Activating People with Dementia using Natural User Interface Interaction on a Surface Computer

Ramazan Gündogdu, Alexander Bejan, Christophe Kunze
Faculty Health, Safety & Society
Furtwangen University, Germany
{gza, beja, kuc}@hs-furtwangen.de

Matthias Wölfel
Faculty Digital Media
Furtwangen University, Germany
woma@hs-furtwangen.de

ABSTRACT

Reminiscence Therapy can act as an effective and conducive method for increasing the Quality of Life (QoL) of people with dementia (PwD) when implemented properly. In addition to non-digital approaches, digitally enhanced systems can be built to elicit positive memories as well as emotions using multimodal interaction and digital content. In the same line, interactive multimedia systems can also be used to provide meaningful, engaging and joyful activities for PwD in order to further increase well-being and QoL.

The aim of this study was to investigate whether using natural user interfaces (NUI) provides benefits to interactive multimedia systems for PwD. Elaborated interaction possibilities should further facilitate the physical and mental activation of PwD as well as stimulate positive feelings, empowerment and joy. Since there are no applications available that satisfy the particular requirements of our user group, we developed an interactive aquarium application as our study object. The application supports touch gestures as well as tangible object interaction.

The application can be used to playfully activate and engage PwD. It can help to establish and to improve communication with PwD, promote positive feelings and, last but not least, be fun. The study demonstrated that interactive multimedia systems using NUI and object interaction are a promising approach to improve the QoL of PwD.

ACM Classification Keywords

H.5.2 [INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)]: User Interfaces– User-centered design.

Author Keywords

Natural User Interface; Reminiscence Therapy; People with Dementia; Multi-touch table; Surface computing; Human-computer interaction.

PervasiveHealth '17, May 23–26, 2017, Barcelona, Spain

ACM ISBN 978-1-4503-6363-1/17/05…$15.00
https://doi.org/10.1145/3154862.3154929

INTRODUCTION

The increasing number of people with dementia (PwD) is a direct consequence of the aging society. Alzheimer's Disease International determined a number of 46.8 million PwD in 2015. Current predictions indicate that the number of PwD will globally increase to 74.7 million in 2030 [15]. Therefore, measures have to be taken to reduce the social consequences of the demographic change, such as expensive healthcare costs.

The syndrome itself is highly age-correlated. A study from 2014 determined that 33% of the people in Germany with the age of 90 were affected by dementia. Due to the longer life expectancy of women, the number of affected females is higher than the number of affected males [15].

Dementia is a severe loss of mental performance due to a prolonged dysfunction of the brain [8]. Figure 1 (a) shows the typical course of the cognitive performance of different forms of dementia. The green line illustrates the typical course of Alzheimer's disease (AD) – the most common form of dementia –, which progresses relatively slow in the first years but ultimately leads to a visible cognitive deterioration (cognitive disorders such as loss of memory and orientation, sensory disturbances and sensorimotor disorders). In later stages of the disease, extensive care support for the PwD is needed. Figure 1 (b) shows the impairment of individual functions in the different stages of AD. So called challenging behavior (such as wandering, agitation, aggressive behavior) is especially occurring at middle to late stages.

The progress of dementia is usually moderated by pharmacological and/or non-pharmacological treatments [13]. The therapeutic goals aim to reach a delay of the disease progression, stabilize the well-being of the affected persons and with that increase self-esteem and Quality of Life (QoL), hence resulting in delay of residential care and cost reductions [13].

Reminiscence Therapy (RT) is an important non-pharmacological method to treat dementia [10, 12, 31, 35]. In RT, content and artifacts related to the personal biography of the affected person are used to increase well-being and to support identity. For example, personally meaningful pictures, items or music can be presented to PwD in order to trigger positive memories and associated feelings.

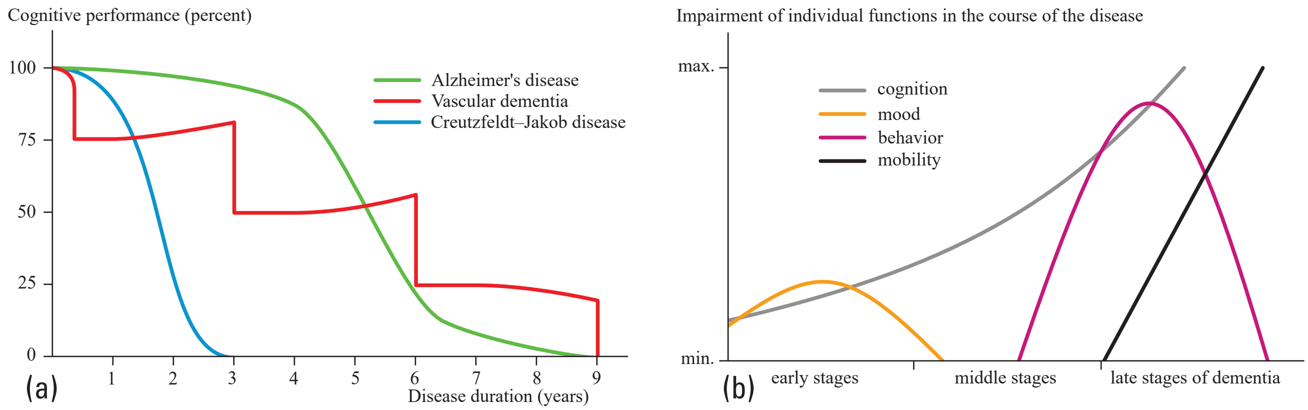

Figure 1. (a) The degradation of cognitive performance in PwD. (b) Progress of several affected traits during Alzheimer's Disease [4]

Interactive systems as dementia interventions

Recently, ICT-based solutions are used in addition to paper-based approaches in RT. New interactive media based therapies offer alternative possibilities to support people with physical and/or cognitive impairments. While the cognitive abilities of PwD decrease, the capabilities of the body's memory and emotional resonance are partially retained. Thus, the memories and communication activities of PwD can also be stimulated by using software solutions that show reminiscence-triggering content on interactive devices, e.g. touchscreen computers [1]. The natural and direct interaction paradigms as defined by Natural User Interfaces (NUI) can simplify the interaction with the necessary computer systems in contrast to plain graphical user interfaces (GUIs) [34]. The interaction can be used to evoke various memories in PwD through metaphors and physical (tangible) objects.

A corresponding interface design for the needs of the addressed user group is important to increase the interaction and fun factor, especially when users are presented with more options and opportunities to interact with the respective system [11].

The content of the interactive systems should also vary regarding the individual stages of dementia and should have an adequate "difficulty level" if applicable. However, it is hard to determine which systems or devices support interactivity as well as multimedia content representation in the best possible way regarding PwD.

Research aims and questions

The aim of this study was to investigate whether using a NUI approach provides benefits for interactive multimedia systems meant to facilitate the physical and mental activation of PwD as well as the stimulation of positive feelings and joy. It is embedded in the "Interactive Memories (InterMem)" project. The InterMem project is investigating the use of multimedia artefacts as memory triggers (amongst other things texts, films and photos) in mixed-reality systems.

In order to evaluate interaction principles for PwD, a simple and user-friendly interactive 3D visualization of an aquarium controlled by touch gestures and augmented tangibles was developed. The application is used to explore the ways of interaction of PwD with a system adhering to NUI principles. Based on a qualitative approach, some aspects regarding the effectivity, usability and user experience of the application were evaluated in trial in a dementia care institution.

RELATED WORK

NUI describe the most "natural" way how a user can interact with a computer. The term natural in the perception of interactive systems is based on the familiarity, intuitiveness, experiences from the real world, use of familiar gestures, short learning curve as well as waiving additional input devices like mouse and keyboard and thus eliminating an additional abstraction layer [34]. According to this paradigm, the interfaces have to be designed for "natural users" – the interface shouldn't be the focus, the user himself should perform his "natural action". Moreover, Wigdor and Wixon emphasize three important factors by which they are defining NUIs. A NUI should be enjoyable, leading to skilled practice, and be appropriate regarding the context.

In addition to that, usability factors such as ease-of-use and joy-of-use must be considered when creating NUIs. To provide further enjoyment, the application can be augmented by a gamification approach and/or by implementing activities playfully and thus trying to reach a certain "fun factor" (e.g. ludic engagement and ludic interface) [7, 19].

Adapting NUIs for elderly PwD

Villaroman et al. [33] understand NUIs as interfaces which are designed specifically for a particular type of human interaction. They should be designed to keep the learning curve of the users as short and instinctively as possible – a trait that becomes important when targeting PwD as users.

In their study, Loureiro et al. [21] have demonstrated that traditional input devices such as mouse and keyboard can be a major barrier for the elderly. Older adults can quickly learn to use touchscreens; however, inadequate interfaces (small font, button and icon sizes, too much complexity or "user-unfriendliness") can disappoint and prevent them from further use [21]. The resulting classifications of the study show that multi-touch as an interaction modality of NUIs offers new opportunities for the elderly to interact with the computer.

Luiz et al. [17] have presented a series of guidelines for creating applications for older adults by using NUIs as interface paradigms. The authors have proposed these guidelines for applications that promote the entertainment, recreation and rehabilitation of older adults especially through games and serious games. The results have also indicated that a user test of such a novel interface is highly important in order to promote user confidence.

Leone et al. [18] have conducted an investigation using a NUI-based virtual trainer for the cognitive rehabilitation of PwD. By using the "Cognitive Rehabilitation Home system", the patient can perform rehabilitation-conducive practice directly at home. The main question was how the cognitive domain – such as orientation, memory, attention, verbal articulation and logic – of PwD can be improved. The results also indicate that such NUI-based training systems can be used by PwD without the presence of any caregivers.

Astell presented four basic principles for the development of technical solutions to address the needs of PwD [2]. The so-called REAFF-principles ("Responding", "Enabling", "Augmenting" and "Failure-free") should be implemented in order to increase the well-being of PwD. The NUI and REAFF principles are similar and compatible in many respects. Thus, NUI principles adapted to this specific context can be seen as the extensions of the REAFF concept. For example, NUIs are adaptive to the context of their users and offer a direct and non-restricted interaction with the system; they aim to entertain and have a high fun factor and thus play an activating role; they are quickly learnable and their modalities are based on already learned skills.

Technology-supported RT

Sixsmith et al. [30] analyzed the demand for technical support from the perspective of PwD. On their "technology wish-list for PwD", they have identified the topics of promoting reminiscence, supporting conversations and encouraging the use of music as most important points.

A review study and expert consultations [28] have shown that there are new therapeutic potentials based on supportive technological systems – or rather interactive systems – for activating as well as promoting PwD and that these interactive systems are particularly well received by caregivers of PwD. Experts also consider computer games and interactive applications (e.g. Serious Games) very useful for activation and memory training.

Siriaraya and Ang [29] have studied how the use of 3D virtual environments can be used to trigger memories of PwD. With gestured-base interaction, PwD were able to interact with each other and with their caregivers in virtual rooms. Their results have shown that the positive emotions of PwD were stimulated and that the virtualized environments helped to set the mood of residents to a more positive state.

Touch-interaction based multimedia systems for RT have also been investigated in several studies in the past [6, 24, 27], most notably in the CIRCA project [3]. The studies are suggesting positive effects on QoL.

In a preliminary study, we tested a surface computer enhanced with object interaction for technology-based RT [26]. Surface computers – with their large sized screen, including multi-touch and optionally allowing for object recognition, culminating in an ergonomic and familiar (table-like) interface –, seem especially suitable for this purpose. These systems inherently support natural interaction modalities and offer opportunities to create novel multimodal interactive applications that can be designed similar to real activities performed on a table, e.g. playing tabletop games or reading books.

Furthermore, tangible-based RT was put to test by Huldtgren et al. in their study [14] using augmented artefacts acting as "memory triggers". A "reminiscence window" was developed in a similar study [23] of Mertl et al., which allows the PwD to experience thematic digital window-views depending on the chosen RFID-augmented postcard.

In summary, the literature shows that multimedia systems based on touch interaction, surface computing, an tangible interaction seem promising approaches for enhancing and improving RT for PwD. However, only very small scale trials are available regarding systems with interaction possibilities beyond touch screens. Research on the influence of different interaction modalities and other system design aspects (such as device type, screen size, 2D/3D perspective) on the usability and efficacy of technology-based RT is still lacking.

In order to investigate different interaction modalities, we developed and evaluated a multimedia system with multi-mode NUI interaction to create a potentially accessible as well as empowering experience for PwD.

SYSTEM DESIGN AND IMPLEMENTATION

This chapter describes the user-centered design process and various implementation aspects of the developed system.

Preliminary design phase

A user- and context-centered application development approach is vital in the context of dementia [20]. Based on the literature research, 8 different design ideas were generated and illustrated in the form of Mockups embedded in application scenarios. These ideas were presented to three caregivers in a nursing home for PwD in an expert interview. Individual experts expressed their opinion on the presented mockups including negative as well as positive impressions. The aim of the expert interviews was to find out the needs of PwD from the perspective of an expert group and to develop and improve possible application ideas collaboratively. Based on the data obtained from interviews, the aquarium application scenario was selected and requirements for the application were derived. On one hand, the application is expected to trigger specific memories if the PwD had his or her own aquarium (or went to a public aquarium) and on the other hand, well-being can be achieved via playful activities implemented into the virtual aquarium as an added value compared to real world aquaria.

Basic system design and architecture

The application was developed for a surface computer with the Microsoft PixelSense IR-pixel technology, namely the 40 inch Samsung SUR 40 (see Figure 2). Figure 3 shows an overview of the system architecture. The Open Source application reacTIVision[1] is used for object recognition and tracking touch interaction. Since this only works with the Linux IR camera drivers on the PixelSense table, we used the cross-platform game engine Unity 3D on Linux as the main development environment instead of the Microsoft Surface SDK. The generated touch and marker information is sent to the application using the "TUIO" message protocol via UDP [16]. The TUIO message is duplicated using the "Samplicator" application so that it is received from both the Unity Touch (Uniducial) and Marker-detection (Unity3d- tuio) plug-ins, thus enabling both touch and marker inputs.

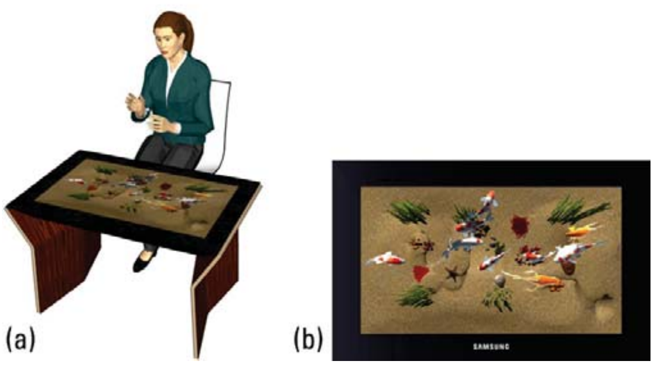

Figure 2. (a) Touch table/ Surface computer MS PixelSense; (b) frontal view

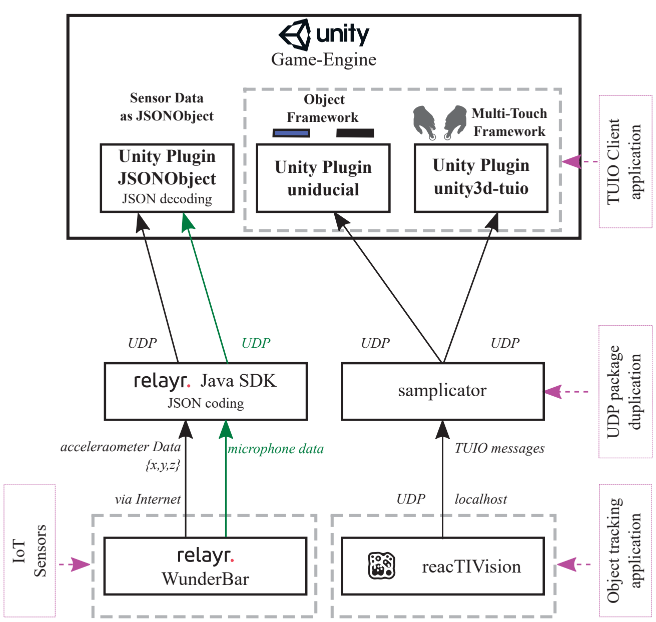

Figure 3. The architecture of the application

[1] http://reactivision.sourceforge.net/

In addition to touch-input and marker-based object recognition on the table, we used an IoT-based sensor framework (relayr Wunderbar) to augment objects with movement and sound sensors. In order to read the sensor data from the relayr cloud platform, an additional application was developed using the relayr Java SDK, which encodes sensor data in the JSON format and sends it to the client application.

Interaction design: Touch, gesture and tangible interaction

Figure 4 shows the physical objects used as haptic interaction elements in the application. Only objects that can be associated to certain real-world actions have been used as haptic elements to be used for an "extended interaction". As such, a further distinction can be made between augmented "real" objects with authentic proportions (as well as appearances) and proxy objects, which solely represent real objects or actions. In any case, it is important that the physical objects are easy to handle and, if applicable, produce acoustic feedbacks. For example, it has been ensured that the food can generates a natural sound when being shook, a notion that may lead to the association of the extended virtual interaction with the proper real life interaction.

Optical markers were used to augment plastic toys and beakers that could be moved on the surface to interact with the application. The fish "flee" from the (proxy) boat object (Figure 4 (a)) when it is placed on the top of the surface right above or near them. The fish catching function is triggered by the (proxy) cup object shown in Figure 4 (b). Figure 4 (c) represents the (real) food can and shows how the acceleration sensor is installed internally (Figure 4 (d)) in a way that the hidden technology behind it isn't seen when interacting with it. Furthermore, Figure 4 (e) also shows the cube "navigation object" which can be used to switch between the side view and the top view. Three objects of each type have been created so that the application and its functions can be simultaneously interacted with by several users. This allows to observe whether and how these objects are used collaboratively by PwD in group sessions.

Interaction modes implemented in the system

Following design recommendations in [5, 17, 22, 34], the following interaction modes and input modalities were implemented in the application (see Figure 5):

Touch events

- *Double-tap fish*: A double-tap on a fish will provoke it to move randomly and quickly.
- *Swipe over fish*: If the fish are touched and the finger is moved back and forth, they follow the trajectory of the user's finger. The application also has multi-touch-capable features which allow the aforementioned as well as the following actions with multiple fingers from multiple users at the same time.
- *Touch surroundings*: If the finger is held down on the interaction surface, all fish move together with the same speed in the direction of the finger's position.

Figure 4. (a) Boat object; (b) "fish catcher"; (c) food can; (d) food can with IoT-acceleration sensor; (e) Navigation cube

- *Tap fish if caught*: The caught fish can be released with a touch on it.

Object placing events

- *Food can*: When the fish food can is placed on the interaction surface, the fish move in the direction of the food can. If the food can is then moved on the surface, the fish follow it.
- *Boat*: The boat object is pushed back and forth on the surface, the fish that are in its vicinity "flee".
- *Catcher cup*: With this object, the fish are caught and added to a visual box at the bottom right of the surface by placing the cup directly on the fish. Hence, the fish are trapped in a box on the surface, but they are still alive and can be set free again with a simple touch (see touch events above).
- *Mode toggle / navigation cube*: The cube object can be used to toggle between a side view and a top view and thus serves as a navigation object between both views.

Non-surface interaction events

- *Accelerating the food can*: By using an acceleration sensor to augment the fish food can, the fish can be "fed" without placing the can on the interaction surface. If the food can object is shaken fast enough, all fish move to the centre of the aquarium.
- *Clapping hands*: With the sound sensor installed at the edge of the touch table, noises can be detected either by knocking on the edge of the table or by clapping the hands. When enough noise is generated, the fish are "frightened", so that they randomly move in all directions.

EVALUATION SETUP AND METHODS

Designing and evaluating assistive technologies for and with PwD implies several methodological challenges [20, 32]. Many standardized instruments that are well established in usability research (such as questionnaires) cannot be used due to the cognitive impairments of the target group. For instance, most of the residents included in this study can hardly communicate verbally. Measurement approaches that use wearable sensors (including psycho-physiological sensors and head-worn eyetracking systems) cannot be used for PwD because wearable systems are very poorly accepted by PwD. These possibly evoke states of anxiety and such measurements would be hard to justify ethically.

For PwD in a particular stage, the most sufficient examination is an observation with a specific observational form. Observation approaches such as dementia care mapping [9] are widely used for measuring QoL of PwD in care settings. Another challenge is the day-to-day variation of mood and cognitive performance of PwD that makes it very hard to compare outcomes of interventions in short-term trials.

The interactive aquarium application was tested in a dementia care institution in individual and group sessions with n=16 PwD as participants: The initial 11 participants were observed in individual sessions and were later joined by 5 new participants for the group session tests. The sample consisted of 15 females and 1 male participant. For the testing, 6 participants with early, 6 with medium and 4 with late stage of dementia (according to the dementia care home assessments) were selected. Each individual and group session was accompanied by two caregivers. All application parts (see Table 1) were executed successively with the help of caregivers in both session types and were tested for 1 up to 4 minutes, as the interest of the residents usually subsided after a few minutes.

On the basis of a self-created observation protocol, the behavior of the participants was documented in order to draw further conclusions. The observation protocol has been used to investigate the following aspects: The residents general response to and interest in the interaction modalities and the content; the perception of the haptic elements and their interaction with the virtual content; evaluation of cognitive and physical constraints during the execution of the inputs; association of the device with a real aquarium; triggered entertainment/fun and conversation of residents during the interaction.

EXPERIMENTAL RESULTS

In the following paragraphs, the findings are firstly described regarding the reactions of the PwD in general and secondly regarding selected interaction modalities and specific system traits. Subjective impressions of caregivers regarding the interaction modalities are shown in Table 1. The caregivers rated the different parts of the application for the activation session of PwD with "rather positive" (+), "rather negative" (-) and with "neutral" (0). The accompanying measures relating to the single sessions are shown in Table 2.

General findings regarding the single sessions

It was observed that each of the participants was at least "rather awake" before the test session, thus meeting a vital require-

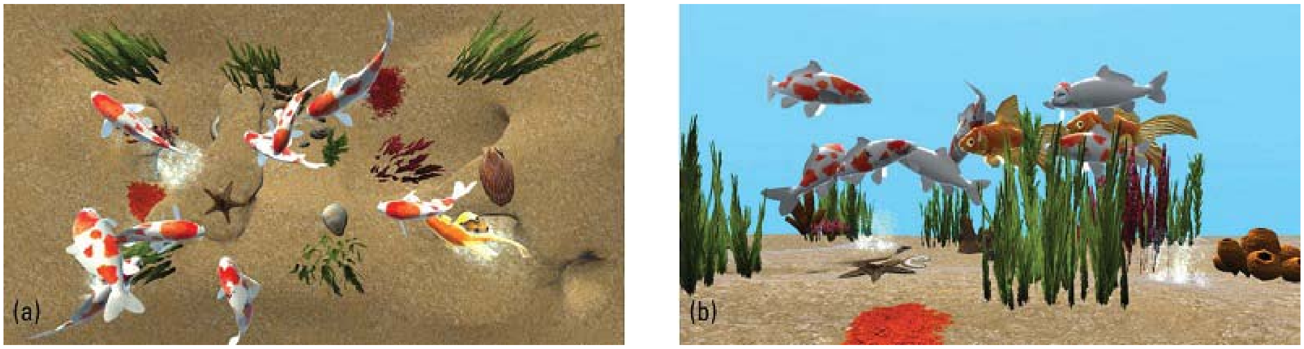

Figure 5. (a) Top view; (b) Side view of aquarium

Application parts	Interaction modalities	Ease-of-use	Joy-of-use
Touching and moving the fish	Touch	0	+
Feeding the fish	Object and sensors	-	+
Scaring the fish	(Acoustic) clapping gesture	+	+
Catching the fish	Object	0	+
Freeing the fish from the box	Touch	+	+
The boat	Object	+	+
Top view	N/A	+	+
Side view	N/A	-	+
Mode change via cube object	Object	+	+

Table 1. Ratings of the different application parts according to the caregivers

ment for the study's progress. However, the specific aquarium setting merely triggered the interest and reactions of a subset of the PwD. In the same line, immediate interactions were seldom initiated by the PwD themselves.

Independent use of the NUI system
Concerning the interaction process itself, the PwD needed permanent help and prompting while using the system. Independent interactions were uncommon. In this regard, the provided support by the caregivers can help in overcoming cognitive and physical impairments and provide assistance, a sense of security and emotional closeness.

Object interaction using the example of the fish food can
Before interacting with physical objects, the residents had the opportunity to smell the fish food can. The food can contained real fish food that had a very intensive smell: Some of the test persons were activated by the smell, leading to an association of the object to fish food. 46% have – verbally as well as non-verbally – reacted to the use of the physical food can either by showing their joy in the form of smiles or by watching the fish in a joyful manner. 36% of the residents were unable or unwilling to move the food can on the touch table due to impaired motor skills or lack of interest.

The acoustic feedback, which was produced by a shaking motion with the can, has elicited a reaction leading to some of the PwD being afraid to soil the table with fish food. In the same line, some have asked why no food is spread on the table after shaking (for detailed interaction ratings see Table 1).

Perception of virtuality vs reality
Depending on their state of dementia, the perception between virtuality and reality varied. In later stages, residents seemingly couldn't distinguish the virtually generated effect from the real one: In a group session, one PwD tried to collect the fish with both hands indicating that she perceived the fish as real animals. To the best of our knowledge, this has not been observed before.

Interaction and direct feedback
PwD seem to expect rapid feedback mechanisms directly after the interaction. It has been observed that they have a need for immediate cause-effect-feedback. Technical unreliability and latencies may cause an impaired recognition of the situation, thus leading to confusion, which can ultimately lead to diminishing interest in terms of further interactions.

In contrast, PwD in middle to late dementia stages seem to have no discernment for latencies and delayed system-side feedbacks. Because of this, a "faulty" interaction could be mistaken as a normal interaction.

Enjoyment and fun factor
After completion of the test phase, the residents were asked if they had enjoyed the interaction with the aquarium: 46% of residents answered the question with "yes". The entertainment and the fun factor of the residents was also clearly visible during the sessions. In contrast, 27% of them answered the

How awake/ alert where the residents before the session?		
fully awake	rather awake	sleepy/ asleep
3 (27%)	8 (73%)	0 (0%)
How was the reaction at first sight to the application?		
verbal	non-verbal	no reaction to the application
6 (55%)	1 (9%)	4 (36%)
Have the fish triggered the interest of the residents at first sight?		
very much	rather less	not at all
4 (36%)	2 (18%)	5 (46%)
Could the residents associate the application with an aquarium?		
yes, immediately	yes, with support	no, not at all
4 (36%)	4 (36%)	3 (28%)
Have the residents attempted to touch the fish at first sight?		
yes, immediately	yes, with support	no
1 (9%)	3 (27%)	7 (64%)
How did the residents try to touch the fish?		
with index finger	with whole hand	no reaction
5 (46%)	3 (27%)	3 (27%)
How often did the residents need help/support?		
permanently	partially	no support needed at all
9 (82%)	2 (18%)	0 (0%)
How did the residents react to the movement of the fish food can and the following fish?		
verbal	non-verbal	no reaction
1 (10%)	5 (45%)	5 (45%)
When they were asked, did the residents perceive the top- to side-view change as different?		
answer: yes	answer: no	no reaction
2 (18%)	7 (64%)	2 (18%)
Did the residents enjoy it? (Question posed after the session)		
answer: yes	answer: no	no reaction to question
5 (46%)	3 (27%)	3 (27%)

Table 2. Selected results from the evaluation of the single sessions (n = 11)

question with a "no". Here, the content of the application didn't seem to address the interest of these residents.

Reminiscence and activation factor

In general, it could be observed that the aquarium, even if not personalized, could contribute to reminiscence and activation of PwD with a certain fun and joy factor. The virtual fish and the aquarium acted as metaphors that had a memory-triggering function: Some of the PwD have begun to tell stories about real aquaria they got to know in their past lives and some have confused the virtual fish with their old pets.

Immersiveness and realism factor

With correctly mapped NUIs, immersive applications can be implemented so that the difference between virtuality and reality is becoming increasingly blurred to the users. In the context of the aquarium at hand, it seems that PwD don't always see the difference between the "real thing" and the virtual thing – even if the visual orientation mapping is incorrect – and therefore interact with virtual fish in an authentic and haptic manner. The conjunction of a haptic interface and authentic content in combination with the impaired cognition seems to trigger the perception-shift from virtual fish and aquaria to real fish and aquaria. Thus, many PwD couldn't distinguish that the fish on the table were virtual objects. In turn, it wasn't always possible to determine whether they had perceived the fish as virtual objects.

DISCUSSION

Beside the positive and "activating" results the intervention was able to yield via immersive NUI and object inputs, the general interaction with these input modalities is highly dependent on the surrounding conditions, i.e. on the stages of dementia and the individual form on the day. Especially the PwD's declining perception of the physical as well as virtual objects confirms this: People with middle to late stage of dementia oftentimes couldn't associate the interaction objects with their underlying metaphor due to their impaired cognition. The same group couldn't distinguish the virtual aquarium from a real one. In addition to the perception, the reaction times in these stages decreased as well, indicating an impaired situation recognition.

The perception of the virtual fish by PwD may have been strongly influenced by a non-acceptance stance towards them in line with the undesirable *Uncanny Valley* effect [25]. Said effect, which is evoked by seemingly innocuous perceptual stimuli, e.g. an effigy of nature which appears almost, but not exactly, like real nature and hence elicits feelings of eeriness and revulsion – can occur more quickly with PwD in middle to late stages of dementia as compared to PwD in early stages dementia.

Many established research approaches are difficult to implement and hard to justify for PwD because wearable systems (including psycho-physiological sensors and head-worn eye-tracking systems) are very poorly accepted by PwD.

Possible solutions and outlook

To compensate for some of the encountered deficits, the theme of an interactive device in the context of PwD should correspond to the personal interests and life experiences of the individual users, as suitable personal biographic content makes the interaction more appealing to PwD. Furthermore, a correct visual orientation mapping should be implemented to avoid confusion. These statements equally apply to all other virtual and physical content objects in an interactive system for PwD. But even if the aquarium was suboptimal for RT as it could only activate the memories of some PwD with its very specific topic, it was in turn still accepted by the target group and could be effectively used to enhance the QoL through playful activation and occupation.

In addition to the touch and object interactions, odour also seems to play an important role in the given context. Odours are still perceived even in late stages of dementia. Because there was real fish food in the food can, the participants were more or less stimulated to the extent that some of them could understand that the said object should represent fish food. Through harmonizing odours, physical interaction objects can be quickly identified and correctly assigned to their non-augmented counterparts. Thus, the "odour factor" should be incorporated in future research to further improve the immersiveness of the application.

Apart from some of the more complex context-specific problems, it can be concluded that interactive systems based on the NUI paradigm are valuable tools for creating multimedia-based interventions that playfully coach and activate motoric abilities as well as memories and ultimately increase the well-being and QoL of PwD.

REFERENCES

1. Norman Alm, Arlene J. Astell, Maggie Ellis, Richard Dye, Gary Gowans, and Jim Campbell. 2004. A cognitive prosthesis and communication support for people with dementia. *Neuropsychological Rehabilitation* 14, 1-2 (2004), 117–134.
2. Arlene J. Astell. 2009. REAFF - A framework for developing technology to address the needs of people with dementia. In *CEUR Workshop Proceedings*, Vol. 499. 5–10.
3. Arlene J. Astell, Norman Alm, Gary Gowans, Maggie P Ellis, Philip Vaughan, Richard Dye, and Jim Campbell. 2009. Working with people with dementia to develop technology: The CIRCA and Living in the Moment projects. Vol. 17. Hawker Publications Ltd, 36–39.
4. Roland Bischoff, Michael Simm, and Rolf A. Zell. 2004. Der Kampf gegen das Vergessen - Demenzforschung im Fokus. PDF. (2004). Retrieved Febuary 20, 2017 from `http://www.gesundheitsforschung-bmbf.de/_media/Demenzforschung.pdf`.
5. Joshua Blake. 2012. *Natural User Interfaces in .Net*. Manning Publications Company.
6. Justine Cassell. 1998. *A Framework for Gesture Generation and Interpretation*. Cambridge University Press, 191–216.
7. Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. 2011. From Game Design Elements to Gamefulness: Defining "Gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments (MindTrek '11)*. ACM, New York, NY, USA, 9–15.
8. Hans Förstl and Christoph Lang. 2011. *Was ist »Demenz«?* Springer Berlin Heidelberg, Berlin, Heidelberg, 3–9.
9. Jane Fossey, Lesley Lee, and Clive Ballard. 2002. Dementia care mapping as a research tool for measuring quality of life in care settings: psychometric properties. *International Journal of Geriatric Psychiatry* 17, 11 (2002), 1064–1070.
10. Deutsche Alzheimer Gesellschaft. 2016. Die nicht-medikamentöse Behandlung von Demenzerkrankungen. PDF. (2016). Retrieved March 14, 2017 from `https://www.deutsche-alzheimer.de/fileadmin/alz/pdf/factsheets/infoblatt6_nichtmedikamentoese_behandlung.pdf`.
11. Peter Gregor, Alan F. Newell, and Mary Zajicek. 2002. Designing for Dynamic Diversity: Interfaces for Older People. In *Proceedings of the Fifth International ACM Conference on Assistive Technologies (Assets '02)*. ACM, New York, NY, USA, 151–156.
12. Elmar Gräßel, Jelena Siebert, and Gudrun Ulbrecht. 2013. Was leisten nicht-medikamentöse Therapien bei Demenz? Ein Überblick über aktuelle Projekte. *Informationsdienst Altersfragen* 40, 2 (2013), 9–16.
13. Hans Gutzmann and Richard Mahlberg. 2011. *Rationelle Therapie*. Springer Berlin Heidelberg, Berlin, Heidelberg, 299–315.
14. Alina Huldtgren, Anja Vormann, and Christian Geiger. 2015. Reminiscence map: Insights to design for people with dementia from a tangible prototype. In *ICT4AgeingWell 2015 - Proceedings of the 1st International Conference on Information and Communication Technologies for Ageing Well and e-Health*. 233–242.

15. Alzheimer's Disease International. 2016. World Alzheimer Report 2016. PDF. (2016). Retrieved Febuary 15, 2017 from `https://www.alz.co.uk/research/worldalzheimerreport2016sheet.pdf`.

16. Martin Kaltenbrunner, Till Bovermann, Ross Bencina, and Enrico Costanza. 2005. TUIO: A Protocol for Table-Top Tangible User Interfaces. In *Proceedings of the 6th International Workshop on Gesture in Human-Computer Interaction and Simulation*. Vannes, France.

17. André Luiz Satoshi Kawamoto, Valéria Farinazzo Martins, and Flavio Soares Corrêa da Silva. 2014. Converging Natural User Interfaces Guidelines and the Design of Applications for Older Adults. *International Conference on Systems, Man, and Cybernetics* (2014), 2328–2334.

18. Alessandro Leone, Andrea Caroppo, and Pietro Siciliano. 2014. A virtual trainer by natural user interface for cognitive rehabilitation in dementia. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, Vol. 8515 LNCS. 300–309.

19. Craig A. Lindley. 2004. *Ludic Engagement and Immersion as a Generic Paradigm for Human-Computer Interaction Design*. Springer Berlin Heidelberg, Berlin, Heidelberg, 3–13.

20. Stephen Lindsay, Katie Brittain, Daniel Jackson, Cassim Ladha, Karim Ladha, and Patrick Olivier. 2012. Empathy, Participatory Design and People with Dementia. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 521–530.

21. Bruno Loureiro and Rui Rodrigues. 2011. Multi-touch as a Natural User Interface for elders: A survey. *6th Iberian Conference on Information Systems and Technologies (CISTI 2011)* (2011), 1–6.

22. Bruno Loureiro and Rui Rodrigues. 2014. Design Guidelines and Design Recommendations of Multi-Touch Interfaces for Elders. In *Proceedings of the 2014 International Conference on Advances in Computer-Human Interactions*. 41–47.

23. Fabian Mertl, Bastian Dewitz, Uli Braas, Arthur Glomb, Alina Huldtgren, Anja Vormann, and Christian Geiger. 2015. Erinnerungsfenster für Demenzkranke. In *Mensch und Computer 2015 – Proceedings*, Sarah Diefenbach, Niels Henze, and Martin Pielot (Eds.). De Gruyter Oldenbourg, Berlin, Germany, 295–298.

24. Outi Mäki and Päivi Topo. 2009. User needs and user requirements of people with dementia: Multimedia application for entertainment. *Dementia, design and technology: Time to get involved* (2009), 61–75.

25. Masahiro Mori, Karl F. MacDorman, and Norri Kageki. 2012. The Uncanny Valley [From the Field]. *IEEE Robotics Automation Magazine* 19, 2 (2012), 98–100.

26. Patrizia Murko and Cristophe Kunze. 2015. Tangible Memories: Exploring the use of tangible interfaces for occupational therapy in dementia care. In *Proceedings of the 3rd European Conference on Design4Health, Sheffield 13-16th July 2015*.

27. Kanvar Nayer, Arthur de Bono, Selby Coxon, Eva van der Ploeg, and Daniel O'Connor. 2014. *Memory Box: A Personalised Multimedia Device for Individuals with Dementia*. Springer International Publishing, Cham, 333–341.

28. Tanja Schultz, Felix Putze, Ralf Mikut, Nora Weinberger, Katrin Boch, Eric Schmitt, Michael Decker, Dagmar Lind-Matthäus, and Brigitte R. Metz. 2014. Technische Unterstützung für Menschen mit Demenz – Ein Überblick. In *Technikkompatibilität von Netzwerken in der ambulanten Pflege von Menschen mit Demenz*, T. Schultz, F. Putze, and A. Kruse (Eds.). KIT Scientific Publishing, Karlsruhe, Germany.

29. Panote Siriaraya and Chee Siang Ang. 2014. Recreating Living Experiences from Past Memories Through Virtual Worlds for People with Dementia. In *Proceedings of the 32Nd Annual ACM Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 3977–3986.

30. Andrew J. Sixsmith, Grant Gibson, Roger D. Orpwood, and Judith M. Torrington. 2007. Developing a technology "wish-list" to enhance the quality of life of people with dementia. *Gerontechnology* 6, 1 (2007), 2–19.

31. Ponnusamy Subramaniam and Bob Woods. 2012. The impact of individual reminiscence therapy for people with dementia: systematic review. *Expert Review of Neurotherapeutics* 12, 5 (2012), 545–555.

32. Päivi Topo. 2009. Technology Studies to Meet the Needs of People With Dementia and Their Caregivers. *Journal of Applied Gerontology* 28, 1 (2009), 5–37.

33. Norman Villaroman, Dale Rowe, and Bret Swan. 2011. Teaching natural user interaction using OpenNI and the Microsoft Kinect sensor. *Proceedings of the 2011 conference on Information technology education - SIGITE '11* (2011), 227.

34. Daniel Wigdor and Dennis Wixon. 2011. *Brave NUI world: designing natural user interfaces for touch and gesture*. Morgan Kaufmann, Burlington, Mass.

35. Bob Woods, Aimee E. Spector, Catherine A. Jones, Martin Orrell, and Stephen P. Davies. 2005. Reminiscence therapy for dementia. *Cochrane Database of Systematic Reviews* 2 (2005).