A Virtual Environment Gesture Interaction System for People with Dementia

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Abstract
As dementia will most likely become an impactful challenge for our future society, it is imperative to maintain the well-being of the diverse group of people with dementia (PwD). Thus, appropriate interventions that effectively trigger identity-stabilizing memories, and at the same time encourage sensorimotor activities, have to be designed and implemented. To that end, we present a novel natural user interface (NUI) system combined with a reminiscence-provoking virtual 3D environment (VE). With it, PwD can delve into memories while interacting with the VE over dementia-fitted gestures. The results of the preliminary evaluations are promising, as they show that most PwD get immersed and cheerfully engage in gesture interactions after a short settling-in period.

Author Keywords
Dementia; natural user interfaces; virtual reality; virtual environment; reminiscence therapy; gesture interaction; joyful, fun moments; memory triggering.

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

Experimental set-up of the *RT-GIS*

Figure 1: Lateral view of the experimental set-up showing the participant and caregiver as well as the display wall and camera.

Figure 2: Dorsal view showing a "gesture in progress" as well as the Kinect gesture sensor.

Introduction and motivation

The combination of the demographic change with the predicted shortage of nursing staff will most certainly lead to complex challenges for our future society. For 2030, a worldwide number of about 75 million people with dementia (PwD) is predicted [1]. As dementia is an age-correlated syndrome, a very specific research and development field will have to cope with its characteristic problems in order to maintain the well-being of the affected persons.

Embedded into the project infrastructure of *InterMem* (Interactive Memories for PwD) [14], this preliminary study aims to explore the mere possibility of effectively using natural user interfaces (*NUI*s, esp. gesture systems; please note that touchscreens are not regarded as NUIs in this paper) [24] by the PwD themselves in a virtual 3D environment (*VE*) in order to trigger reminiscent and joyful moments for them. In turn, the ensuing reminiscence moments are thought to keep the quality of life of the highly diverse, individual as well as vulnerable target group on a steady level.

Related work and approach

In modern dementia care, Kitwood's well-known *person-centered care* approach [13] – putting the PwD as a person in the middle of the care process – has been adopted as gold standard in many dementia care institutions. In line with his philosophy, reminiscence therapy (*RT*) is a viable option to validate PwD as the individuals they are, by triggering positive memories with biographically relevant cues (e.g. pictures, videos, music or physical objects).

Several studies [7, 19] have shown that RT can have a positive impact on identity stabilization and thus quality of life, albeit the whole process is heavily dependent on the particular surroundings and the state of dementia of the PwD participating in the RT session. This also applies to the highly sought-after [20] technological systems [15] trying to add value by providing a time-saving and easy-to-access multimedia pool as compared to the non-technological process. As a prominent example, the Computer Interactive Reminiscence and Communication Aid (*CIRCA*) [2] system successfully activated the reminiscence of PwD by providing several interactive virtual audio-visual experiences with several themes to choose from.

However, we could not fully replicate the findings of other studies pertaining to "interactivity" in some of our own studies – e.g., the PwD didn't seem to feel the need to interact with our wall-mounted touchscreen display, they often said "sitting here is just fine" when prompted by the caregiver to interact with it. This may have been a problem caused by the more "receptive" "TV-like" format of some of the sessions, as more multimodal NUI-like approaches based on large surface table computers in conjunction with augmented objects [4, 5, 9] seemed to elicit independent interactions by the PwD. As independent interactions add an important active "motor" value [10] when compared to the merely passive-receptive RT approaches and VE seem generally suited for PwD interactions [8], we propose a novel way of activating the reminiscence of PwD via a virtual environment "reminiscence therapy gesture interaction system" (***RT-GIS***).

Methods, design and challenges

Based on the insights of the related work, *human-centered design* [12] was used in combination with the *REAFF* principles (i.e. responding, enabling,

Gestural interaction of the PwD *together* with the caregiver

Figure 3: The caregiver shows the PwD how to interact with the VE: here it is the motion of the *feeding* gesture.

Figure 4: The PwD repeats the motion of the caregiver.

augmenting, failure-free) [3] and Bouchard et al.'s guidelines [6] to create an appropriate experience. Taking the location of our partner dementia care institution into consideration, we "biographically" tailored the content of the RT-GIS to PwD that grew up in the Black Forest area: hence, the VE consisted of an old country house with either a cat or a dog as pet avatar (for prompting as well as feedback purposes).

Consequently, the aforementioned pre-fabricated 3D assets were integrated into a software based on the *Unity3D* engine [22]. On the hardware side, we decided to use the already tried and tested 4x55-inch *display wall* as the VE display device (the usage of a head-mounted device was disapproved of by the care staff). In order to represent the wide field of gestural NUIs, three different gesture recognition systems – with slightly different interaction modes – were chosen: The Microsoft *Kinect* 3D sensor [18] (frequently used in assistive technology research for elderly people [23]), the *Leap Motion* [17] tracking device and the myoelectric bracelet *Myo* [21]. Subsequently, a suitable set of 8 easy-to-use gestures (see Figures 3, 4 and 5 for excerpts) with direct relations to the multi-modal actions in the VE world had to be designed, e.g. "stroke pet", "feed pet" or "turn radio on/off".

Finally, a small scale field study was conducted at our project partner in Hüfingen, Germany: n = 5 PwD (mid-stage dementia) were tested in two consecutive RT-GIS sessions (avg. 13 min./session; see Figure 1 and 2 for the experimental set-up). The first session tested the Leap Motion sensor whereas the second session used the Kinect and the Myo sensor. Both sessions were conducted in the same room with the same plan of action: The PwD (always accompanied by a caregiver) had to enter the house by opening the door, then pet and feed the animal avatar and ultimately turn on the radio in the kitchen. The session was controlled and observed by an out-of-sight "Wizard-of-Oz" (the system did not yet react automatically to the particular PwD's gestural input) in order to avoid false-positives. Furthermore, the session was recorded on video and the caregivers accompanying the PwD were interviewed and asked about their impressions regarding the RT-GIS sessions. The whole material was then logically transcribed and further analyzed, leading to some of the results described in the next section.

Results

In essence, the RT-GIS sessions seemed to have a rather positive effect on the PwD: in most cases, the PwDs' facial expressions showed pleasure and interest rather than fear or anger (as partially measured with the *Proxemo* smartwatch tool [11]; see Table 1 for the results). In addition to that, their verbal statements – in several cases reminiscence statements – validated the aforementioned affects most of the time. The gestures themselves had to be introduced by the caregiver, but after that, most of the PwD were able to carry them out independently. One of the participants even remembered the first session in the second evaluation about a month later.

Notwithstanding, some unexpected events also occurred: As we initially tried to make the sessions more objective by providing a "standardized" plan of action, one PwD did not want to follow the plan but rather his own interests and explore the old 3D house. Thus, the wizard listened to the ensuing conversation and changed the view accordingly, pointing the screen area to the desired photograph on the old wooden

Gestural interaction and emotional response in detail

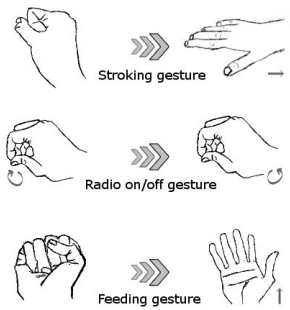

Figure 5: Three exemplary RT-GIS gestures with horizontal, rotary and vertical motion requirements.

	KIN	LEA	MYO
alertness	13:10	8:13	2:52
pleasure	11:26	4:49	6:27
sadness	1:06	0:04	0:17
anxiety	0:21	0:21	-
anger	-	-	0:04

Table 1: Observed emotion time in minutes relating to the gesture recognition hardware (OERS-scale [16]).

armoire. After that, the PwD and the caregiver conversed about the content of the virtual picture which seemed to be an old wedding photograph. In another session, a PwD who was in a late stage of dementia, appeared to acoustically understand the caregiver's instructions to open the door to the old house (intended "as usual" from the sitting position), but reacted in an unexpected way: she stood up and went directly to the display wall to "open the door" – the immersion into the VE seemed "too" high in this particular case.

On the other hand, some of the PwD were even so delighted to interact with the animal avatar, that they repeated the gestural interaction motions for stroking and feeding while uttering "come here, kitty kitty" and happily waiting for the avatar to react. Conversely, one participant showed disapproval of the dog avatar by showing a short tremble – the particular type of animal appeared to trigger uneasiness instead of a positive emotion. In any way, the individual biography, stage of dementia and form on the day seemed to have a high impact on the test situation. Additionally, the caregiver is an important "moderator": while most of the feedback in the interviews was positive, it was also stated that the RT-GIS VE is "almost too realistic".

Conclusion

With this prototype of an RT-GIS, the PwD were given an opportunity to delve into a virtual world while being able to actively interact with it in a seemingly natural way, and thus ultimately keep their sensorimotor and reminiscence systems "in high gear". Moreover, VEs and avatars were initially merely conceived as setting for the gestural interaction test environment. Some of the "serendipitous" results of the evaluation sessions suggest that both concepts may be used – if well-adjusted to the biography of the individual PwD – to further trigger reminiscence as well as joyful moments.

Regarding the gesture interaction technology itself, the Kinect hardware seemed to show the best, least "intrusive", results (e.g. the Myo had to be "sold" to the PwD as "magic armband", a fact that may evoke ethical problems) in combination with gestures connected to well-known daily life actions. With the next step, a (possibly non-tech) baseline condition is needed for better comparability. On the downside, there appear to be some universal challenges when evaluating scientific research questions involving PwD. Besides the problem of getting accurate as well as up-to-date assessments of the individuals' dementia stages, it is difficult to attribute the observed effects to either the intervention or the caregiver. With the RT-GIS in mind, it is also debatable if the system really evokes reminiscence or mere "nice moments" and if there will be further ethical implications if the PwD cannot distinguish the VE's virtual reality from the actual reality.

As this field test can only give a small qualitative insight into the workings of gesture NUI VEs, further studies are planned. These are likely to include a fully automatic gesture recognition system as well as more elaborate possibilities of VE reminiscence and exploration. In any case, the current RT-GIS produced joyful, memorable moments that may pave the way to more personally meaningful VEs that put the individual PwD in the center of the experience – maybe even with the help of virtual reality head-mounted displays.

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