Closer to Nature: Multi-sensory Engagement in Interactive Nature Experience for Seniors with Dementia

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ABSTRACT

People with dementia experience gradually diminished functional abilities caused by this disease. Declined cognitive functioning, increased difficulties in mobility, loss of memory and the lack of inner motivation provides inevitable challenges in engaging this group of people in activities. In this paper, we elaborate on the possibilities of utilizing an iterative installation design, based on the original prototype of Closer to Nature for improving quality of life of people with dementia in Long-Term Care. The installation was built as a permanent part of the living environment in a Dutch nursing home with the purpose of long-term use. User evaluation in real-life setting was conducted with 15 residents, 4 family members and 2 professional caregivers. Preliminary user feedback was gathered through interviews and showed sufficient positive evidence of enhanced engagement. Additionally, a new design concept developed upon insights from the user evaluation is introduced which utilizes a plaster goat covered with sensors for initiating interactions. Implications and future studies of the designs are proposed.

Author Keywords

People with dementia; long-term care; interaction design; multi-sensory stimulation.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION

People suffering from dementia are gradually experiencing diminished functional abilities caused by this long-term disease: declined cognitive functioning, increased difficulties in mobility, loss of memory and the lack of inner motivation will result in the inability of performing daily activities, which further leads to the loss of autonomy and independence in living life by themselves [11]. Long-Term Care (LTC) facilities can provide formal and intensive caring services which help relieve the burden from informal, non-professional caregivers (for instance, families and friends) and support with the basic needs. However, the residents in LTC are reported commonly to spend the majority of their time not engaged in activity, and this is more evident in moderate to severe stage of dementia [21]. A lack of engagement is associated with disruptive Behavioral and Psychological Symptoms of Dementia (BPSD) such as agitation, apathy, passivity, and depression. Activities can help reduce related BPSD and increase positive emotions [11,21]. Without a cure in sight, developing and evaluating meaningful activities that foster and sustain engagement is critical for improving quality of life of seniors with dementia in LTC [21].

However, there are inevitable challenges in engaging this group in activities considering their limitations in multiple fundamental aspects. The progressive decrease of their cognitive functions, language abilities, disorientation in time and places makes engagement within abilities difficult. Additionally, people with dementia in their moderate-to-severe stage often have psychological difficulties like passivity and apathy [22,14]. The lack of internal motivation, interest, and concentration makes achieving engagement even harder.

Non-pharmacological interventions were proposed by geriatric psychiatry studies as treatments for promoting the quality of life in people with dementia [15]. Subsequently, the project Closer to Nature (CtN) was derived from interdisciplinary work between researchers from occupational therapy and design [23]. It is an interactive design with the aim of engaging seniors with dementia in a relaxing nature experience through multi-sensory stimulations and rich interaction to achieve enhanced engagement and reduced BPSD. As being exposed to nature environments and elements is rather well recognized for promoting health, elevating mood state and preventing illness [7].

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In this paper, we first present an improved version of the CtN installation which was further co-developed within a Dutch nursing home. Several improvements were made to turn this into a long-term appliance for real-life use in the LTC context. Followed by a long-term user evaluation. Initial user feedback was gathered through interviews with 21 participants after 4 weeks of free exploration with the installation. Preliminary results showed sufficient positive evidence of enhanced engagement. Based on the feedback, the design was further developed and introduced with an animal figure with tactile feedback to trigger intuitive interaction. Lastly, implications and future work on effectiveness study are proposed as well.

RELATED WORK

Non-pharmacological intervention adopting multi-sensory stimulation for improving quality of life of people with dementia is widely studied and proven to be effective [6]. HCI research utilizing multi-sensory stimulation for people with dementia is an emerging field and a promising way of providing active engagement.

Multi-sensory stimulation for enhanced engagement

Although engaging people with dementia in activities can be challenging, research states that one promising strategy is to actively engage them in activities that stimulate their remaining functions [10]. Multi-sensory stimulation provides stimulation of the senses (visual, auditory, tactile, olfactory and taste) without the need for complicated reasoning, and are ideal for people of any stages of dementia. It has been widely studied and proven to have positive effects, improve functional performance, reduce the frequency of BPSD, help foster communication, restore attentiveness and social connectedness [6,10]. Although early works within HCI consider technology as a tool, lots of recent work embrace technology as a trigger to experience the world and seek to exploit our full range of senses [13,8].

Designed Artifacts for Embodied Interaction

From design perspective, through technology, designed artefacts provide and mimic sensory stimulations better; through interaction, the function of the designed artefacts can be enlarged with the interpretation of users themselves ("*Interpretive Flexibility*") [20]; through the designed form, a sensory stimulus can be provided in a manner that is appropriate and understandable by individual users (instead of purely sensory stimulations for an occupation of time, for instance, *Snoezelen rooms*), especially like people with dementia. Interaction design encourages users by attracting their attention and maintaining their interest. In general, sensory enhancement through design may have more significant impact on dementia care and generate positive influences which could improve quality of life for both people with dementia and their caregivers.

Researchers in HCI have begun to explore how embodied interaction influences engagement of people with dementia [2]. *PARO* is an assistive robot, commercially available and widely used as a social companion for older adults in institutional and domestic contexts [13]. It resembles a baby seal with its attractive white appearance, furry texture, and eye and tail movement. *PARO* caters people with dementia through multi-sensory stimulation and strives to increase activity levels. Studies in institutions all over the world provide evidence of its therapeutic and social effects on people with dementia. *Tovertafel* is also a successfully commercialized product initially developed for people with dementia in late stage [2]. It utilizes a projector on the ceiling and transforms an ordinary dining table into a sensory-stimulating game space. The colorful projection and intriguing images respond to the hand and arm movements of the users and encourage them to play with the light. *The Virtual Forest*, designed by Alzheimer's Australia Vic, is another example of multimodal sensory stimulus design for people with dementia [16]. It utilizes the technology from video games and renders animated graphics such as a meandering river and flowers on a display. Users interact with the objects through hand and arm movements using a motion sensor.

These cases have shown successful influences of designed artifacts on improving the quality of life of people with dementia. However, most of these designs need assistance to provide or facilitate the use. To overcome this gap, the CtN project was implemented in a nursing home with the aim of permanent use and take all stakeholders into consideration within the LTC context. The user can freely explore the installation at any given time both with and without facilitation. CtN as an application of multi-sensory stimulation creates relaxing spaces inspired by both Nature Therapy [7,3] and Animal Therapy [17], which could help reduce agitation and anxiety of people with dementia. It would also engage and delight users, stimulate reactions and encourage communication, and even create a purposeful feeling.

CLOSER TO NATURE INSTALLATION

The CtN project started with an initial prototype that was developed as a tangible user interface to support people with dementia [23]. The design concept aims to connect residents with the outdoors through an indoor interactive experience, due to their limited contact with real nature. Simple tactile interaction with a low engagement threshold was adopted to match and stimulate the residents' reduced cognitive abilities. The prototype showed pre-recorded sceneries of a typical Dutch farm on an 87 inch display. In front of this screen, an actual old-fashioned water pump that pumps real water into one half of the animal feeding water trough, which was built as an extension of the virtual farm trough, continuously visible on the bottom of the display. When the system detects a user interacting with the pump, it shows a video feed of the animals being fed from the trough. It immerses residents with dementia in an interactive outdoor nature experience with the aim to provide appropriate sensory stimulation and meaningful

reminiscent activities through physical and virtual interaction.

Permanent Installation in Vitalis

A design iteration has been made from the prototype to the current CtN installation, as shown in Figure 1. With the collaboration of a Dutch nursing home Vitalis, in Eindhoven, the Netherlands, the installation was rebuilt in the public domain, on a shared space as a permanent setting. The display resembles a real life like window with an outlook to the farm.

The system consists of: an ultra-high definition display which was embedded in a newly built wall. In front of the wall, a wooden frame which has an old-fashioned water pump mounted on top, with next to it a metal plated water trough. The latter has a self-built circulatory system inside the wooden frame, utilizing an electric water pump. An infrared sensor was built inside the pump to register movement. In the hidden space behind the new wall, a computer is connected to an Arduino which controls the pump, filter and sensors. Nine different pre-recorded videos with different animals are selected randomly when the system detects user input from the pump. The installation intends to optimally engage people with dementia by providing interactive activity through suitable functional and aesthetic qualities such as visual and physical content which residents are familiar with, in a relatively low level form of interactivity from a design perspective.

The common space in Vitalis was chosen as residents with dementia are living in a closed living environment behind a door with a password code, and there is little opportunity for them to get access to the outside unless being accompanied. Research shows that the physical and social environment can have huge influence on the well-being of people with dementia [1]. Through transforming the common space into an enriched sensory environment with preferred videos of nature, the mood of residents with BPSD could be significantly improved [9,4].

Figure 1. The permanent Closer to Nature installation in the common space of Vitalis.

In HCI research for people with dementia, numerous designs and have tried to enhance their engagement in activities and improve their quality of life. However, little has been implemented in the field to explore how such designs work in real-life settings and which effects it could bring to people with dementia during long-term use. We think that it is crucial to first implement this interactive installation in a designated LTC home and then further co-develop and investigate with the inhabitants. To fit the purpose of long-term use, several improvements to the appearance, system, and structure have been made:

- Appearance: a design was made so the whole installation could fit into the general interior design of the nursing home's common space. We built a clean wall with same details of the Vitalis decoration, with a hidden inner structure for supporting and securing the ultra-high definition display and a weight structure for safety concerns and to make sure it is always firm and steady during interaction.
- Water trough: a new water trough was welded (waterproof) and removed of any sharp edges (safety proof). It was mounted on top of the wooden frame and designed exactly like the other half in the video feeds. Additionally, the back of the trough which stands against the display is made of transparent polycarbonate for depth perception.
- Water circulation system: a new water circulation system was installed inside the wooden frame for safety and maintenance considerations. We applied a high-quality water filter (Philips InstantTrust Marine) for maintaining the quality of the water to a drinkable level, as the residents may touch it directly or accidentally drink from it.
- Sensor system: an infrared sensor inside the pump was relocated for a more accurate reading on distance change.
- Software: the threshold of pumping gestures was also adjusted so that it can detect continuous pumping and give corresponding video feedback. Pumping actions are logged. The software avoided that the same video is repeatedly shown, yet it was still random from the ones not showed.
- Controlling hardware: an always-on computer is situated in between the walls for video image processing. It connects to a custom-made Arduino enclosure which links to the sensors and regulates the water circulation system. A remote connection is available for reading out logs and updating software, so the residents would not often see on-site maintenance.

USER EVALUATION

To explore how users respond to this installation, we conducted a user evaluation with semi-structured interviews. The interviews focused on three perspectives: 1. the residents from the living space, 2. the family members of the residents (when visiting), and 3. the professional

caregivers working there, to evaluate the overall experience of the users in the real-life setting.

Participants

Fifteen residents, 4 family members of residents (all are children of residents) and 2 professional caregivers were recruited for the evaluation after 4 weeks of free exploration with the installation being operational around the clock. Participants were invited for their opinion in front of the installation for a 10-minute interview, as shown in Figure 2. The residents' age range is between 79 and 97. They are registered inhabitants of the enclosed living environment of Vitalis for over six months and with a formal diagnosis of various types and stages of dementia. Participant demographics are shown in Table 1.

Figure 2. User evaluation of an interviewer with a resident with dementia in Vitalis.

	Residents P01-P15 (n=15)	Family members F01-F04 (n=4)	Professional caregivers C01-C02 (n=2)
Age M(SD)	87 (5)	47 (4)	36 (6)
Gender			
Female	12	1	2
Male	3	3	0
Diagnosis of dementia			
Alzheimer's	6	-	-
Vascular	3	-	-
Mixed	6	-	-
Stage of dementia			
Mild	4	-	-
Moderate	6	-	-
Severe	5	-	-

Table 1. Demographics of participated residents, family members, and professional caregivers.

User Feedback

The content of interviews was first transcribed from the recordings and translated by the Dutch interviewer, then coded using thematic analysis to identify the key information emerged from the interview materials. The qualitative findings below are supported by exemplar quotations with the coded representation of participation plus their participation number, for instance, P01 (resident participant 1), F02 (family member 2) and C02 (professional caregiver 2).

Feedback from residents

All the residents expressed their appreciation for the beautiful scenery on the display. Moreover, almost all residents (14 out of 15) showed excitement, even surprise, when they saw the animals come to drink water after interaction with the water pump. P02 is a lady who grew up on a farm and later became a farmer's wife. She said, *"Every time I pass by, I come here to pump to see the sheep, they remind me of my beautiful youth."* During the interviews, 7 out of 15 residents initiated pumping interaction without help. P07 recognized the display being a window and said: *"You know, it would also be nice if I can go out and be on the other side as well."* (Referring to actually being on the farm.) *"I can already imagine that I'm with the cows, rabbits, giving them food, playing with them behind the display."*

The qualitative results also showed that the installation could help lift their mood and trigger their memory during their experience. Many residents (12 out of 15) started to share their own stories when they were asked about their opinion on the installation. P09 who used to live on a farm claimed that she could recognize the place, *"I know it is the child farm in my neighborhood. You take a right turn after the […]."* Although later during the conversation with her son we discovered that it was not the same farm shown on the display, however, her memory about how to navigate to the farm she mentioned was vivid and surprisingly accurate. The installation brought out all kinds of great memories that would not be triggered by playing cognitive games, singing songs or other task activities during their regularly scheduled activities from the previous experience. P08 shared more personal stories beyond talking about farm or farm animals. She showed the interviewer her family photo album from her stroller and emphasized the story about her dog named *"Sinta"*. P06 shared her occupation as a telephone operator, her hobby of philately, and her favorite music band.

Four participants said they were able to recollect their thoughts on using the installation from the last four weeks. When invited to come over to the installation, P09 asked *"Where are the goats? I'd really like to see them."* Although he could not grasp the logic between the pumping and the animals being fed with water, this was likely due to his late-stage condition of dementia, he could still remember the goats very well and even came back looking

for them. He also said, *"Oh, kids would love this very much, I brought them to the farm to see the goats and feed the animals."* Interviews also showed that not all the residents could initiate interaction without help from others. P05 expressed her concern: *"Oh, no, it is made of metal which is too heavy for me."* Additionally, we found that P10 added her imagination to the scenery which did not exist: *"See, the washed clothes were hanging there to dry."* indicates that her imagination was stimulated by the multi-sensory inputs.

Feedback and suggestions from family members

All family members reached an agreement that their parents, in general, responded positive to the installation. They stated that their parents experienced a calm and enjoyment from just watching the scenery. Two family members commented that it could also be a great communication tool for bonding with their parents when they come for a visit. F01 said *"My mother talked to me about the installation, the donkeys, and goats. She showed me in the hallway and said she feeds the goats every day."* Quote from F02 as *"She [her mother] is addicted to the pump." "My mother grew up on a farm in Eindhoven. She became very talkative when mentioned about how she fed the animals, telling vivid stories about the baby goat."* F02 also suggested that *"It would be nice if they can have a real goat after this, something to carry away, a doll or something."* F03 expressed her concerns that excitement may fade away if the installation stays unchanged for too long.

Feedback from professional caregivers

In general, the professional caregivers appreciated the attractive visual appearance and reported the soothing effect of the installation. They commented that the residents were happy and relaxed when watching the display. They noticed the elevated mood of some residents and expressed the positive influence it has in their everyday life. Supporting comments from C01 as, *"the installation gives them a feeling of being in the control and meaningfulness."* During interviews, both of the professional caregivers empathized the value of nature and the animal elements as *"they are mostly women who either grew up on a farm or have family members used to work on a farm. The fluffiness of the animal figure plays an important role in the success of this design. [C02]" "It recalls their nurturing nature as most of the residents we have here are women. [C01]"* C01 also mentioned about residents' improvement in cognition as *"they start to remember things from the past, which holds great value for them."* C02 stated the value between the residents and their relatives as *"it provides great bonding for the family and the residents."* Both professional caregivers also pinpointed that because of the location of the installation, and it performed as a great occupation of attention when the residents were confused and asked to go back to where they lived before in the afternoon. Also, C02 mentioned that *"I'm happy that if one of the residents are awake during the night and wondering, now I know a good place to go and keep them accompanied."*

FURTHER CONCEPT DEVELOPMENT

Based on the initial feedback from the user evaluation, a recent improvement is under development as an add-on of the installation utilizing a goat figure. The results of user evaluation indicate a design opportunity for enhanced nature and animal therapy through multi-sensory stimulation and a proactive strategy for better initiation of engagement. Therefore, this development focuses on stimulating a more natural and intuitive interaction with the application of two supporting methodologies (the principle of proximity and tactile interaction). By applying the principle of proximity to self-exploring interaction, we lower the requirements for cognitive ability and create more interpretation possibilities for users in different stages of dementia. Moreover, the enhancement of tactile interaction will contribute to the wholeness of the created multi-sensory environment. In literature, the aforementioned have shown to influence the emotional communication between a user and designed artifact, increase social bonding and provocation [4].

The newly introduced concept continues the idea of a tangible extension of the virtual nature experience. A goat covered with sensors is developed as a mediator for the connection between the simulated farm scene and physical context of the residents. The goat is designed to be visually appealing and inviting to touch by using a body cover of soft and furry textile, as shown in Figure 3. The furry textile on the goat is equipped with several patches of conductive thread that senses various petting gestures and produces a different reaction through the virtual goat on the display. An intelligent learning algorithm is used so that when the input from a user is detected, the system responds accordingly to where and how the user touches the goat.

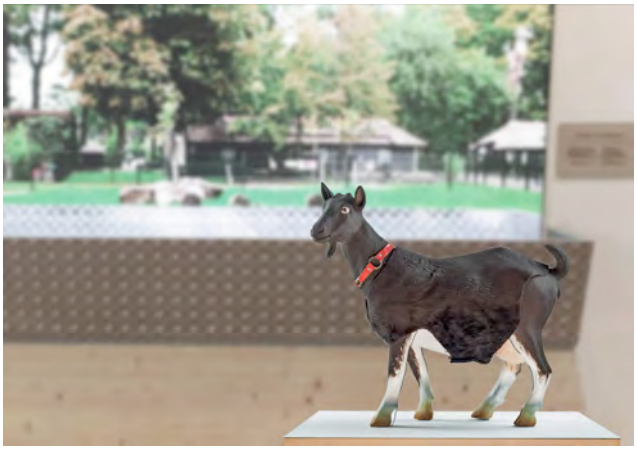

Figure 3. The goat design covered with sensors showing on a stand in Vitalis.

We expect the goat concept to allow for richer possibilities in engaging people with dementia at different stages. Depending on their cognitive ability and mobility, the user can freely choose between the water pump and the plaster goat to interact with the scenery. For those people in a relatively early stage of dementia, the water pump can still

serve as an activity that exercises their motor skills and provides the calming effect of water running and animal feeding. Meanwhile, the goat design offers residents with supportive strollers or residents in wheelchairs a more inviting interaction through an easier motor action.

The functional design of the system, which adopts the principle of proximity, inspires the curiosity in people with early-stage dementia. They are encouraged to build the logic connection between different gestural inputs and the reactions from the display through self-exploration. For those who are living in late stages of dementia, the goat achieves to incite the sense of touch and establishes an emotional communication that is pleasant and soothing. Thus, our proposed solution would play a role in improving the living environment of residents in the LTC and serve as a therapeutic activity. This concept still needs further evaluation and development. What appeals to residents with dementia, excites them, and makes them remember forgotten memories, needs to be fine-tuned and is expected to gradually change. The outcome aims to achieve a natural interaction interface, through embodied behaviors enacted by technology since the fundamental senses play important roles in parts of the brain.

IMPLICATIONS AND FUTURE WORK

The user evaluation generated several valuable insights to design for people with dementia:

- The implementation of the design in a real-life setting holds great value for further co-designing and engaging users and stakeholders in research. Firstly, designers designing for people with dementia are often lack of understanding, experience and critical knowledge, and therefore have difficulties in being empathic; secondly, designing for residents with dementia in LTC needs to take all users and stakeholders (residents, family members, professional or non-professional caregivers, volunteers) into consideration. They are all involved and influenced in the flow; thirdly, long-term effects of design are often understudied, while it could prove designs are more valuable or, in some cases, less valuable than expected.
- People with dementia may have language disorders or reduced emotionality depending on their conditions of dementia. It is very challenging for a new person to create and build a connection with a patient to fully understand their expressions. The interpretation of emotions and language from family members or caregivers are invaluable help.
- A proactive strategy is needed to engage people with dementia in becoming active. The affordance of design should help facilitate intuitive interaction without the need of complicated reasoning, and capture and maintain their interests.
- Encourage the “in the moment” enjoyment. People with dementia are usually suffering from memory loss and have difficulties maintaining their short-term memories. Proffer enriched sensory experience is an effective way to facilitate enjoyment while in activity.
- Ingrained memories such as personal experiences, characters and interests, play an important role in generating positive effects on people with dementia [12]. For instance, user feedback shows that people who grew up on a farm or worked there are more related to the installation and respond more positively to it.

Further study of the following aspects should be addressed: although initial feedback from interviews of participants is positive, a further effectiveness study is needed to study the long-term effects of the installation on interaction triggered engagement, affection and agitation of users [5]. Also, effectiveness evaluation with people with dementia is very challenging since self-report is often not reliable due to their limited abilities. Therefore, observational-based explorative studies through behavior analysis could be beneficial for a better understanding of user experience and engagement [18,19]. Feedback indicates positive impact of tangible interaction on engaging the user group. Further exploration using a comparison study between with and without the tangible interaction could be conducted to identify the role, and key factors that contribute to their engagement. In addition, given the fact that residents in the LTC come with different etiology and stages of dementia, a further study regarding how users in different stages of dementia respond to the installation will be of great value for understanding how to design for this group.

CONCLUDING REMARKS

The preliminary findings from interviews suggest that the Closer to Nature (CtN) installation encourages positive recollection of memories and a soothing outlook for residents living with dementia when immersed in the interactive nature experience within LTC context. The user evaluation confirms it can bring seniors with dementia calmness, enjoyment, and happiness through rich sensory stimulations by simulating nature and nature elements. It succeeded in stimulating people with dementia’s memories through the use of a farm scenery and an old-fashioned water pump. Feedback also indicates that the installation can bring the user a sense of responsibility, self-control, and meaningfulness. The CtN design is also acknowledged as a useful bonding tool for facilitating communication between residents and family members, between residents and caregivers and between residents themselves.

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