an introduction into the game but merely observed test run 1.

[1]The author himself assumed the role of the test leader because no other person was available. It should nevertheless be noted that this can compromise the objectivity of the study as mentioned in section 2.8.2.

- At every stage in the game, a non-resident had to guide the game flow. Even after multiple rounds, constant reminders were necessary for most of the residents to keep the game going.
- The majority of the residents had no difficulties with the usage of the touch screen. At the beginning, R4 used the finger nail and not the finger tip. In test run 3, R3 had trouble to identify the virtual pieces. Therefore, normal pieces were used as an aid and S1 executed the necessary touch. Very rarely, a resident clicked next to a piece.
- All participants in test phase A (R1-R5) played the application for three rounds and showed excitement and joy while playing. Only one resident (R0) cancelled within the first round because she seemed a bit overwhelmed and was not in the mood to continue playing.
- If no input was recognized for more than 25 seconds, the virtual agent was automatically activated to show a helping message. As the game was led by a non-resident, this only seemed to disturb the game flow. Some residents also showed difficulties in reading the help messages.
- For one resident, using physical pieces (see test run 3) provided valuable support.
- Using the virtual dice by clicking on the tablet did not cause any problems. The size could however be improved as R5 seemed to have difficulties to see the dice result.
- The virtual dice was sometimes thrown by mistake, because the piece moved too fast and hence, it was already the opponent's turn when the resident was still touching the device, which in turn triggered a dice throw event.
- Overall, more room for error needs to be given.

Design

- The colors of a player's board pieces and his start and end tiles were too similar and could sometimes not be distinguished. This resulted in the users clicking on the tiles instead of the pieces.
- For some residents, the board design seemed to be a bit overloaded. This could be due to the blinking tiles (see next point) or the background image (a picnic blanket).
- If a player threw the dice, all movable pieces are highlighted and their resulting end tiles are blinking. The residents sometimes clicked on the blinking tile instead of the piece to move it.
- The pieces seemed to move a bit too fast for the residents to track.
- Start and finish tiles were not always perceived as such.

- Placing the pause button in the middle of the board confused one resident as she thought, it was part of the board.
- Even though the companion dog could not offer the planned assistance, it was received as friendly and sparked joy, especially when it performed a somersault once a player won.

Peripherals

- The physical dice was received as a valuable addition to the game.
- While nearly all of the residents perceived the size of the dice as fitting, R3 mentioned that it was too big and tough to throw. Encouraging her to use more force and ensuring that the dice was robust seemed to improved the resident's perception.
- The transmission of the physical Bluetooth dice result to the application was, at some times, too early and therefore resulted in a mismatch between the physical dice value and the registered dice value in the application. In consequence, this did not only confuse the residents but also C1. In addition to that, if a user only slightly touched the dice and then let go, this was recognized as a throw by the application.

4.9. Software increment

Test phase A provided lots of insights and valuable feedback. This led to the following changes that aim to improve the application:

- A design rework was done. This includes the color selection such that player pieces and the different tile types can be distinguished more easily, an increase of the colliders and the virtual dice size as well as a replacing the background image with a calmer background. In addition, the start and finish tiles were labeled and arrows for the movement direction were added. The pause button was moved next to the board.
- The movement of the pieces was slowed down. This should make it easier for the users to track the game progress and prevent unintentional dice throws with the virtual dice.
- More options for the player to move a piece were created. If a player throws the dice, the pieces (instead of the resulting end tiles) are now marked in a blinking fashion. Additionally, the possible paths of the pieces are marked in a light color and the end tiles, where the pieces would land, are marked in a dark color. The player can move the piece, if he or she clicks on the piece or the marked end tile.
- More room for errors was provided. A virtual button was added that enables the user to revert the last two actions. This is helpful, if the dice was thrown or the wrong piece was moved by mistake.

- The state detection of the physical Bluetooth dice was improved, making use of the integrated accelerometer. The gyroscope values for the side detection were tweaked to improve the reliability.
- Physical pieces, that can be tracked by the application, were developed (see section 3.7.9). These are aimed to increase physical interaction as well as the familiarity to the classic Ludo game.
- The activation time of the companion was increased such that it does not affect the game flow of a non-resident guided game. The companion did however stay in the game as it could prove useful for less impaired users during the game or non-impaired users in the different menus.

4.10. Test phase B

The second phase of the evaluation, test phase B, was carried out on the 13th of May, 2019. This time, only the afternoon slot from 3:00 PM until 5:00 PM was available to test the application. During the evaluation, S1 and T1 were attending.
Similarly to the first test phase, Mr. Schiertz gave a short introduction and informal chats with the residents were held. It was decided to increase the number of players per test run in comparison to test phase A. Even though this might result in less test runs overall, it should give more insights regarding the socialization between the residents and whether or not multiple physical pieces on the board could be handled by the residents. The physical pieces with conductive paint were used. This resulted in the following test run (see Table 4.2):

Test run	Participants	Rounds	Survey methods	Details
1	R6 + R7 + R8 + T1	3	Q + O + T	The physical pieces and the Bluetooth dice were used. The board sizes Small and Medium were tested. In the first round, R6 and R7 played against each other. Then, T1 joined the game and R8 teamed up with R7 to play as a team. In the third round, R6, R7, R8 and T1 played as four individual players.

Table 4.2.: Summary of the test runs in test phase B

The test run provided many great insights. Although only one was performed due to limited availability of the residents, it gave valuable feedback regarding the design rework and the new features among others:

General usage

- There was a continuous game flow during the session. Only in rare cases, the residents needed to be reminded to perform an action. This might be due to the improved design, the familiarity to the classic Ludo game because of the physical pieces or merely because the patients were motivated and in a good mood.
- During and in between the rounds, many small informal chats were held about the game and general topics. As a result, the atmosphere was fun and relaxed. Even after the game, the residents shared their feedback and stories of their youth.
- R8 was perceived as quite a passive resident at first. The reasons might be because she comes from abroad, has difficulties articulating and is physically impaired. In the first round, she merely observed the game between R6 and R7. When the next round started, R6 integrated R8 into the game by offering her to roll the dice and he would move the pieces. Even though it took R8 longer to throw the dice, R6 and R7 were patient and motivated her to participate. In the third and last round, R6, R7, R8 and T1 played a game with four players. Whenever R8 had difficulties to move a piece, all other participants either waited until she finished or aided her in moving the piece for her.
- The reset button proved to be a valuable addition to the game. Even though it only had to be used sparsely, there were situations when a reset was necessary, e.g. when a patient accidentally dropped the dice.
- Some special rules, e.g. re-throwing the dice once a six is thrown, were not implemented to simplify the game flow. These should be added as configurable options to the game since this was asked for by some users.

Design

- The simplistic design was well received by the residents. The improved color selection distinguished the pieces clearly from the tiles. Labels for the start and finish tiles were a useful aid. The buttons were moved next to the board and hence did not confuse the participants anymore.
- Marking the possible paths of the pieces helped the players to plan their moves and was perceived as a helpful addition.
- Slowing down the piece movement allowed the residents to follow the trace.
- By increasing the activation time of the companion dog, the residents were able to perform their actions without interference. The virtual agent was merely activated, when it reminded the participants to drink or one of the players had won.

Peripherals

- The application tracked the physical pieces reliably, when they were touched by the residents. They were well received by the patients due to their physical interaction and familiarity to known experiences. Multiple pieces on the board were handled well.
- With the rework of the Bluetooth dice algorithm, the correct results were transferred at the right time.
- Similar to test run 3 in test phase A, one of the residents mentioned that the dice was a bit too big. This could be investigated in future research (see section 5.5).

Overall, the residents seemed to be in a good mood, which had a positive effect on the results of the second test phase. The software increment proved to be a good improvement of the application. Seeing how the other participants integrated R8 in their game suggests that the application indeed increases socialization. Furthermore, the physical pieces seemed to motivate the residents because this was familiar to their classic Ludo experiences. In addition to the mainly positive feedback, a few more options for improvement were identified.

4.11. Results of the Technology Acceptance Model questions

The results of the *TAM* section in the questionnaire from test phase A and test phase B are displayed in Table 4.3. As can be deduced, most of the measured *TAM* variables were assessed

Variable	test phase A	test phase B
	M (SD)	M (SD)
PU	4.0 (0.7)	4.4 (0.5)
PEU	3.25 (0.4)	4.0 (0.0)
REL	4.0 (0.7)	4.0 (0.0)
CSE	3.25 (0.4)	4.0 (0.0)
CANX	1.25 (0.4)	1.0 (0.0)
PE	4.5 (0.5)	5.0 (0.0)
BI	3.25 (0.8)	4.0 (0.0)

Table 4.3.: Mean (M) and standard deviation (SD) of the *TAM* variables

quite high[2] in the beginning and improved over the course of the evaluation. This implies that the application is overall accepted by residents as well as caregivers and could prove useful in the Alzheimer's department of the retirement home. However, due to the involvement of the thesis author, the varying condition of the patients and the limited number of test runs, especially in test phase B, the results should be treated with caution.

[2]For computer anxiety, a low score is perceived as positive.

4.12. Summary of the evaluation

The evaluation proved to be extremely helpful for the further development of the application. Even though a high focus was put on available literature and research, testing the app in a real-world scenario gave numerous insights. In general, the residents enjoyed playing the game. The connected peripherals added physical interaction and the necessary familiarity to counter computer anxiety. Whether or not the application fulfills all intended goals in the long run needs to be examined in a long-term study. But the results, that were gained from this evaluation, do already look very promising.

5. Conclusion

In the concluding chapter of this thesis, the aim of the thesis and the approach are briefly recapitulated. Afterwards, the thesis is summarized and it's scientific contribution is discussed. Finally, suggestions for future work and research are presented.

5.1. Aim

The aim of this thesis was to improve the quality of life of Alzheimer's patients in a pleasurable way. In detail, it should increase their hydration levels, engage them socially as well as challenge them cognitively and physically.

5.2. Approach

To achieve this, an extensive literature review was done in the involved fields to identify strategies and guidelines. Afterwards, a board game was developed on a tablet with a high focus on design, motivation, usability and inclusion for people suffering from Alzheimer's disease. The game was evaluated in a retirement home to test the application under real conditions.

5.3. Summary

The evaluation of the developed application and the collected feedback showed that the application was perceived as a good alternative to the classic Ludo board game. It can, however, only be used in an supportive way due to the cognitive impairment and short term memory deficits of people suffering from Alzheimer's disease. Future research will have to examine whether the applications could prove useful for non-impaired elderly users and if it fulfills the desired benefits (socialization, cognitive engagement, etc.) in the long run (see section 5.5).

5.4. Scientific contributions

This thesis generated the following scientific contributions:

Literature review An interdisciplinary literature review was performed, including the fields of Alzheimer's disease, age-related decline, application development, evaluation methods for elderly and AD patients, and hybrid tabletop games. In this context, information was accumulated and guidelines were recapitulated or developed.

Application development for Alzheimer's patients An application was developed that is specifically designed for people suffering from Alzheimer's disease with the aim to improve their quality of life in numerous ways. This was done in a structured approach by focusing on scientific research of the connected fields.

Evaluation study The developed application was evaluated in a retirement home with residents suffering from Alzheimer's disease. It's evaluation gave insights into benefits and shortcomings of the application as well as particularities when developing for and evaluating with AD patients.

Suggestions for further work During the creation of this thesis, different topics for future research were identified. These are summarized and presented in section 5.5 to promote research in the respective fields.

5.5. Future work and research

This final section presents a selection of possible topics for further research:

Further application development The application could be further developed in a variety of ways. Once the drinking devices (see section 3.4) are developed, they can be integrated into the game flow to investigate their effect on hydration levels. The gathered feedback in chapter 4 suggests that the Bluetooth dice was perceived as too big by some users. Different sizes could hence be examined.
Furthermore, the game could be extended with incentives and peripherals to improve malnutrition of the elderly. In addition, a larger tablet could be used. This would allow for an easier recognition and bigger board pieces. One could also reevaluate the concept of *PUCs* in this regard.

Tangibles for AD patients When performing the literature review, no studies could be identified that examine the development of tangibles for AD patients. In the evaluation, the residents appreciated the involvement of physical elements, but the feedback on their size and shape was mixed. This could be explored in a future work.

Different user group As could be observed from the evaluation in chapter 4, patients with Alzheimer's disease are most likely not capable of playing a digital game or using an application without external help. The implemented supportive features like color blindness, difficulty adjustment etc. could however prove useful for seniors that are not affected by dementia. By reducing computer anxiety and improving computer self-efficacy in a playful way, the seniors could acquire important skills that benefit them in their everyday life.

Longterm testing To examine the effects of the application on AD patients, the application could be tested in a long term study over several months, including researchers from other fields like psychology and medicine. The evaluation could check for changes in social connectedness, hydration, cognitive and physical activity of the patients before and after the study. Additionally, it could be tested if and how using the application affects the progress of the Alzheimer's disease.

Identify literature deficiencies The application was developed with the identified literature from chapter 2 in mind. Even though the review was done extensively, it has no claim to completeness. In a future work, this review could be critically investigated to identify shortcomings and include new progress in the respective fields.

A. Appendix

A.1. Questionnaire

Umfrage

Vielen Dank, dass Sie bei der Umfrage mitmachen. Dies hilft mir, die "Mensch-Ärgere-Dicht-Nicht"-App im Rahmen meiner Masterarbeit zu evaluieren und zu verbessern, um den Patienten ein besseres Spielerlebnis bieten zu können.

1. **Abkürzung / Geschlecht / Alter**

____

2. **Allgemeine Fragen**

Markieren Sie nur ein Oval pro Zeile.

	Stimme nicht zu	Stimme eher nicht zu	Teils - teils	Stimme eher zu	Stimme zu
Die Benutzer sind in der Lage, mit elektronischen Geräten (z.B. Tablet) umzugehen.	⬭	⬭	⬭	⬭	⬭
Die Benutzer haben Angst davor, elektronische Geräte (z.B. Tablet) zu bedienen.	⬭	⬭	⬭	⬭	⬭
Es fällt den Benutzern leicht, das Spiel zu spielen.	⬭	⬭	⬭	⬭	⬭
Die Benutzer werden mental gefordert, wenn sie das Spiel spielen.	⬭	⬭	⬭	⬭	⬭
Die Benutzer sind beim Spielen unterhalten.	⬭	⬭	⬭	⬭	⬭
Es macht den Benutzern Spaß, das Spiel zu spielen.	⬭	⬭	⬭	⬭	⬭
Die Benutzer sind beim Spielen mit anderen Patienten in Kontakt.	⬭	⬭	⬭	⬭	⬭
Die Unterstützungen (blinkende Felder, Helfer-Hund, Erinnerung wer dran ist, ...) im Spiel sind hilfreich.	⬭	⬭	⬭	⬭	⬭
Das Spiel ist eine gute Alternative für das klassische Mensch-Ärgere-Dich-Nicht.	⬭	⬭	⬭	⬭	⬭
Ich sehe Vorteile darin, das Spiel in meinem Beruf zu benutzen.	⬭	⬭	⬭	⬭	⬭
Wenn das Spiel verfügbar wäre, würde ich es mit Patienten einsetzen.	⬭	⬭	⬭	⬭	⬭

Figure A.1.: Page 1 of the evaluation questionnaire

3. **Was man noch verbessern kann. Dies kann sich z.B. auf Design, verfügbare Optionen, den Helfer-Hund oder andere Aspekte beziehen.**

4. **Sonstige Anmerkungen**

Figure A.2.: Page 2 of the evaluation questionnaire

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Acronyms

AD Alzheimer's disease. 3, 5, 8, 9, 12, 13, 17, 31, 33, 34, 36, 41, 45, 58, 59, 62

ADL Activities of Daily Living. 4, 5, 9

PUCs Passive Untouched Capacitive Widgets. 25, 44, 58

QoL Quality of Life. 12

TAM Technology Acceptance Model. 26–28, 47, 50, 55, 62, 63

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