Designing Interactive Systems with Rich Interaction for Enhancing Engagement of People with Dementia Living in Long-term Care Facilities

RICH INTERACTION for PEOPLE with DEMENTIA

YUAN FENG

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PROEFSCHRIFT

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Yuan Feng

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Het onderzoek of ontwerp dat in dit proefschrift wordt beschreven is uitgevoerd in overeenstemming met de TU/e Gedragscode Wetenschapsbeoefening.

This work is dedicated to
my dear grandfather.

A note to readers

How to Use this Book

- **To navigate through the content:** Explore section 1.3 “Thesis Outline” (Page 7).
- **To find out the conclusions of this research:** Explore Chapter 9 for answers to research questions, then check the corresponding chapters for details (Page 199).
- **To prepare yourself when conducting design research with and for people with dementia:** Explore Chapter 8 to learn concluded design guidelines, recommended practical operations, and ethical protocols (Page 177).
- **To gain empathy with users of people with dementia and learn the care strategies:** Explore section 3.3 “Sensitivity Gaining of Target Users within the Dynamic Care Context” (Page 46).
- **To learn what current approaches are available for engaging people with dementia:** Explore section 2.3 “Meaningful Activities for Engaging People with Dementia” (Page 19).
- **To learn how to evaluate your design with people with dementia:** Check section 2.4 “Measuring the Effects of Meaningful Activities on People with Dementia” (Page 34); and sub-section of 8.2.2 “Measurement Use for Assessing Design’s Effectiveness” (Page 185 – 187).

SUMMARY

Motivation and background. This doctoral research is mainly motivated by the current inactivity and disengaged living style of People with Dementia (PWD) admitted to Long-Term Care (LTC) facilities. The prolonged lack of engagement in sensory, physical, and social activities can lead to accelerated disease development and improved risks of depression, thus threatening their physical and psychosocial well-being. To tackle such an issue, existing traditional approaches, such as non-pharmacological interventions, were proposed and have demonstrated promising effectiveness in promoting engagement and reducing behaviors perceived as challenging in practical dementia care. However, studies also suggest that for those traditional strategies to work towards a more positive impact on PWD, they emphasize the adaptability of facilitators' role to tailor and customize a variety of solutions to individual needs. In addition, they argue that the resources required to implement many of the strategies far exceed that are available in most LTC facilities, which leads to limited use or no use in practice.

Interactive systems for PWD of Human-Computer Interaction (HCI) withhold excellent potential in enabling motivations in intuitive interaction, fostering and sustaining engagement, supporting independent use, providing appropriate sensory and physical stimulations, and addressing the social and emotional needs of PWD. However, with most of the work focusing on safety issues and caregiver well-being, there is a huge gap where technology-empowered psychosocial activities are needed to engage PWD living in LTC environments and those in more advanced stages of dementia in contemporary care. On the other hand, it is still a void in design research regarding how interactive systems can be designed toward enhanced engagement for PWD.

Design researchers have explored how unique system features can influence user engagement, performance, and presence (Attfield et al., 2011). And there is a general understanding within HCI that "richer" interactions are considered associated with better user experience (Rozendaal, 2007). However, not much research extends this to dementia users. Rich interaction is a broad idea that has been used in many research areas, and what constitutes "rich" is constantly changing. Thus, in this present thesis, we endeavor to find out what rich interaction constitutes in our research scope and clarify how it can be designed to promote the engagement of PWD within a context-specific situation of PWD in LTC

environments.

Objectives. This thesis aims to design interactive systems with rich interaction as meaningful activities for PWD living in LTC environments towards enhanced engagement, which improves their quality of life and subjective well-being during daily living. The main objective is two-fold: On the one hand, the research explores how the activity provisions through design could be meaningful for our target user group within their current living environments. On the other hand, the research endeavors to investigate how to design interactive systems for PWD that increases engagement.

Approach and Method. To address the first research objective, we found our answers through a combined desktop literature search (Chapter 2) with empirical field explorations (Chapter 3). The former aims to acquire insights from existing research and clarify "engaging PWD in meaningful activities" from three aspects: the challenges that prevent meaningful engagement of PWD in LTC; the existing documented "meaningful activities" in literature; and the effectiveness evaluation of meaningful activities' impact on PWD. The latter aims to gain the sensitivity of our target user group, dynamic care context, and related multi-stakeholders within their real-living environment.

To address the second research objective, we found our answers through a combined Design Phase (Chapters 4 and 6) and Research Phase (Chapters 5 and 7). The Design Phase follows a traditional research-through-design process. It focuses on iterated prototype designs (the *Closer to Nature* and the *LiveNature*), real-life implementations, and preliminary user studies through qualitative interviews. Within the Research Phase, investigations were conducted through two well-controlled experimental studies to obtain conclusive evidence on the role of rich interaction (Chapter 5) and its two features - multimodality and system interactivity (Chapter 7) on the engagement of PWD. A mixed method of video coding analysis and rating scales were adopted in both experiments for comprehensive evaluations of the design effectiveness on user engagement of PWD.

Research outcomes. This research contains a series of explorations, multiple iterated designs, and two experimental studies dedicated to designing for persons living with dementia within an LTC environment with a better wish of living well with this disease after formal diagnosis. The first research outcome corresponds to the first research objective, which is the design knowledge that contributes to the meaningful activity design suitable for PWD within their current living environments of the LTC context. We proposed our understanding of the psychosocial activities for PWD as potentially suitable activity provisions. And we identified the contributing qualities through context explorations, which can be summarized as: A psychosocial activity design that provides multisensory engagement to comfort or stimulate residents; encourages explorative and playful experiences without the concerns of making mistakes; with rich interaction possibilities that are intuitive, familiar, and can use previous living experiences as references; with affordance that supports independent use, allows easy access, and enables social inclusion of multi-stakeholders within an LTC context.

As the second research outcome, which corresponds to the second research objective, we offer insights regards the nature and features of rich interaction and to what extent they could influence the engagement of PWD. These insights are: (a) Designing interactive systems for PWD to enable rich experiences behaviorally through adding tangible augmentation; this might be one contributor to enhance the attention aspect of engagement and (b) Rich Interaction in terms of the sensorial level of experienced richness through multimodal stimuli; this might be one contributor for a successful enhanced valence aspect of the engagement. These two insights could be potentially used as a motivation strategy in future research to improve user attentiveness to PWD, emotional elements of activity-related engagement, and social interaction with the human partner.

As the last research outcome, the thesis offers summarized implications, reflections, principles, and protocols that come along with this research (Chapter 8) to help inform future designers and researchers when working with and for PWD.

CONTENTS

ACRONYMS

AAT	Animal-Assisted Therapy
ANOVA	Analysis of Variance
BPSD	Behavioral and Psychological Symptoms of Dementia
CBT	Cognitive-Behavioral Therapy
CMAI	Cohen-Mansfield Agitation Inventory
CTN	Closer to Nature (One of the experimental conditions adopted in Chapter 5)
ELICSE	Ethnographic and Laban-Inspired Coding System of Engagement
EPWDS	Engagement of a Person with Dementia Scale
HCI	Human-Computer Interaction
HRI	human-Robot Interaction
ICT	Information and Communication Technology
IRR	Inter-Rater Reliability
LMA	Laban Movement Analysis
LTC	Long-Term Care
MMSE	Mini-Mental State Examination
MSE	Multisensory Environment
MSS	Multisensory Stimulation
OERS	Observed Emotional Rating Scale
OME	Observational Measurement of Engagement
PEAR-Apathy	People Environment Apathy Rating Scales – Apathy subscale
PWD	People with Dementia
SD	Standard Deviation
VC-IOE	Video Coding Incorporating Observed Emotion
VCTN	Virtual Closer to Nature (One of the experimental conditions adopted in Chapter 5)
VR	Virtual Reality
WHO	World Health Organization

Part 1
INTRODUCTION

Chapter 1 | Introduction

1.1 Context and Motivations

Dementia is a neurodegenerative disease addressed by the World Health Organization (WHO) and Alzheimer’s Disease International as a public health priority (World Health Organization, 2012). The medical term dementia refers to the global impairment of higher cortical function. It impairs one’s cognitive function (including memory), executive function (e.g., planning and problem-solving), independent function for a job or personal care, and the psychosocial function such as correct use of social skills and the control of emotional reactions. It can be divided into different disease types or categories according to varied etiologies (e.g., Alzheimer’s Dementia, Vascular Dementia, Lewy Body Dementia, Frontotemporal Dementia, or more commonly Mixed Dementia) or developed stages of the disease (e.g., mild, moderate, or severe stages of dementia) (Sheehan, 2012). It is not a part of normal aging but a progressive disease that erodes People with Dementia’s (PWD) ability to perform daily tasks. They will gradually experience loss of memory, learning skills, language ability, and impaired affect regulation. With no existing cure in sight, PWD’s condition can only get worse with the affected behaviors further exaggerated.

The need for high levels of assistance, professional, and intensive care means that most PWD are eventually admitted to Long-Term Care (LTC) facilities where they can receive quality care. Such facilities can efficiently meet physical needs (e.g., hygiene, meals, accommodations, or medication use). However, they often fail in addressing psychosocial needs (Hancock et al., 2006). In consequence, the well-being of PWD in LTC facilities is hindered, as they usually spend most of their time alone, bored with nothing to do, have limited meaningful conversations, and are exposed to inappropriate sensory stimulations. This prolonged lack of engagement in sensory, physical, and social activities will accelerate disease development and worse living conditions.

Engaging in meaningful activities is well acknowledged in multiple research areas as the most persistent and crucial way for improving the quality of life of PWD (Miranda-Castillo et al., 2010). It highly correlates with reduced challenging behaviors, decreased psychological symptoms, and increased social connections (Trahan et al., 2014). However, while most research highlights the positive impact of meaningful engagement on dementia well-being, few of them, regrettably, identify or define what meaningful activities are, nor what engagement means for PWD. Achieving engagement is exceptionally complex for this group of people due to inevitable challenges from three factors: 1) the accompanied multiple functional deteriorations which limit the activities that PWD could participate in and benefit from; 2) the lack of internal motivation, interests, and concentration which challenges the foster and sustain of user engagement; and 3) consider the context of LTC, the unfamiliar physical environments, inadequate resources, ambiguous situations, continual change, and multiple relationships can make achieving engagement ever harder.

For decades, research on supporting PWD's well-being after diagnosis has long been dominated by occupational health research of psychiatrists and psychologists (O'Neil et al., 2011). As the primary research outcomes from those studies, non-pharmacological interventions refer to a particular set of approaches developed for managing challenging behaviors, engaging individuals in activities that can keep them active, help maintain functions, and moderate mood and behaviors (Wang et al., 2018). On the one hand, proper facilitated non-pharmacological interventions have shown promising effectiveness in fulfilling the purpose. However, on the other hand, recent research also suggests that for those traditional strategies to work towards a more positive impact on PWD, they emphasize the adaptability of facilitators' role to tailor and customize a variety of solutions to individual needs. Furthermore, they argue that the resources (e.g., time, staff, and training) required to implement many of the strategies far exceed that are available in most LTC facilities, which leads to the limited use or no use in practice (Cohen-Mansfield et al., 2012b). This calls for the urgent need of technological solutions such as interactive system mediated activities for meaningful engagement for this group of users.

Interactive technologies from the field of Human-Computer Interaction (HCI) that enable support of PWD and their caregivers have started to gain mainstream attention and taken place alongside traditional approaches. Although the topic has already become an emerging field within the HCI community, current design research is still at a very preliminary stage with a strong bias towards the emphasis on safety issues and caregiver well-being (Topo, 2009). With the focus of dementia care shifting from addressing physiological defects to person-centered care, design and HCI research also starts to change the emphasis from compensating for disability to promoting psychosocial well-being. Interactive system design for PWD withholds excellent potential in enabling motivations in intuitive interaction, fostering and sustaining engagement, supporting independent use, providing appropriate sensory and physical stimulations, and addressing the social and emotional needs of PWD. However, there is a considerable gap in work where technology-empowered psychosocial activities are needed for better engaging PWD living in LTC environments and for those in more advanced stages of dementia in contemporary care.

There is a general understanding within HCI that “richer” interactions are considered associated with better user experiences. Rich interaction is a broad idea that has been used in many research areas, and what constitutes “rich” is constantly changing. In this present thesis, we endeavor to find out what rich interaction constitutes in our research scope and clarify how it can be designed to promote the engagement of PWD. Throughout the research, we envision “rich” interaction for PWD neither as the complexities experienced during interaction in gamification studies nor the amount of information exchanged between users and systems. Instead, it represents a more intuitive, emotional, sensory-enriched, flexible interpretation, and embodied way of interaction. For decades, design researchers have explored how unique system features can influence user engagement, performance, and presence (Rozendaal, 2007). However, not much research extends this to dementia users. Creating engaging and meaningful technology-enhanced experiences for PWD requires 1) focusing intentionally and strategically on the amounts and types of sensory stimuli a person experiences; 2) the balance between challenges and abilities a user in control; and 3) the context of interaction a user positioned in; to motivate initiation, support participation, help maintain interests, and ensure comfort, enjoyment, and quality of life.

1.2 Research Objectives and Questions

Thus, based on the above introduction of background and motivations, this design research focuses on:

Design interactive systems with rich interaction as meaningful activities for PWD living in LTC facilities towards enhanced engagement, consequently improving their quality of life and subjective well-being during daily living.

To address the primary objective, we propose two sub-research objectives with related research questions, and they are:

- **Research Objective 1:** *To explore how interactive system design could enable meaningful engagement within the specific context of LTC for*

PWD and multi-stakeholders.

In responses to our first research objective, our first research question is:

RQ1: *How to design interactive systems as meaningful activities for PWD within the specific context of LTC environments?*

More specifically, we attempt to answer the following sub-research questions:

RQ1.a: *What is the status of meaningful activities for engaging PWD in the existing literature?*

RQ1.b: *Which qualities interactive systems possess could potentially contribute to a meaningful activity design for PWD and multi-stakeholders living in the LTC context?*

To answer the above questions, we conducted a thorough literature review and field context explorations within a specific Dutch residential care home to clarify activity design opportunities and narrow design solutions within the LTC context.

- **Research Objective 2:** *To investigate how to design interactive systems towards increased levels of engagement by exploring the role of rich interaction in terms of which aspects and features could help achieve higher user engagement of this particular user group.*

Corresponds to the second research objective, our second research question is:

RQ2: *How to design interactive systems towards increased levels of engagement for PWD?*

RQ2.a: *To what extent can interactive systems with rich tangible interaction enhance engagement and reduce challenging behaviors of PWD living in an LTC environment?*

To answer this sub-research question, we have implemented the interactive installation *Closer to Nature* in a real-life living environment and conducted an experiment to discover the effects of adding tangible augmentation on the digital multimedia presentation in enhancing user engagement and reducing challenging behaviors.

RQ2.b: *To what extent can the features of rich interaction in terms of the system interactivity and the multimodal stimuli influence the engagement of PWD living in an LTC environment?*

To answer the above question, we have developed and implemented the installation *LiveNature* to further investigate to what extent the two identified features – the system interactivity and the multimodal stimuli – would influence user engagement of PWD.

1.3 Thesis Outline

This dissertation unfolds in four parts: Introduction, Foundation & Exploration, Investigation, and Conclusion. See Figure 1.1 for the thesis outline.

1.3.1 Part 1 – INTRODUCTION

Part 1 contains **Chapter 1**, which introduces the background and motivation of this research. In addition, it presents how the research questions are formulated and the thesis is organized.

1.3.2 Part 2 – FOUNDATION & EXPLORATION

Part 2 contains **Chapters 2 and 3**. It addresses the first research objective and answers **RQ1** based on systematic literature reviews and empirical context explorations.

Within Part 2, **Chapter 2** answers **RQ1.a** and provides a comprehensive, multidisciplinary, and critical review of relevant research focusing on two keywords – "meaningful activities" and "engagement of PWD." This chapter unfolds into three sections:

Section 1: *Challenges in Engaging PWD in LTC.* The first section explains the sources of inevitable challenges in engaging PWD. We identified three factors of challenges that researchers and designers may have the potential to influence to have the expected positive impact on PWD living in LTC environments: the individual, contextual, and stimuli factors. Related coping strategies were proposed accordingly. Among these, our research on the last factor, which is then extended in section 2 using the terminology – "meaningful activities."

Section 2: *Meaningful Activities for Engaging PWD.* To design meaningful activities, we first need to learn from existing ones. Thus, this section aims to provide a systemic overview of two identified categorical activities. They are the "traditional activities" – a set of non-pharmacological interventions that have been widely adopted in dementia care for decades. The "technology-empowered activities" arise with HCI development and aim to provide technology-mediated interventions for promoting the psychosocial well-being of PWD.

Section 3: *Measuring Effects of Meaningful Activities on PWD.* Reliable, valid, and robust measurements are essential for design research with PWD. This section thoroughly reviews how impacts of the above-mentioned meaningful activities are measured with PWD. We narrowed the evaluation to engagement assessment and clarified our engagement definition by examining its theoretical development, construction, and measurement. Furthermore, we propose our method of engagement assessment of PWD with qualitative and quantitative data collection combined during different design and research phases in this research.

Chapter 3 provide answers to **RQ1.b** and presents context research using a specific residential care facility to represent the LTC environment (Vitalis Kleinschalig Wonen, Eindhoven, the Netherlands). To ensure our design solutions are meaningful within the real-living context of PWD. This chapter aims to gather a deeper understanding of the complex context of PWD in LTC, the dynamic care relationship, problems and challenges encountered, and multiple needs of multi-stakeholders within their real-living environment. The context explorations are two-fold. On the one hand, three sub-studies were conducted to gain sensitivity of our target user group and dynamic dementia care context to better understand practical challenges and current coping strategies. On the other hand, to generate critical design knowledge for guiding the activity and zoom vital qualities that ensure the meaningfulness for PWD in LTC, we tested four design concepts using empirical studies with residents and caregivers at Vitalis.

As the outcome, we propose a list of qualities that designed activities should possess which might contribute to the meaningful engagement for PWD within the LTC context. This design knowledge will be the foundation of our system designs, which further allow investigations of **RQ2** in the next part of the thesis.

1.3.3 Part 3 – INVESTIGATION

Part 3 aims to address the second research objective and **answers to RQ2**. It consists of this thesis's core chapters (Chapter 4-7).

Within Part 3, two phases were distinguished – the Design Phase and the Research Phase.

Design Phase (**Chapters 4 and 6**). The design phase adopted a research-through-design process. Two design iterations were presented, implemented in the real-life living environment, and preliminarily evaluated with PWD (*Closer to Nature* in Chapter 4 and *LiveNature* in

Chapter 6). The design phase aims to 1) provide sufficient evidence that the proposed designs are meaningful and effective for further research; 2) implement the proposed designs in the real-life living environment to form a study setting where further investigations could be conducted; 3) gather preliminary feedback from multi-stakeholders through qualitative interviews for potential improvements.

Research Phase (**Chapters 5 and 7**). The research phase aims to investigate two research questions, **RQ2.a** and **RQ2.b**, through two well-controlled experimental studies based on implemented design iterations, respectively. A mixed method of quantitative observations using video coding analysis and observational measurement of rating scales were adopted in both studies for comprehensive evaluations on the engagement of PWD in the real-life setting.

Chapter 4 presents the design considerations and implementation of the interactive system - *Closer to Nature* - an augmented nature viewing installation that facilitates multisensory engagement with rich interaction for PWD living in LTC environments. *Closer to Nature* aims to provide a relaxing and refreshing activity by connecting the residents with the outdoor due to their limited connection with real nature. A public display was mounted on the wall of the common area of an LTC facility to play a typical Dutch farm scenery that is beneficial to a generation of Dutch elderly for reminiscence purposes. The display is further augmented with a tangible interface (including an old-fashioned interactive pump, half of a metal water bin, and the wooden trough with a water circulation system and all sensors and actuators for actualization) to enable rich interaction and active participation. We adopted the old-fashioned pump to provide interaction with low-threshold physical effort and applied interactive video materials to stimulate animal watering experiences. The location allows easy access and enables the potential inclusion of multi-stakeholders. Overall, the installation design is grounded on the suggested positive effects of reminiscence therapy, nature therapy, and animal-assisted therapy on PWD. It was implemented in the real-life setting as an appliance for further research and design. A preliminary user study with 21 participants (15 residents, four family members, and two caregivers) after four weeks of free exploration was performed using semi-structured interviews for gathering initial feedback on user experience.

Chapter 5 attempts to answer **RQ2.a.** Reflected on the *Closer to Nature* design regards its tangible augmentation that would contribute to the "richer" interaction. We, therefore, investigated the effects of adding tangible augmentation based on the digital multimedia presentation on enhancing engagement and reducing challenging behaviors of PWD. An experiment was conducted with 15 residents living in Vitalis. Three conditions were adopted, including two experimental conditions - with and without tangible augmentation to represent with and without rich interaction, and a control condition using one-on-one interaction with a selection of tactile stimuli. The control activity was chosen as the materials have tangibility quality, however, offer no designed feedback during an interaction. Effectiveness evaluations were performed using a mixed method of video coding analysis and four observational rating scales on observed engagement, affective states, apathy, and agitation. The main findings of both video coding analysis and rating scales demonstrated enhanced positive user engagement with improved attentiveness. In addition, they enabled more recollections of memories with rich interaction than without or the control condition. The results indicate that richer interaction for PWD through adding tangible augmentation might be one contributing factor for enhanced attention and, therefore, engagement. Besides, the findings suggest that different provocative strategies to promote emotional responses and behavioral participation are still needed.

Based on lessons learned from Chapters 4 and 5, **Chapter 6** presents design iterations that lead to the *LiveNature* design. The system design of *LiveNature* suggests a novel approach that combines the interaction with a tangible social robot with an augmented reality display for provoking positive emotional responses and enabling rich interaction possibilities. It aims to provide holistic multisensory engagement through an interactive animal petting experience reinforced with tactile sensations. The social agent, a robotic animal, works as a tangible interface to interact with multisensory media content provided through the augmented reality display. The dynamic context was responsive, as the interaction with the robot triggers the motion and sound feedback of the robot and the visual-audio responses from the display. A preliminary user study with 20 participants (nine residents, five family members, two caregivers, and four volunteers) was performed to compare interaction experiences of *LiveNature* with *Closer to Nature* using qualitative interviews and gather initial user feedback from multi-stakeholders.

Chapter 7 attempts to answer **RQ2.b** by investigating two related features of rich interaction that contribute to a positive, engaging experience – the system interactivity and multimodal stimuli (Rozendaal, 2007). In this chapter, an experiment was conducted with 16 participants to reveal the effects of two features as two independent variables and their interaction effect on the engagement of PWD based on different system configurations of *LiveNature*. Five conditions were adopted, including four experimental conditions using a two-by-two full-factorial experimental design with levels of system interactivity as a between-subject factor and different multimodal stimuli as a within-subject factor; and a control condition. The sensorial level of experienced richness was addressed by the designed multimodality sensory feedback. And the system interactivity was varied based on whether the HRI was accompanied by contextual cues from the augmented reality display. The engagement of participants was assessed using a mixed assessment method involving video analysis and three observational rating scales. Results disclose that when additional auditory modality was included besides the visual-tactile stimuli, participants had significantly higher scores on attitude, more positive behavioral engagement during activity, and a higher percentage of communications displayed. The multimodal stimuli also promoted social interaction between participants and the facilitator. The statistical findings indicate that rich interaction in terms of sensory richness through multimodal stimuli might contribute to a successful enhanced Valence aspect of the engagement. And these findings could be used as motivation strategies in future design to improve emotional aspects of activity-related engagement and social interaction with the human partner.

1.3.4 Part 4 - CONCLUSION

The last part of this thesis - **Part 4** – contains implications, reflections, and conclusions. Within part 4, **Chapter 8** endeavors to present the implications and reflections gleaned from this research journey to help inform future design and research processes when working with and for PWD. Specifically, we summarize the design, practical, ethical, and theoretical implications, raise reflections through three dementia-related research dilemmas, and demonstrate how they inspired the thinking process of this research. Finally**, chapter 9** concludes formulated answers to address our research objectives and questions, reports limitations and options for future works, and summarizes research contributions.

Figure 1.1 Thesis outline.

Part 2
FOUNDATION & EXPLORATION

Chapter 2 | State-of-the-Art

Engaging PWD in Meaningful Activities

2.1 Introduction

Provisions of activities that can have an effective and meaningful impact on the well-being of PWD are challenging. These activities need to be sensitive to user needs, applicable within the context, and respectful to individuals. The literature highlights the positive impact of meaningful engagement on dementia well-being, however, few answers and clarifies what "meaningful activities" are and what "engagement" means for PWD. Thus, this chapter presents the collected knowledge from the last 24 years devoted to engagement enhancement for PWD from different disciplines to provide a comprehensive, multidisciplinary, and critical review of the state-of-the-art. We carried out a literature search addressing the keywords – "meaningful activities", "engagement", and "PWD". As a result, we summarized results addressing three topics: 1) challenges for engaging PWD in LTC; 2) meaningful activities identified in existing literature for engaging and positively influencing behaviors of PWD; and 3) the evaluation of such meaningful activities through engagement assessment for improvements towards better solutions.

The **objectives** of this chapter are:

- To understand why PWD living in LTC environments are disengaged and under-stimulated in the first place; and orient focus of research targeting unmet needs of PWD in LTC with solid support from previous research.
- To find existing effective approaches as ground truth for ensuring the meaningful engagement of PWD; and to zoom research focus of technology use through a selective and critical evaluation of these interactive technologies.
- To determine how the impact of provided design solutions on the targeted user group should be evaluated.

This chapter is motivated by the following three questions:

1. Why is it so challenging to effectively engage residents with dementia living in the context of LTC?

2. What are the existing activities identified as meaningful in literature for PWD?

It is well acknowledged that measuring a design's impact comprehensively and accurately on users can be challenging. And it is even more so for our target users due to multiple functional limitations. Thus, last question is:

3. How did previous works measure the effects of meaningful activities on PWD? Why do we choose the "engagement of PWD" as an essential indicator for our evaluative research? In addition, how should we understand and assess the engagement of PWD in this research?

2.2 Challenges of Engaging PWD in LTC

The experience of PWD living in LTC environments is a condition traditionally portrayed as "a slow living death." The situation has been much improved thanks to the modern person-centered dementia care approaches and the support of various technologies. However, it illustrates the deepest fear that one may spend his/her later life in an unwanted lifestyle with loss of control and numerous unmet needs.

Dementia is currently the leading cause of older adults' admission to LTC facilities. During the early stages of the disease, PWD often remain to stay at home and have been taken care of by their loved ones (i.e., informal caregivers). With the decrease of capabilities coming from both the aging process and disease itself, most PWD will ultimately be admitted to LTC facilities. However, LTC facilities are often limited in resources and skilled care professionals in order to meet the diverse needs of PWD (Hansen et al., 2017), (Cadieux et al., 2013), (Schölzel-Dorenbos et al., 2010), (Karrer et al., 2020), which results in high levels of passivity/boredom and low level of stimulation/interaction among residents.

Previous research has intensively reported that PWD's displayed challenging behaviors[1], also referred to as Behavioral and Psychological Symptoms of Dementia (BPSD), are highly correlated with inactivity and unengaged situations. For example, there is a close relationship between agitation and physical inactivity (Scherder et al., 2010). The other examples are associations between agitation and inappropriate sensory stimulations (Strøm et al., 2016); passivity, apathy, depression and limited social interaction (Jao et al., 2018), (Cohen-Mansfield et al., 2012a), (Chen et al., 2018). Before we further discuss how to support dementia care and

[1] For detailed descriptions of challenging behaviors of people with dementia, please refer to the book "Understanding Behaviour in Dementia that Challenges" by Ian Andrew James.

improve the current living condition of PWD in LTC, we first review the related literature to answer the question: Why is it so challenging to effectively engage residents with dementia living in the context of LTC?

The first reason concerns the challenges from the individual perspective - the various conditions and uniqueness of individuals with dementia. Tom Kitwood once famously said, *"When you've met one person with dementia, you've met one person with dementia*" (Dewing, 2008). Indeed, dementia unfolds differently for each individual during multiple development stages. And people with various capabilities need different coping strategies in practical care. It asks for highly concentrated resource investment such as staff, time, and customized care routine that often exceeds what most care facilities can provide (Hansen et al., 2017).

There were different systems for determining dementia severity and stages (Olde Rikkert et al., 2011), (Sheehan, 2012). In the following thesis, we will mainly be using the three-stage model (i.e., the early/mild, middle/moderate, and late/severe stages) as it is the easiest for the reader to grasp the representation of the dementia progression. It is generally recognized that people with the early stage of dementia often have trouble memorizing recent events and handling complex situations. However, social judgment is still maintained so that they are still able to engage in certain activities. PWD in their middle stage need assistance with daily activities. They experience conditions like lost orientation in time and space and are severely impaired in handling problems or social judgment. Therefore, hardly engaged in any activities but simple chores. People in their late stage dispossess the ability to make judgments or solve problems. Therefore, they often experience a significant drop in function and rely solely on help with personal care[2].

While the general descriptions emphasize memory, cognitive and functional aspects, growing evidence suggests that the psychological and emotional states of PWD also vary across the disease trajectory. According to Landes et al. (2005), the prevalence of apathy, dysphoria (symptoms such as sad mood, guilt feelings, low self-esteem, and hopelessness), and depression is associated with dementia severity. The loss of inner motivations, interest, and apathetic behaviors presents significant barriers for engaging PWD in activities or interventions. In addition, individual personhood (including components such as personality, lifelong

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[2] Despite the three-stage model - mild/moderate/severe stages of dementia – has been widely used for describing disease progression of dementia. The division of stages can only provide an overall impression of the dysfunction and cognitive impairment with the ongoing process. Functional ability may not be in line with cognitive impairment (e.g., for frontotemporal dementia, it does not always include memory loss; or people with other comorbidities like Parkinson's disease).

experience, hobbies, preferences, and dislikes) will also determine how PWD interact with and respond to the environment, people, and interventions. It will influence the extent PWD benefit from the provided solutions and will shape engagement with meaningful pursuits (Buron, 2008).

The second reason concerns the challenges from the hidden complexity of the LTC. The Hidden Complexity of Long-Term Care model of Cammer and colleagues (2014) identifies six contextual factors and two facilitating features that enmesh to create a context that impacts care provisions in practice. The six contextual factors contain the most easily identifiable "Physical Environment" – which covers from overall facility design, room layout, location, decoration, to lighting design (Vogt et al., 2012); and "Relationships" - the relationship and social interactions happening within the community setting. But also, four more which are not evident for casual observers include: "Resources," "Flux," "Ambiguity," and "Philosophies." "Resources" consist of physical resources (e.g., equipment and supplies), human resources, and intangible features (e.g., information, training, or time). Staff needs to make quick responses and sometimes lacks sufficient training due to work overload and scarce numbers of caregivers. The low staff-resident ratios increase caregivers' stress, which in turn lowers the quality of care. "Flux" encapsulated the situation of constant changes that are happening within the care facilities. For instance, the caregivers constantly need to cope with all kinds of incidents due to the caring nature of dementia disease, which makes it very difficult to keep a routine. And maintaining the routine is suggested as one of the best care solutions for PWD. "Ambiguity" refers to the uncertainty of coping strategies of care practices that the caregivers often need to weigh the factors based on situations. The last factor, "Philosophies," captures the value of care of organizations and implies the top-down policy that guides caring practice and focus. The above shows that there is increasing recognition that care providers and solution designs need to understand the complexity of caring and treating for PWD.

The third reason concerns the challenges from the lack of innovative approaches to stimulate and engage PWD. And this shall be expanded in section 2.3.

To summarize, we conclude three sources of factors that make engaging residents with dementia in LTC challenging:

- **Individual factors:** The accompanied multiple memory, cognitive, and functional deterioration limit the activities that PWD could participate in and benefit from. Furthermore, the social, emotional, and psychological performance decreased with a progression such as lack of internal motivation, interests, and concentration also presents significant barriers for fostering and sustaining engagement of PWD in LTC, especially in later stages of progression.

- **Contextual factors:** The unfamiliar physical environments, inadequate resources, ambiguous situations, continual change, and multiple relationships together mixed a complicated context of LTC that highlights the challenging fact of achieving enhanced engagement and improved quality of life.
- **Stimuli factors:** The lack of effective activities, interventions, and innovative designs for mitigating challenging behaviors, addressing inactivity, and promoting engagement.

Then, we propose our fair evaluations based on the above lessons learned:

- To accommodate challenges raised from the individual factors, we need strategies suitable for personal abilities and interests that can motivate participation and engagement.
- To accommodate challenges raised from the contextual factors, we need a deep understanding of their current living situation and to involve PWD's living context and multi-stakeholders as much as possible to provide meaningful solutions.
- The challenges raised from the stimuli factors call for innovative solutions addressing the psychosocial needs of PWD living in LTC that will lead to an enjoyable, engaging experience and improved subjective well-being.

2.3 Meaningful Activities for Engaging PWD

In literature, the topic of engagement in meaningful activities of PWD is highly concentrated in two general fields: the "traditional research" field of psychiatry and psychology studies; and the interactive technologies that emerged from HCI.

For decades, research on supporting PWD's well-being besides medical treatments has long been dominated by occupational health research of psychiatrists and psychologists. As the primary research outcomes from those studies, non-pharmacological interventions are a set of approaches, which alongside pharmacological treatments, physically restrain, and seclusion, aim to improve quality of life, maximize functions, and ensure safety. The literal meaning of the term may be general and includes all interventions that do not require pharmaceutical use. In the specific context of dementia care, it refers to a particular set of approaches developed for managing BPSD, engaging PWD in activities that can help alleviate the feeling of boredom, reduce sensory deprivation, and at the same time ease care burden.

On the other hand, in the field of HCI, interactive systems in the forms of products, games, services, robots, and so on, are another set of novel approaches. These approaches are enhanced by technologies and developed to help to assist daily living and engage PWD to motivate physical exercise, manage behavioral problems, maintain cognitive abilities, or recreational purposes.

Next, we provide a state-of-the-art of the developed "meaningful activities": non-pharmacological interventions and technology-empowered activities for PWD.

2.3.1 "Traditional Activities" - Non-pharmacological Interventions for PWD

Non-pharmacological interventions were initially put into clinical practice in line with medication use to help to manage challenging behaviors (e.g., aggression, agitation, wandering, abnormal vocalizations), as: 1) challenging behaviors are the most common reason for increasing caregivers' stress and burden; 2) pharmacological treatments has been shown to have low efficacy and serious side effects, such as increased fall risk, mortality rate, and stroke occurrence (Seppala et al., 2018). Thus, the development of non-pharmacological Interventions was initially based on the conceptual understanding of behaviors that were perceived as challenging. In particular, such interventions were developed to explore whether the symptoms of PWD are a result of the disease itself or the inappropriate treatments, discontent, or other difficulties.

Literature pointed out four theoretical frameworks that explain the etiology of behavior disorders, including: *Biological Theory* - the behavioral disorders stem from neurologic changes and brain deterioration; *Environmental Vulnerability Theory* - behavioral disorders was triggered and reinforced by the environment; *Reduced Stress-Threshold Theory* - the reduced capability of PWD to cope with the situation; *Unmet Needs Theory* - behavioral disorders as a form of communicating and fulfilling underlying needs (Ayalon et al., 2006), (Cohen-Mansfield, 2013). Targeting the etiologies "traditional therapies" includes interventions that can stimulate remaining cognitive abilities, differentiate reinforcement from the environment, manage stimulus control, orient reality was developed for managing behavioral problems.

More recent research, especially since the popularity of person-centered care in practice, suggests that being engaged in such interventions apart from help managing challenging behaviors can also address psychosocial needs. As engagement in therapeutic interventions is highly associated with increased positive affect, reduced loneliness (Cohen-Mansfield & Perach, 2015), decreased depression, and sensory deprivations (Strøm et al., 2016). The findings initiate a shift of perspective from a staff-oriented approach towards a client-centered one. And those interventions are no longer treated only as solutions to control behaviors but a meaningful pursuit for unmet psychosocial needs (Vernooij-Dassen et al., 2010).

Categories of Non-pharmacological Interventions

Several literature reviews have systematic enlisted non-pharmacologic interventions for PWD (Douglas et al., 2004), (Samus et al., 2005), (Yamaguchi et al., 2010), (O'Neil et al., 2011), (Cooper et al., 2012), (Cohen-Mansfield, 2013), (Mclaren et al., 2013), (Livingston et al., 2014), (Cohen-Mansfield & Perach, 2015), (Wang et al., 2018). Based on the results of previous reviews, we categorized the existing non-pharmacological interventions into five categories that cover cognitive/behavioral, sensory, social, environmental, and other aspects for summarizing the effects. See full detailed categories with examples of interventions, descriptions, and reported effectiveness in literature in Table A1 of Appendix A.

- **Cognitive/behavioral oriented interventions** are developed to compensate memory/cognitive deficits and manage challenging behaviors of PWD. This category contains: 1) cognitive-oriented interventions (e.g., reality orientation, validation therapy, reminiscence therapy, simulated presence therapy, cognitive stimulation); 2) behavioral-oriented interventions (e.g., behavioral therapy, differential reinforcement); and 3) cognitive-behavioral combined interventions (e.g., Cognitive-Behavioral Therapy - CBT).
- **Sensory interventions** utilize different human senses and aim at providing engaging sensory experiences to stimulate PWD through sensory enhancement or calm PWD through relaxing approaches. This category consists of: 1) the use of the singular sensory system: such as auditory (e.g., music therapy, sound therapy/white noise), visual (e.g., art therapy), tactile (e.g., massage/touch, reflexology, reiki, and acupuncture), or olfaction (e.g., aromatherapy); and 2) the integrative use of multimodal sensory systems: tactile, visual, auditory, olfaction even gustatory (e.g., Snoezelen/ Multisensory Stimulation Therapy) (Jakob & Collier, 2017a).

- **Social interventions** focus on promoting social interactions of PWD through increasing social contact with humans, animals (e.g., animal-assisted therapy), or simulated humans/animals. Social contact with humans can be further divided into one-on-one interaction or group interaction with other residents, family members, volunteers, or care professionals.
- **Environmental interventions** address the influence of environment design on the quality of life of PWD. For instance, the influence of sufficient light on diurnal rhythms (e.g., bright-light therapy), the balance of coping mechanism of PWD and environmental factors on behaviors (e.g., reduced-stimulation unit), interventions targeting specific disrupted behaviors (e.g., wandering areas), enhanced environment through providing access to the outdoor environment, exposure to simulated outdoor environment or simulated familiar domestic environment***.***
- **Structured activities** consist of activities that are organized in groups (e.g., group games, reading roundtable, and sing-along activity) and for individuals (e.g., manipulative games, work-like tasks, and physical activities).
- **Customized activities** are activities that are customized into individual needs, abilities, interests, and preferences. The customized activities are advocated by many researchers and can achieve better therapeutic effects and motivate engagement by capturing personal interests.

Barriers and Limitations

The current existing non-pharmacological interventions demonstrate a promise in promoting living conditions for PWD staying at home or LTC environment. However, still have many reported barriers and limitations in practice. Cohen-Mansfield et al., (2012b) studied the current barriers to performing non-pharmacological interventions in the nursing home environment. They concluded three factors of confronted barriers: the resident barriers, barriers related to resident unavailability, and external barriers. Moreover, it suggests that resident barriers (i.e., unwillingness to participate and resident attributes) and barriers related to resident unavailability (e.g., asleep, eating, in the shower, etc.) are factors that cannot be changed and therefore need to be accommodated. In contrast, external barriers, such as staff-related barriers, family-related barriers, environmental barriers, and system process variables, are factors that could be improved, changed, or strengthened to achieve a positive impact.

Cohen-Mansfield’s study gives a comprehensive understanding of the sources of barriers when delivering such interventions. However, it is limited as this study did not capture the opinions of nursing staff.

Ervin and colleagues (2014) conducted qualitative research on the staff perceptions of the limitations of non-pharmacological interventions in residential care. The qualitative finding identifies five themes that account for current barriers and argues that the resources required to implement many strategies far exceed available in most LTC facilities. The research suggests that perceptions of time constraints are the most significant barrier to care staff using non-pharmacological interventions. The caregivers are often overloaded with care activities and short of personnel. This was also confirmed in many other studies (Becker et al., 2017), (Takai et al., 2010), (Etters et al., 2008). Furthermore, staff commonly reported a lack of knowledge and experience in the use of diversional therapies/programs. This results in the need for more education and training to use the strategy effectively. The third theme reported is the lack of effectiveness of the strategy as an intervention in managing behaviors, even adverse effects of particular interventions when employed to certain people at a specific time. Therefore, it generates the need to provide more robust diversional therapies/activities/programs. Apart from the above, staff also reported difficulties engaging advanced cognitive impairment residents in such interventions. Their refusal to participate, limited ability and attention span, and aggressive, inappropriate behaviors may influence other residents, even intimidating younger staff.

Besides the abovementioned, we conclude four concerns (C1-C4) that limit non-pharmacological interventions from working effectively and to their maximized impacts from our literature studies:

C1: *The passive role of PWD during intervention delivery – PWD as recipients of non-pharmacological interventions.*

The first identified concern is the passive role of PWD as recipients of such interventions. The provided and arranged interventions induce a passive expectation of the caregivers’ capacity to enact change of PWD’s current conditions. Most interventions listed in Table A1 of Appendix A are selected, arranged, and facilitated by professionals in practice. The provision of activities prevents PWD, especially those living in LTC who have little control over their lives, from gaining a sense of control (Lazar et al., 2016a). Moreover, care professionals commonly view PWD as a loss of coping mechanism, inability to self-regulate, and incapable of making complex decisions, resulting in a lack of motivation or initiation during engagement in activities. Literature suggests that interventions that promote and empower one's self-action tend to have more pervasive and enduring results (Hooley, 2016). And it is generally acknowledged that self-motivated participation in interventions is far more beneficial than enforced interventions in the psychotherapy field.

C2: *The effectiveness of non-pharmacological interventions highly depends on facilitation quality from professionals.*

According to Yamaguchi et al. (2010), the key for non-pharmacological interventions to work effectively is not "what" approach is taken but "how" the provider communicates with the receiver. This concern is also reinforced by and closely related to the C1. The quality of interventions can vary enormously depending on the quality of facilitation. Interventions can achieve great success through the appropriate mediation from a very experienced caregiver, but it can encounter adverse effects due to inaccurate evaluation of the user's status, and the repetitive and stressful nature of the facilitation. It also requires the expertise to sense the user conditions and combine the use of multiple strategies and tailor them to individual needs. Despite the fact that most literature sees this issue as a lack of proper critical knowledge, experience, and training of staff, it demonstrates a need for proper and effective mediums that: 1) acquire user needs accurately and effectively; 2) guide the facilitation of interventions, instead of only relying on caregivers; more importantly, 3) bond caregiver-resident relationship during activity delivery process, as the nature of the relationship will impact on care and subsequent BPSD depending on whether the person is being respected or depersonalized.

C3: *Non-pharmacological interventions can hardly achieve expected attentiveness and social connectedness in a community-based group such as residents in LTC.*

In a community-based group like an LTC, structured activities are commonly organized and performed on a regular basis aiming for positive therapeutic effects. This kind of pre-planned activities can hardly work as expected to bring connectedness and attentiveness, especially for users with more advanced stages of dementia due to compromised abilities and limited social interactions (Cohen-Mansfield et al., 1992), (Campo & Chaudhury, 2012). Literature suggests that PWD's attentiveness is higher when users are engaged in activities that they are interested in (Kolanowski et al., 2001), capable of (Cohen-Mansfield et al., 2015), familiar with (Mileski et al., 2018), and related to (Cohen-mansfield et al., 2006). Social interaction for PWD is suggested more effective in close ties, within family members, intimate friends, and preferred caregivers, which structured activities in a group of residents cannot meet.

C4: *Current widely adopted non-pharmacological interventions can hardly address the higher level unmet psychosocial needs of PWD.*

As one might already notice from Appendix A. Majority of reported effective non-pharmacological interventions are still focusing on suppressing or eliminating behavior problems (e.g., agitation, aggression, and inappropriate vocalization). Some aim to improve psychological states and functional behaviors. Only a few interventions touch on a higher level of psychosocial needs (according to the Hierarchy Model of Needs in Dementia) in terms of self-identity, self-esteem, sense of control, and sense of meaning (Schölzel-Dorenbos et al., 2010).

In conclusion, non-pharmacological interventions that cover cognitive, behavioral, sensory, social, environmental factors have paved the road for modern dementia care and greatly contributed to improving the quality of life of PWD after diagnosis. These approaches are proven to be effective in managing BPSD (O'Neil et al., 2011), (Cohen-Mansfield, 2013), (Samus et al., 2005), (Livingston et al., 2014), delaying functional decline (Mclaren et al., 2013), stimulating cognitive abilities (Yamaguchi et al., 2010), and engaging PWD in meaningful activities. These activities can alleviate boredom (Cohen-Mansfield et al., 2015), facilitate social interactions (Campo & Chaudhury, 2012), (Cohen-Mansfield & Perach, 2015), enable sensory stimulations (Strøm et al., 2016), cope with environmental challenges (Samus et al., 2005), and promote quality of life (Cooper et al., 2012).

Literature on effective use of non-pharmacological interventions suggests a combined use of multimodal strategies tailored to individual needs and highlights the importance of social interactions (Wang et al., 2018). Such effectiveness also requires significant personnel resources with skilled expertise, which far exceeds what is available in most LTC. It can ultimately lead to interventions improperly used without expected effects. These barriers and challenges call for research and technology to cope with the above limitations. Therefore, the following sections further discuss the use of innovative technology solutions for supporting the quality of life of PWD.

2.3.2 Technology-Empowered Activities - Interactive Technologies for PWD

Interactive technologies from HCI have shown exciting potential and success in supporting the well-being of PWD. In this section, before we dive into the specific designs for PWD, we first illustrate the proportion of technology applications within this domain to guide our research to a particular area that needs attention.

According to a thorough evidence-based scientific research report of the project - "Long-term care strategies for independent living of older people (ICT-AGE)" by Carretero (2015) for European Union policymaking, the practices in technology-based services are now focused on four areas, including independent living, the productivity of care, quality of care, and sustainability of care systems. The report shows that large technology development efforts are concentrated on care practices and care systems. Consistent with the above, Topo (2009) in his review, addressed that in a considerable large number of studies of technology use in dementia care, most are focused on the needs of the formal caregivers, while less than a quarter of them actually explored how PWD used technologies.

Regarding technologies developed for PWD themselves, Evans and colleagues (2015) suggest an overrepresentation of compensatory memory aids to improve independent daily living and safety devices, compared to the limited number of studies using technology to enhance leisure activities. This situation is also confirmed by two more recent representative reviews of technology use and dementia. Lorenz et al. (2019) state that cognitive and memory support is the main focus for PWD in the early stages, while safety and security are for those with advanced stages. Regarding moderate to severe stages of PWD living in LTC, care delivery composes a large part of technology use. However, psychosocial aspects are often ignored. In line with Lorenz's work, Fabricatore et al. (2019) articulate that the most frequent purposes of technology use were utility-oriented. This review first addressed the relationship between technology use and user engagement and pointed out few studies addressed this issue. In a most recent review of Pappadà et al. (2021), besides the aforementioned aspects of monitoring, security, and daily living sustainment, there appears an emerging field of technology-based interventions that address psychosocial care and benefit to mental health and social aspects.

To brief the key points provided by the above literature reviews regards technology use and dementia:

- Most technology solutions available that support PWD and caregivers are not specifically designed for PWD but to improve productivity and quality of care practice.
- Current technology solutions designed for PWD are mainly utility-oriented, focusing on compensating functional performances and daily living sustainment, while psychosocial aspects are often ignored (Gowans et al., 2004). Literature suggests that for PWD in their early

stages, cognitive and memory support is often the main focus; for moderate to severe stages, the focus is on supporting care delivery and quality; and for advanced stages, safety and security.

- Limited studies emphasize PWD's psychosocial needs and targeting on more advanced stages of dementia. Psychosocial needs are the most reported unmet needs for those in LTC, which includes the need for sensory and physical stimulation, emotional support, mental health, and social needs. Meeting the psychosocial needs of PWD is highly correlated with behavioral management. Therefore, it is essential for improving quality of life and well-being.

The above findings illustrated an indisputable fact that there is a huge gap of work where technology-empowered psychosocial activities for engaging PWD with more advanced stages and those who live in LTC are needed in contemporary dementia care. And only recently, designing for PWD is shifting its focus from assisting independent living and monitoring safety to addressing hedonic aspects of well-being such as fun and engagement.

Technology-Empowered Psychosocial Activities

This research focuses on the psychosocial needs of PWD living in the LTC environment and endeavors to contribute to this issue through design research. In literature, technology-empowered psychosocial activity does not have a singular definition but appears in many other names. It is termed as technology mediated recreational activities in (Lazar et al., 2016b), leisure activities in (Astell et al., 2019), restorative activities in (Jansen & von Sadovszky, 2004), or design for playfulness in (Treadaway et al., 2019b) and (Treadaway et al., 2019a).

Combining different perspectives of views, our understanding of **psychosocial activities** is:

Activities that enable sensory, cognitive, and physical stimulations, provide support in social and emotional experiences, promote engagement and fun, and are beneficial to mental health for PWD.

Although there were few comprehensive literature reviews on this topic, a recent review of Astell et al. (2019) concludes that up-till-recent technology applications on PWD that supports socialization and leisure focus on six areas, including: 1) music playing and making, such as interactive radio for music-playing or tablet-based individual or collaborative music-making; 2) creative art program, such as interactive art installation in nursing homes; 3) simulated outdoor activities, such as virtual cycling, and navigating and locating in virtual environments; 4) socializing, such as remote socializing with families and friends using video conferencing technology and mobile applications; 5) games and other digital pastimes for pleasure and brain training, such as motion-based gaming systems (e.g., Nintendo Wii and Microsoft Xbox Kinect); and 6) Augmented Reality (AR) experiences. Meanwhile, Treadaway et al. (2019a) suggested three themes that recent design research has focused on for PWD with advanced stages, including design for sensory environments (Jakob et al., 2017), tangible and assistive technologies (Iversen, 2015), (Bennett et al., 2016) and communication (Huber et al., 2019).

Referencing to above articles and in combination with our literature research, we classify and highlight four main areas of technology-empowered design solutions for addressing the psychosocial needs of PWD. These areas can be intertwined with each other.

Sensory-based Designs

Sensory-based designs in line with sensory-based interventions (one category of non-pharmacological interventions) are where most designs allocate, as they: 1) demonstrate significant social and emotional benefits to improve vitality, self-esteem, social relationships, and participation (Strøm et al., 2016); 2) do not require complex cognitive reasoning, therefore, are suitable for various stages of PWD. The existing designs in the forms of products, systems, services, and agents address either one particular sensory channel or multisensory channels.

Most efforts of sensory-based designs for PWD emphasize sensuous engagement through auditory and tactile modalities. On the one hand, a large proportion of work focuses on music and sound-related technologies. The role of music has demonstrated well-acknowledged benefits for PWD (Wesselink et al., 2020). A recent review of Creech (2019) indicates that music-related technologies for PWD mainly focus on five purposes: using technology for accessing preferred music, using music technology for reminiscence, music technology to support singing, support music perception and appreciation, and collaborative musicking [3]. With the development of HCI technologies, "musicking" in literature collaborates closely with tangible interaction for PWD. As a result, "Musicking Tangibles" is an innovative approach that can promote self-independence and personhood beyond cognitive stimulating and positive emotional benefits that general music enjoyment can provide (Cappelen & Andersson, 2014). An example is *Sentic* by Thoolen et al. (2020a). Houben et al. (2019) have

[3] "Musicking" is defined as "*equal, meaning making, and relation building activities related to music, such as listening, playing, composing and dancing*" in the work of (Cappelen & Andersson, 2014).

also researched the role of everyday sounds and soundscapes on PWD. There is beginning evidence that sound also possesses great potential in engaging PWD by bringing playfulness, stimulating conversations, and building connections with others (Houben et al., 2020a).

On the other hand, a growing body of work focused on sensory-based design with haptic and tactile related experience. Previous works indicate such experiences can be particularly beneficial to PWD in later stages (Treadaway et al., 2016). Sensory playful artifacts like interactive textiles, especially with heat features, can comfort and soothe those chair/bed bound with severe verbal communication impairment (Jakob & Collier, 2017b). The LAUGH project provided several examples (e.g., Hug, a long-arm pillow with a beating heart to give a hug; Steering Wheel, a tangible wheel to simulate personalized driving experience; Giggle balls, softballs in the shape of smiling faces that giggle when held in hand) to demonstrate the use of haptic/tangible quality in design for playfulness (Treadaway et al., 2019a). Therapeutic touch that utilizes motor and sensory functions of the brain is more likely to be effective in motivating active participation and engagement.

In line with the pursuit for immersive experiences in the HCI research field, sensory-based designs for PWD aim to provide engagement in multiple sensory modalities. For instance, Bennett et al. (2016) developed a resonant interface rocking chair to emphasize stimulation of proprioception and vestibular senses with the auditory sense. The chair plays music when activated by rocking motion; Anderiesen (2017) designed a commercially available projector - *Tovertafel*, which transforms an ordinary dining table into a sensory-stimulating game space. This product was initially developed for PWD in advanced stages and aimed to motivate users to be actively engaged through interactive features, colorful and intriguing images projection, and sound effects.

Design for Reminiscence, Communication and Connection

Since memory appears to be the most noticeable challenge of PWD, reminiscence that evokes memory and counteracts the loss of self-identity is another major area of design for PWD. Besides commonly acknowledged benefits of reminiscence on emotional memories and personhood, one huge positive contribution of reminiscence activities is to take a more active part in conversations and social interaction.

In practical care, reminiscence activities primarily employ non-digital cues, such as showing pictures, listening to music, mentioning familiar things that were once relevant to PWD. Modern research employed technologies such as tablet-based systems that withhold great advantages of incorporating various multimedia materials into one easily accessible device. Computer Interactive Reminiscence and Conversation Aid (CIRCA), as one example, is a successful milestone that facilitates free-flowing conversations between a user and a family/caregiver through photographs, videos, and music (Alm et al., 2007). CIRCA works as a communication aid to enable memory sharing, facilitate conversations, support personhood, and build connections between caregivers and PWD.

Although most technologies that support reminiscence activities use are tablet-based, there is also an emerging trend of employing tangible interfaces in facilitating reminiscing in dementia care (Lazar et al., 2014), (Huber et al., 2019). Tangible reminiscence, referred to as "*objects as dialogues for PWD*", has the reminiscent affordance that calls on long-term memories and invites interactions with reduced barriers of accessibility issues (Wallace et al., 2013). The ideas of reminiscence, communication, and connection are interconnected. Reminiscence activity can be one way to facilitate communication and further achieve social connection with the partner you share your experience with.

Social interaction plays a crucial role in maintaining the quality of life, especially for those living in LTC who are at high risk of social isolation. Besides reminiscence related designs, technology applications that were used for promoting social interactions and connections allocate to four other areas: 1) mobile/tablet applications as toolkits to reshape family dynamics, facilitate intergeneration communications, and bring out societal awareness, examples including *DemYouth* (McNaney et al., 2017), *Ticket to Talk* (Welsh et al., 2018), and *Care and Connect* (Morrissey et al., 2017); 2) telepresence technologies to support face-to-face conversations, an example like (Moyle et al., 2018); 3) tangible prompts to address social skills imbalance, an example as (Houben et al., 2020c); and 4) social/conversational agents to achieve social interactions. Examples of social agents include humanoid robots – NAO (Valentí Soler et al., 2015), and Mini (Salichs et al., 2020); robotic companion pets – PARO (Moyle et al., 2017b), AIBO (Tamura et al., 2004), NeCoRo (Libin & Cohen-Mansfield, 2004), and Huggable (Stiehl et al., 2006); and conversation agent – the "digital pet" (Chi et al., 2017). Compared to the first two areas, in which the primary users are usually partners in collective use, the latter two areas are more likely to support independent use of PWD.

Augmented Environment Designs

Augmented environment describes a set of products/systems that aim to transform a daily living environment into sensory-enriching experiences. Such approaches are essentially sensory-based designs that adopt the nature of multisensory stimulations. However, different from general sensory-based designs, it utilizes the contextual environment to create a more immersive sensory engagement.

Most applications employ a projector or a large display for visual immersion. One example is a successful commercially available product - *Qwiek.up*[4]. *Qwiek.up* is a projector on wheels that provides diverse interventions for care facilities through different designed modules. The system offers a wide range of experiences, for instance, a simulated walk at forests through projecting nature settings on walls or ceilings, a concert experience, sensory-stimulating sessions through the use of special light effects with odor, and reminiscent experiences by playing personal images, music or videos. Another example would be a tablet-based digital application - *HealingSpaces*[5], that extends the virtual nature experience to physical space by collaborating with commercially available components such as Philips Hue smart lights, speakers, and projectors (Gomes et al., 2020). The *HealingSpaces* was developed for PWD to focus, engage, and relax. Two natural scenes (a forest and a seaside) and two ambient settings (a stimulating one and a calming one separated by different times of the day – dawn and dusk) within each scene are offered for customized selection according to user needs. Similarly, *AmbientEcho* is an interactive media system that consists of a simulated window with virtual scenes and a digital photo frame with ambient environmental light and music. It aims to provide personalized media experience in residential dementia care (Thoolen et al., 2020b). When artifacts that represent personal identity (a necklace or a color disc) are detected, the system will automatically show preset customized media content.

Although these designs provide entertaining sessions that allow a certain degree of personal preference, they curate passive sensory experiences with limited possibilities of self-initiated interactions. Inspired by somatic games, the *Virtual Forest* (Moyle et al., 2018) and *Tovertafel* (Anderiesen, 2017) allow users to interact with the projected graphics through hand and arm movements captured by sensing-based technologies (e.g., Microsoft Kinect sensors).

Others – ICT, Exergaming, and VR

Other technology-related designs that could deliver meaningful activities include Information and Communication Technology (ICT) systems, exergaming, and the use of Virtual Reality (VR) on PWD. ICT systems are

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[4] https://www.qwiek.eu/up

[5] http://www.aboutgabi.com/healing-spaces/

Figure 2.1 Examples of augmented environment designs that use multimedia approaches to transform a daily living environment into sensory enrichment experiences[6]. With (a) and (b) the product *Qwiek.up*; (c) the *AmbientEcho*; (e) the *HealingSpaces*; (d) and (f) the product *Tovertafel*.

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[6] **Photo credits**
Qwiek.up: Images reproduced with permission from Qwiek BV. URL: https://www.qwiek.eu/up
AmbientEcho: Image reproduced with permission from Myrte Thoolen, Rens Brankaert, and Yuan Lu. "AmbientEcho: exploring interactive media experiences in the context of residential dementia care." Proceedings of the ACM Designing Interactive Systems Conference. 2020.
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URL: https://www.tover.care/uk/tovertafel/seniors.
HealingSpaces: Image reproduced with permission from Gabi Purri R. Gomes.
URL: https://www.aboutgabi.com/healing-spaces/

suggested to have great potential to facilitate and enrich activity engagement with regard to reducing care costs and staff time (Lazar et al., 2016a), (Liapis & Harding, 2017). Such multifunctional systems could combine different purposeful applications into one system to provide accessible and feasible interventions for PWD (Unbehaun et al., 2019). Exergaming addresses the physical inactivity of PWD and aims to provide playful physical exercise to motivate movement and maintain motor skills.

Participation in exergames for PWD is related to positive social dynamics, increased motivation, improved cognition, alleviated mood, and physical health (van Santen et al., 2018). VR for PWD attempts to use immersion technologies to create a total simulated sensory experience (Garcia et al., 2012). Suggested by the review by Strong (Strong, 2020), the use of immersive VR with PWD is very limited, and research mainly focuses on feasibility. The effectiveness of VR experience on PWD is based on anecdotal evidence with little known from those in the later stages of dementia. In general, the use of these technologies presents a certain level of challenge for those with more severe conditions. Therefore, addressing the accessibility, feasibility, and involving people in their later stage of dementia is still needed.

To summarize, our literature review on designing technology-empowered psychosocial activities reveals that:

- Most designs that promote psychosocial well-being for PWD are through creating sensory experiences. Within which, most efforts of sensuous engagement are through auditory and tactile modalities due to its effectiveness in engaging a wider range of PWD regardless of individual conditions. In line with the pursuit of immersive experience in HCI, sensory-based designs for PWD aim to enable richer sensory channels through multisensory experiences than engagement in certain senses.
- Design for reminiscence, communication, and connection is another significant area, and the technology use is mainly digital applications based on tablets or cellphones with primary users not PWD themselves. The use of richer interfaces such as tangible interfaces and social/conversational agents is an emerging field with initial positive evidence in this design area.
- Augmented environment designs that involve contextual environment as part of the design and transform the daily living environment into sensory-enriching experiences are the third identified design focus. Most current designs that curate passive sensory experiences view participants as passive recipients and with

limited possibilities of self-initiated interactions. Experience that allows richer interaction possibilities may boost positive effects and is an arising field with development in sensing-based technologies.

- For the last identified design area - ICT technologies, exergaming, and VR, these technological applications are mainly tested with PWD with mild to moderate stages. It still presents challenges for engaging PWD with more severe conditions, and future studies need more evidence.

Although the topic of designing for PWD has already become an emerging field within the HCI community, current design research is still preliminary. From the user perspective, design researchers are trying to fit in the shoes of PWD and developing user-centered and user-involved compassionate design approaches to better understand user requirements. From the technology perspective, developers are investigating how PWD responds to certain new technologies and how we could better utilize them in practice. From the therapeutic effect perspective, multidisciplinary research teams are trying to bridge existing therapies and transform those interventions into the technology-enhanced version of systems, services, or designed artifacts. The literature review shows a lack of a repertoire of design that considers context, user needs, and abilities to shape meaningful activities through technology use.

2.4 Measuring the Effects of Meaningful Activities on PWD

The above section provides a state-of-the-art of meaningful activities for engaging PWD. In the following, we aim to review how the impact of addressed meaningful activities was evaluated in the literature. Corresponding to two categories of meaningful activities mentioned in the previous section, we present the measuring of the effectiveness of traditional activities and designed activities in separate subsections.

2.4.1 Measuring the Effectiveness of Traditional Activities

In the literature, many indicators were used for assessing the effectiveness of traditional activities on PWD within different contexts. These indicators range from a general evaluation of the quality of life to drug consumption, monitoring of vital signs (e.g., blood pressures), pain, cognition and mental health conditions, amount of physical activity, quality of interaction with caregivers, and emotions or beliefs. Traditional non-pharmacological interventions were originally proposed for mitigating behaviors that caregivers find challenging to manage. Thus, there was a large body of work focusing on measuring the effectiveness of reducing such problematic behaviors of PWD, for instance, wandering and pacing

(Robinson et al., 2006), agitation (Livingston et al., 2014), or apathy (Goris et al., 2016). Assessment tools in the form of scales or inventories were developed for identifying and quantifying such disruptive behaviors. The most popular ones are the Neuropsychiatric Inventory (Cummings et al., 1994), the Cohen-Mansfield Agitation Inventory (Cohen-Mansfield & Billig, 1986), and the Challenging Behavior Scale. For an overview of such scales, see examples of (Neville & Byrne, 2001), (Snowden et al., 2003), (Bossers et al., 2012). What is worth noticing is that many of these scales tend to be used in clinical research under the condition of long-term exposure to interventions to have desired behavior changes.

Besides assessment using challenging behaviors of PWD that composed of most documented research, existing evaluative studies often address one or several aspects of the following: (a) sociopsychological parameters (e.g., cognitive status, affective states, mood, loneliness, depression, anxiety, social connections, communication, or quality of life) using scales or questionnaires (Kramer et al., 2009), (Valentí Soler et al., 2015); (b) physiological parameters (e.g., electrodermal activity, or EEG signals) (Wada et al., 2008); (c) qualitative conversational interviews; and (d) behavior indicators of the extent of involvement in the intervention[7] (using measures such as ethograms), such as gazing or manipulating the stimuli (Tamura et al., 2004).

The literature review shows that most relevant studies do not share a consistency in method use and often cannot provide a comprehensive understanding of the situation. With the focus of dementia care shifting from compensating and managing physiological defects to the person-centered approach, the evaluation started involving measures from the psychology field (i.e., the notion of engagement, a more subjective psychological and emotional state of users) within the evaluation process as well. This leads back to our research focus – assessment of engagement of PWD.

According to the literature, engagement in general can be measured on three dimensions: 1) experiential dimension using subjective measures such as self-reports; 2) behavioral dimension assessed through observing bodily expressions using measures such as observational rating scales; and 3) peripheral dimension assessed through physiological parameters. For PWD, the first dimension is often inaccessible due to severe cognitive and language impairments of the disease. Therefore, the self-reports are often

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7 With a more evolved understanding of PWD's engagement, this category, combined with other aspects, has eventually developed into the coding schemes used now for assessments of the behavioral facet of engagement.

replaced by observational reports by people who are familiar with the target users. And the third dimension is limited in studies due to concerns of its intrusive nature. Accurate physiological measures are commonly assessed through multiple wearable sensors, which may distract users during interventions and cause reluctance in practical use. Therefore, existing research that assesses engagement directly on PWD is largely based on the methodologies using behavioral observations (Jones et al., 2015), (Perugia, 2018).

In the next section, we clarify the definition of engagement in PWD, its theoretical constructs including main components, and present an overview of state-of-the-art assessment methods of PWD's engagement.

Understanding Engagement in PWD

The notion of engagement was raised in the field of positive psychology, where Csikszentmihalyi's flow theory first described a state that one acts with total involvement, with intensive focused concentration, even a loss of self-consciousness (Csikszentmihalyi, 1988). The state of flow is the most representative and widely adopted framework of engagement in literature. Meanwhile, in HCI, studies of engagement are seen as an extension and pursuit of a more involved user experience - engaging experience. The concept of engagement was then addressed in different fields within specific contexts. For instance, in the field of gamification, engagement is presented as "immersion" with three levels of intensity: engagement, engrossment, and total immersion (Seaborn & Fels, 2015); in the field of user-product interaction, engagement is described as "*a specific kind of experience that a user acquires when and after using a product frequently, intensively, actively, vividly, and completely, etc.*" and been classified into sensory, physical and emotional engagement (Chou & Conley, 2009); moreover, in a broader perspective that describes the relationship between users and technologies, engagement is defined as "*the emotional, cognitive and behavioral connection that exists, at any point in time and possibly over time, between a user and a resource*" (Attfield et al., 2011).

Although the concept of engagement was addressed in many fields, there were few studies that defined engagement and its construct for users with dementia. At a very early stage, Lawton's "dual-channel" model of engagement describes "*an antecedent pattern for positive and negative psychological states or affect in older people*" (Lawton et al., 1996). The model provided the theoretical construct of the assessment method - Philadelphia Geriatric Center Affective Rating Scale, which further modified into the well-known Observed Emotional Rating Scale (OERS) that is widely used for assessing affective states of PWD until now (Lawton et al., 1996). While Lawton's studies of engagement mainly focused on affective attributes, it also pointed out the engaging events' contributions towards positive affective states.

Moving further, Cohen-Mansfield and colleagues proposed the Comprehensive Process Model of Engagement, the most acknowledged framework of engagement for PWD (Cohen-Mansfield & Dakheel-Ali Maha, 2009), (Cohen-Mansfield et al., 2011). Engagement is defined here as "*the act of being involved or occupied with a stimulus*". Moreover, their work concludes the factors that affect the engagement of PWD, include environment attributes (e.g., noise, temperature, location), person attributes (e.g., cognitive function, demographic characteristics), and stimulus attributes (e.g., social qualities, emulated work role). In the model, engagement is conceptualized as consisting of five dimensions: rate of refusal of the stimulus, duration of time, level of attention to the stimulus, attitude towards the stimulus, and the action towards the stimulus. The construct of engagement and its evaluation is further reflected through the assessment method of Observational Measurement of Engagement (OME) (Cohen-Mansfield & Dakheel-Ali Maha, 2009).

Around the same time, Judge et al. (2000) studied the effectiveness of Montessori-based activities on engagement for PWD in LTC. In which, engagement was divided into four categories: constructive engagement, passive engagement, non-engagement, and self-engagement, and evaluated using the developed Menorah Park Engagement Scale. Constructive engagement was defined as "*any motor or verbal behavior exhibited in response to the activity in which the client was taking part*". Passive engagement was defined as "*listening and/or looking behavior exhibited in response to the activity the client was participating in*". Non-engagement was defined as *"staring off into space or another direction away from the activity, sleeping, or any motor and/or verbal behavior activity in response to an activity the client was not currently participating in*". And self-engagement was defined as "*motor, verbal, listening and/or looking behavior during a transition period when an activity was not currently being offered or when the client chose not to participate in the scheduled activity*" (Judge et al., 2000). The studies show that Montessori-based activities can help increase constructive engagement and reduce passive engagement, while self-engagement and non-engagement were rarely observed. In Judge's construct of engagement, constructive engagement was regarded as a better form of engagement than passive engagement.

Unlike the above research that focused on engagement of PWD with a stimulus/stimuli, Jones et al. (2018) proposed an assessment method that studies engagement within the context of psychosocial activities and first involves social/collective engagement as an aspect of the engagement. The Engagement of a Person with Dementia Scale (EPWDS) was developed based on her former work – Video Coding Incorporating Observed Emotion (VC-IOE) (Jones et al., 2015). The EPWDS examines five areas of engagement: affective, visual, verbal, behavioral, and social engagement, with each area having two separated positive/negative subscales. This opens the understanding of engagement constructs, as 1) the relationship is no longer only restricted between the stimulus and PWD as in traditional psychological research, but extends to interaction with social agents (e.g., social robots) or human partners; 2) each area of engagement was given a meaning of positive or negative nuance, which suggests a better understanding of positive engagement than the general impression that achieving engagement is better than no engagement at all.

More recently, Perugia et al. (2018) provided a systematic engagement study of PWD. She reviewed the state-of-the-art of engagement research and concluded that engagement is the "*positive quality of interaction between a person and an object (e.g., a game, an activity) or agent (e.g., a person, a social robot) which is influenced by the attributes of the person experiencing it, by the characteristic of the object/agent with which the person is involved in, and by the context where the interaction takes place.*" Engagement of PWD here is defined as "*a psychological state of enjoyment and proactive attentiveness experienced by a person with dementia involved in a meaningful activity*" (Perugia et al., 2020). More importantly, built on previous research, her work concludes three observable components as building blocks of engagement - Attention, Affect, and Time (investment/duration). It leaves aside elements influencing engagement (e.g., context, aesthetics, endurability, novelty, richness and control, reputation, trust, and expectation) but concentrates on engagement as a state. This provides a clear guide for developing measures for systemically assessing observable facets of engagement of PWD. As a result, a novel coding scheme - Ethnographic and Laban-Inspired Coding System of Engagement (ELICSE) was developed. In combination with two other assessment techniques - the measurement of electrodermal activity (EDA) and quantity of movement, a final engagement model of PWD - ENGAGE-DEM was built. The model provides a more comprehensive assessment of engagement that includes aspects of observed behaviors and physiological performance.

Although the development of up-to-date research in terms of engagement on PWD still indicates a lack of consistency regarding the concept constructs, our literature review reveals the progress achieved during decades of research. How we understand this notion regards context has evolved from simply occupying PWD with a certain stimulus like a fabric book or a plush toy, towards trying to provoke verbal and nonverbal behaviors through designed activities, then further involving social interactions in contextual designs. From understanding engagement merely from observed emotions to a more comprehensive understanding combined with emotional, behavioral, social, and physiological responses.

To summarize the findings on engagement for PWD that are relevant to the aim of the current study:

- The effectiveness evaluations of traditional activities – non-pharmacological interventions - were mainly based on the examination of the occurrence of BPSD. A small portion was based on the enhancement of PWD's psychological and emotional state – engagement of PWD.
- When engagement was mentioned in the context of dementia research, it often holds a positive meaning by default, that achieves engagement is better than without.
- Motivating self-initiated constructive engagement plays an important role in provoking more behavioral, emotional, and verbal expressions.
- Social engagement has a boosting factor in enhancing the engagement of PWD.
- Due to the challenges of assessing the engagement of PWD from the experiential dimension and peripheral dimension, most engagement assessment methods are based on behavioral dimension through observable behaviors instead of subjective or physiological data collection.
- Attention and Affect, expressed by either verbal/non-verbal behaviors, are the two essential components for constructing observable measures of the engagement of PWD.

Finally, **we propose our interpretation of engagement of PWD as:**

The psychological and cognitive state of a person with dementia being involved in an activity, including the extent of attentiveness directed towards the stimuli or agents; and the affective states with either a positive or negative nuance; that are reflected through time investment in the activity and mixed inward and outward emotional, behavioral, verbal, social, and physiological responses.

2.4.2 Multidisciplinary Approaches for Measuring the Impact of Design Solutions on PWD

In a typical design process, evaluations of designed prototypes, systems, and services are tested with potential users in an iterative process to refine the design towards a "better" solution. Such evaluations can be performed for gathering feedback, understanding, and empathizing with users to build more meaningful outcomes. They can also be adopted for measuring the impact on users, for instance design's effectiveness, usability, feasibility, or acceptability.

To address its function for gaining insights, evaluation with PWD poses additional challenges. As Pullin said, the most challenging thing of design comes from the inability to put ourselves in the shoes of users (Pullin & Newell, 2007). As designers commonly lack empathy, experience, and critical knowledge when designing for this "extra-ordinary" user group, recent research attempts to better involve individual of PWD and their living context within the design process. And the most commonly used techniques are participatory co-design approaches. Examples see (Tsekleves et al., 2018), (Wang et al., 2019), (Thoolen et al., 2020a), (Houben et al., 2020b), and (Hendriks et al., 2013). Other commonly used approaches, including design-led inquiry that uses designs as probes for gathering user responses, see the reference of (Wallace et al., 2013); contextual inquiry, see the reference of (van Gennip et al., 2017); contextual design, see the reference of (Thoolen et al., 2020b); design workshops, see the reference of (McNaney et al., 2017); and Living lab approach that involves not only the potential users but the context they live in, see the reference of (Brankaert, 2016).

Regards evaluative research, most of the design solution's impact on PWD was tested empirically through qualitative methods due to the uniqueness of individual conditions and efficacy considerations. Self-evaluating using interviews or questionnaires is mainly conducted with PWD of mild to moderate stages when self-reflections and language expressions are still relatively valid. For those in the advanced stages of the disease, similar testing is hardly applicable due to the decline of cognitive and emotional abilities. Consequentially, interviews, questionnaires, and scales were often completed by persons who are familiar with the users and observed their participation (i.e., caregivers or family members) (Anderiesen, 2017). Expert critiques from knowledgeable professionals (e.g., therapists) are also used for complementation, see (Welsh et al., 2018) for an example.

Although the qualitative evaluation process can provide valuable information, the unsolicited responses and informal feedback using

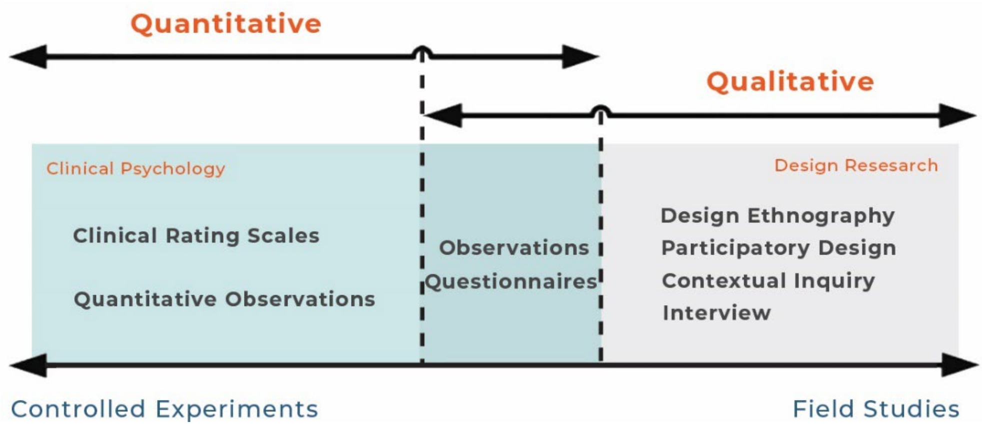

Figure 2.2 Mixed methods approach for measuring the impact of a design on PWD.

"interpretation" reflected through language quotations can sometimes be dismissed as "anecdotal" (Kenning et al., 2018). Moreover, previous work suggests there exist challenges in proving the quality of qualitative research and effectively reporting the findings in a robust and valid way (Twining et al., 2017). And this may further create barriers when introducing designed interventions into practical clinical use in facilities such as LTC. Thus, the knowledge acquired from multidisciplinary fields may be one answer that could be applied to enable a more rigorous evaluation process (Moyle et al., 2017a).

To conclude our review on how the impact of addressed meaningful activities was evaluated on PWD in the literature:

- The qualitative approach of evaluation with PWD performs very well in involving multi-stakeholders closely within the design process and addressing the personhood of individuals. However, the outcomes could be viewed as not "medical" enough for demonstrating to which extent it can benefit a whole group of users and generalization into clinical use.
- Although the methods and techniques based on observable facet of engagement were generally considered robust and valid, the evaluation does not address personal differences but view PWD as one homogeneous patient group.

Thus, in this research, based on the lessons learned, we attempt to combine the above two approaches to provide robust evidence-based findings. And both qualitative and quantitative data collection will be used at different stages during the iterative design process. Figure 2.2 illustrates the multidisciplinary approaches for measuring design's impact on PWD adopted in this research. This mixed method use during different stages of an iterative design process is reflected in detail in Part 3 – Investigations.

In particular, qualitative approaches, such as ethnographic observations, design-led inquiry, and field study with interviews, will be used for acquiring user needs, exploring design opportunities, and preliminary effectiveness study within the specific context of LTC. Experimental studies using quantitative approaches, including observational rating scales and quantitative observation through video analysis, will be used for reporting the effectiveness of design works.

2.5 Conclusion

In this chapter, we provide a literature review on three topics: challenges in engaging PWD in LTC, meaningful activities for engaging PWD, and the effectiveness measurement of meaningful activities on PWD, to help 1) to zoom our research focus to design and deploy innovative solutions as psychosocial activities for PWD; 2) to understand which activities to provide that are meaningful and engaging for PWD; 3) and to clarify our research methods.

First, we conducted a literature review to identify the reasons why it is so challenging to engage PWD in the context of LTC. Three major sources were identified: individual factors, contextual factors, and stimuli factors. Together, these three factors determine how user experience is shaped. As both the individual and contextual perspectives can hardly be addressed in design research and practice, we focus on the stimuli perspective and further conducted a literature review to understand the concept of "meaningful activities for PWD".

Second, based on the literature, two categorical activities were concluded: the "traditional activities" – a set of therapeutic interventions that were widely used in practical dementia care; and the "technology-empowered activities" which aim to provide technology-mediated activities for promoting psychosocial well-being of PWD. We have identified the gap for innovative design solutions in supporting the psychosocial needs of PWD in LTC, and gave a thorough and reflective review on existing design approaches with suggested trends and opportunities as foundations of future design explorations.

At last, to guide our design research, evaluation of meaningful activities is addressed using a thorough review of how the impact of these activities was measured with PWD in both fields of design research and traditional scientific research. Based on the reviews, we find that most clinical studies focus on quantifying behavioral responses, while design research focuses on qualitative evaluations. Thus, we proposed a combination of mixed approaches as a suitable way of assessing engagement to give a thorough understanding of how user engagement is impacted by designed activities as well as features of system design.

Chapter 3 | Context Explorations[8]

3.1 Introduction

The journey of design starts with close contact with real users. In order to design interactive systems that can meaningfully engage PWD living in the LTC environments, we conducted context explorations in the real-living environment of our target users. To complement the knowledge gained through literature reviews, we acquired knowledge through empirical practices in this chapter and see our roles as social researchers. Specifically, we aimed to learn how to design with and for PWD and related multi-stakeholders through collaborating with a specific LTC nursing facility for PWD located in Eindhoven, the Netherlands.

The main goal of this chapter is to find the answers to **RQ1.b:**

Which qualities interactive systems possess could potentially contribute to a meaningful activity design for PWD and multi-stakeholders living in the LTC context?

The **objectives** of this chapter are:

- To gain sensitivity of our target users - PWD and multi-stakeholders - within their real-living context and to gather a deeper understanding of the care practices with barriers and facilitators;
- To explore and further zoom design opportunities of the meaningful activity provision for PWD within their real-living context;
- To conclude qualities that could potentially contribute to the meaningfulness of designed activities within the specific context of LTC.

In this chapter, we first introduce our collaborator, where the research unfolds. Then, to gain the sensitivity of target users within their living context, three sub-studies were conducted to better understand practical challenges and current coping strategies. The findings and derived implications were summarized, which led to design knowledge and

[8] The work presented in this chapter was in collaboration with Ruud J.H.van Reijimersdal (RR) and Tengjia Zuo (TZ). In which, the interviews in Dutch and direct observations in field were done by RR; the guided tour and video-based observations were done by TZ and YF (the author); developing and testing of protypes were done by RR, TZ, and YF; data analysis was done by YF and RR.

opportunities for further investigations. Furthermore, to zoom the design opportunities of the provision of meaningful activities for PWD in LTC, we generated four design concepts and empirically tested them with residents and caregivers. The implications derived from these studies using four prototypes were then concluded as the answers to **RQ1.b**. At the end of this chapter, we present the concluded qualities that could potentially contribute to the meaningfulness of designed activities within the specific context of LTC.

3.2 Research Site - the Vitalis Residential Care Institute

Throughout the whole research, we work and collaborate closely with the Vitalis WoonZorg Groep care center that provides facilities and geriatric care for the elderly with and without dementia with the aim of "highest quality of life." We unfolded our research activities within a specific location named Vitalis Berckelhof, located in Eindhoven, the Netherlands see Figure 3.1 (a). This facility provides rental living facilities for the elderly community, daycare services, and an intensive residential care unit - Vitalis Kleinschalig Wonen, where inhabitants with a formal diagnosis of dementia are admitted to the LTC; see Figure 3.1 (b), (c), and (d). Hereinafter, we used the company brand "Vitalis" as an abbreviation of the specific environment of Vitalis Kleinschalig Wonen.

In Vitalis, around 30 residents with various stages and types of dementia are living in an enclosed environment. This facility has four departments, with each department a living room that connects to 6-8 private rooms. Residents have their meals and spend most of the day in the living room area, where two professional caregivers/nurses are equipped for supervising and conducting daily care. An activity room is located at the center of the space, where planned activities are organized by therapists and volunteers. Residents have free access to other areas within the environment, including two small gardens. However, they do not have free access to the outside of the facility without the company of caregivers or family members for safety concerns.

3.3 Sensitivity Gaining of Target Users within the Dynamic Care Context

3.3.1 Method

A series of field studies were conducted to gather in-depth information about the dynamic dementia care context with multi-stakeholders. Our explorations unfold in three sub-studies: 1) a tour of the Vitalis facility led

Figure 3.1. (a) Research site Vitalis Berckelhof, located in Eindhoven, the Netherlands. (b) Living room 1 of Vitalis Kleinschalig Wonen with residents sitting around the table. (c) A corner of living room 1 with home-like decorations. (d) The hallway leads to the living rooms 1, 2, and private rooms.

by a project coordinator (the project coordinator SA[9]) with open questions and observations. This was then followed by a semi-structured interview after the tour; 2) two types of observations of the residents, including video-recorded observations without an investigator present, and direct observations with observation notes taken throughout a typical day; and last, 3) semi- structured interviews with staff, including three caregivers and a second coordinator of the facility (IR[10]). All names and data were anonymized but used abbreviations of initials instead.

The first sub-study aims to gather general information regarding the physical and social environment, get to know the residents and caregivers working there, and policy strategies from a management level. The second sub-study attempts to learn residents' daily routines and get rich insights

[9] We used the initial of a coordinator's names here to distinguish two coordinators who participated in our studies.

[10] We used the initial of another coordinator's name here to distinguish two coordinators who participated in our studies.

into their daily lives, activities, and social interactions. And the third sub-study strives to acquire opinions from the staff's point of view to reveal care barriers, challenges, and efficient coping strategies. Taken together, we endeavor to discover potential concepts that can be further developed into physical prototypes to test with PWD.

Next, we describe the research goals and techniques adopted for each of three sub-studies with data analysis methods that lead to the final emerged themes of findings.

Sub-study 1: Knowing the Physical-social Environment and Multi-stakeholders of Vitalis

Sub-study 1 addresses the overall care situation through a context inquiry within the actual living environment with a tour guide (SA), residents, and caregivers on-site. The contextual inquiry aims to observe and gather data of a small sample of users in their natural environment while conducting their activities as they normally would. During the 30 minutes tour, all four departments with residents and their primary caregivers were visited. And we were able to communicate with residents and caregivers freely with informal questions. The most crucial findings from the valuable guided tour with an intensive introduction provided by the coordinator were: the general care policymaking, the challenges faced by the small-scale home-like dementia care, the function of each place, potential personnel involved, job descriptions of caregivers, and approaches for engaging residents during daily lives (e.g., design solutions implemented and care approaches). Given permissions, the tour was audio-recorded and typed into transcripts for further analysis according to the six stages of thematic analysis described as in (Braun & Clarke, 2006). The tour was conducted in English with the necessary translation of communications by the coordinator SA.

Sub-study 2: Observations of the Typical Daily Routine of Residents in Vitalis

Sub-study 2 comprises two field observations in different living rooms of Vitalis as small-scale samples for learning about residents' daily lives. Two different observational techniques were adopted: a video-based observation and a direct observation on-site with notes taken. The ethical procedures were undergone prior to the observations with informed consent and permission of the facility board. The observation using video recordings allows events to unfold and be recorded in a natural way in everyday settings without investigators' interference. We set a digital camera at the corner of a living room to record daily events to see potential problems they encounter. The video observation took place from 14:00 to 17:00 and lasted for 3 hours between their lunch and dinner mealtime. During the observation, the members of observed residents (all female) ranged from 3 to 5. The investigator reviewed the video and performed the video coding analysis afterward. The video analysis focused on activities they participated in and the challenging behaviors that were shown. In another living room, a Dutch observer (RR) conducted direct observation with 7 residents (5 female and 2 male) from 9:00 to 17:00 for their typical daily routine. Different from the video-based observation approach that without the interference from the observers, RR actively engaged in daily activities (e.g., reading newspapers) to prompt conversations with open questions. The notes taken during observations by RR were translated from Dutch to English, and then analyzed using general coding procedures for qualitative data (Corbin & Strauss, 2008).

Sub-study 3: Gathering Opinions from Staff's Point of View

Sub-studies 1 and 2 have focused on residents themselves. In sub-study 3, we gathered opinions from the staff's point of view for a deeper understanding of the difficulties and coping strategies in care practice and approaches that work for PWD. We did a focus group interview with three caregivers (all female) during their lunch break and a separate semi-structured interview with a coordinator IR (female) to learn more about activity arrangements within Vitalis. For better expressions of their opinions, the interviews were conducted in Dutch. All the interviews were audio-recorded, translated, then analyzed using a thematic analysis framework (Braun & Clarke, 2006).

3.3.2 Findings

The three sub-studies collected a range of data. The following presents the primary themes that emerged from the findings of our qualitative data analysis. Quotations from interviews and observation notes were used as examples.

The Inhibiting Factors – Challenges and Barriers

One of the goals for conducting the in-depth interviews and observations was to discover potential problems encountered during care practices, as what we called inhibiting factors within the dementia care context of Vitalis. Here, we describe the emerged 8 inhibiting factors of challenges and barriers from both perspectives of staff and residents. See Table 3.1.

Four inhibiting factors from the staff's point of view. In line with literature reviews, the primary inhibiting factor identified from the staff's point of view is the Lack of Personnel to perform care tasks due to various practical reasons. In addition to the knowledge of current barriers in literature (presented in section 2.3.1), such as low staff-client ratio, we found another practical reason for reduced quality of care: the mixed staff team composed of full-time nurses, "flex workers," and volunteers. The hire of part-time flex workers resulted in inadequate communication among team members regarding the care strategy of a particular client. And this can further lead to a chain effect of reduced quality of care due to the inability to perform care activities using consistent strategies and address familiar topics during communication.

The following identified inhibiting factor is the Overloaded Work due to the repetitive care activities and multi-tasking in care. The findings of the complexity of care activities are in line with the literature review presented in section 2.2. Besides the burden of the repetitive nature of the dementia care, the staff also need to cope with other activities that are beyond daily care (such as fixing wash dishes, filing reports) which has been encapsulated using characters of "Flux" (constant change happening within the care facility) and "Ambiguity" (uncertainty of coping strategies) as in (Cammer et al., 2014). This inhibiting factor informs us that activity provision for engaging PWD should consider not resulting in more variations but coordinating with their routine in daily care practices for staff.

Moreover, the studies also revealed Difficulties in Managing Challenging Behaviors (as the third inhibiting factor). Besides commonly reported challenging behaviors (e.g., drastic change of mood and behaviors, aggregation, restless behaviors, and wandering and searching) confirmed by literature reports (James, 2011) and (Cohen-Mansfield & Perach, 2015), two particular challenges - sundowning phenomenon and escaping behaviors that need special attention and proper coping strategies were mentioned. The sundowning phenomenon describes an increase in confusion and restlessness associated with the fading of natural sunlight. During our observations, we noticed that residents were getting confused about the reality of living in a residential care home, which further led to behaviors like trying to escape and asking to go "home." The current coping strategy for this matter is to limit the free access with a password and cover the entrance door with printed nature images to look like a wall.

The last identified factor is the Difficulties in Enabling Personalized Social Interactions between caregivers and residents. The findings show that caregivers lack effective ways to enable social interactions, especially for

Table 3.1 The 8 inhibiting factors derived from reported challenges and barriers from both perspectives of staff and residents.

Inhibiting Factors	Specific Challenges	Exemplar Quotations
4 identified factors from staff's point of view		
1 Short of Personnel	Low staff-client ratio	*"Compared to ten years ago which 26 staff were hired, the staff-clients ratio of the facility keeps dropping down to 16 nurses on 4 departments now."* *"We do not have any time for the inhabitants anymore. In the past, we had a lot of nurses to take care of the people, and there was always one 'host' (gastvrouw) staying in the living room to just be there and to talk with them, and that is gone."*
	A mixed staff team	*"A lot of them are 'flex workers' because Vitalis cannot offer them a steady contract…however, they are not familiar with them (residents) and it is even more difficult for the people…"* *"We cannot share private information including medical treatments with all the volunteers."*
2 Overloaded Work	Burden of repetitive care activities	*"Many people need extra care, for example incontinent. In the past we could have gone to the toilet directly, now, because we are with too few people, they have to wait until we have time to change… It takes at least 30-45 minutes to help one client. So that is the time you will leave them alone in the living room again. Sometimes it takes 3 people to help one client. There are 9 people who are in need of help. This is why we don't have time to be in the living room."*
	Multi-tasking in care	*"There are always things that are breaking down, so we have to fix this ourselves…if someone brings new clothes, we have to label tag them (with residents' names). And the clean towel delivery is already late, be we need the cart for the dirty clothes, so we need to arrange a new cart. That is not easy if you have to continuously take care of elderly with dementia."*
3 Difficulties in Managing Challenging Behaviors of Residents	Drastic change of behaviors and mood	*"The mood of PWD can differ very fast, that is also what makes it hard. You never know how it is going to be, one moment someone is having a tantrum and is super aggressive, 5-10 minutes later the same person can be very happy."*
	Aggregation	*"Aggregation is a big problem in care."*
	Restless behaviors	*"People can become very restless, but you can never know what exactly is causing this. They become restless from too many stimuli and restless from too little stimuli."*
	Wandering and searching	*"They wander a lot. We do not usually do much about it, as they are in need of physical exercise. Unless they*

		walk too much and endanger themselves."
	Sundowning phenomenon	*"Before dinner time, some of them become very emotional and ask to go home. You need to reassure them constantly and respond in their reality."*
	Escaping behaviors	*"…if someone starts to walk you will know he/she is looking to escape…. It is easy to understand why they feel 'locked'."*
4 Difficulties in Enabling Personalized Social Interactions	Limitations in building personal relationship with residents	*"For a nurse, not one day is the same, and you learn new things every day about the people."* *"In general, the stage of dementia is already severed according to the late arrival. This takes away the opportunity (for the caregivers) to get familiar with the clients and therefore makes it hard to operate according to responsible communication."*
4 identified factors from residents' point of view		
1 Disengaged and Inactive Living Situation	Not engaged in any form of activities for most of the time	*"They are just waiting all day to get food and go to bed again. All they do is waiting."* *"While they are sitting, they are staring in front of them, in the direction of the table, to their hands, to the walls, or to each other."*
	Un-addressed attention seeking needs	*"If there is someone is in the living room, they are in general quiet and calm because they get attention, and there is someone who listens and who talks to them."*
2 Lack of Inner Motivation in Care, Leisure, and Social Engagement	Wait for care	*"They are used to letting the nurse do all the work. They do not even do things that they are still capable of, like get a coffee for themselves, but wait for care."*
	Little initiative in participation of activities	*"For many of them, the game stops at arm lengths."*
	Resistant towards interaction with peer residents	*"Some of them (refers to residents) are very close, most do not talk to others much."*
3 Limited Close-tie Relationships	Lack of family bonding experiences	*"A lot of families just drop in, say 'hi' and leave."* *"Family members all react differently. They find it painful when they are not recognized anymore."*
4 Limited Physical Exercise and Access to Outdoor Environment	Lack of physical activities and access to outdoor	*"They do not feel the temperature like we do…they could get cold or fall, that is why we do not usually open the access to gardens unless someone is there for them."*

PWD with severe cognitive impairment. Building a personal relationship with an individual with dementia needs a long process of getting familiar with each other. Therefore, techniques and mediums are required for facilitating social interactions between each other.

Four inhibiting factors from the residents' point of view. Based on the observations, we identified the first major inhibiting factor - the Disengaged and Inactive Living Situation. As the main motivation for this research, disengagement and inactivity have been intensively reported in the literature and were regarded as the major resources for preventing the quality of life of PWD in LTC. Our observations confirmed that although the facility provided well-structured activities organized by therapists and volunteers, residents were unengaged for most of the day. We created an illustration to demonstrate the typical daily schedule for residents in Vitalis, see Figure 3.2. Their daily routine remains mainly the same for most residents. For a large part of the daytime, residents are sitting beside the table in the living room with nothing to do but wait. Examples of other provided materials for potential engagement in leisure activities in the living room are puzzles, newspapers and magazines, radio for music, and television for TV programs. These activities are often ignored by the residents or lack use as they may not be compatible with residents' interests and remaining abilities. The consequential unaddressed attention-seeking needs can lead to the prevalence of restless behaviors or more severe conflicts among residents, which increases the burden of care due to the need to reassure and comfort the clients. In addition, the structured activities offered by Vitalis usually took place in the morning of every Monday (i.e., the praying activity) and the afternoons of one and another day (most activities last about one hour). Thus, we could arrange further research and studies during non-planned activity times based on knowledge of residents' schedules.

As another causation for disengagement of PWD, the second inhibiting factor was summarized as Lack of Inner Motivation in Care, Leisure, and Social Engagement. Our inquiries and observations confirmed with our literature research (discussed in section 2.2 regarding the Individual Factors) that residents showed little initiative in engaging in activities by themselves, participating in care activities with a compliant attitude, and resisting social interaction with peers. Therefore, promoting intrinsic motivations for activity participation and social interactions of PWD should be addressed in our further studies.

The studies also revealed the third factor - Limited Close-tie Relationships. Bonding with close-tie relationships is suggested to be crucial for maximizing positive affect and conserving the energy of limited personal

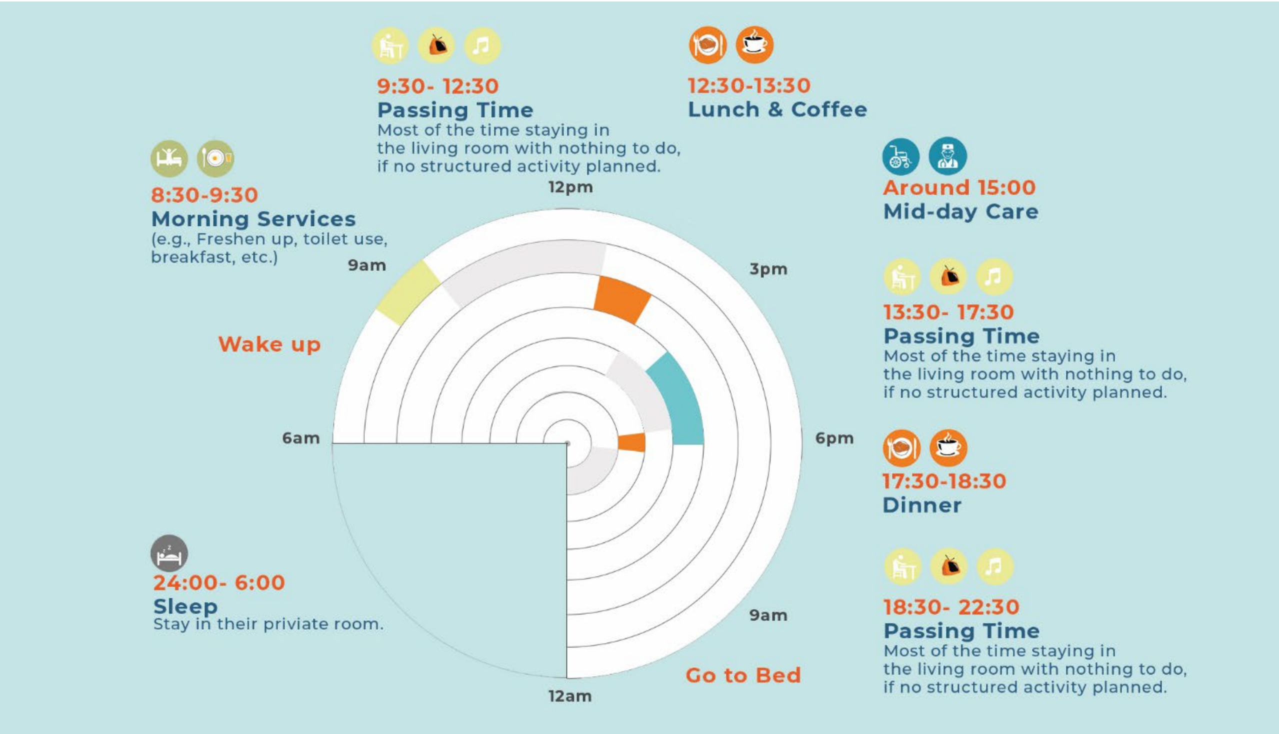

Figure 3.2 An illustration of a typical day of a resident with dementia living in Vitalis.

and psychological resources for PWD. And residents living in an LTC environment generally lack quality social engagement with people who are close-tie relationships with residents (e.g., families, partners, or close friends). Therefore, close-tie family members need suitable mediums to prompt social interactions and facilitate communications.

The last factor identified is the Limited Physical Exercise and Access to Outdoor Environments. Due to safety concerns and mobility issues, PWD has limited opportunities for outdoor activities in most care facilities. Physical inactivity of the elderly can result in muscle weakness which further increases the risks of falls. They can also lead to circulation problems which explains why the majority of residents during observation were with “cold hands”. Future designs could curate opportunities for the encouragement of appropriate physical exercises to maintain their functional abilities.

The Enabling Factors - Coping Strategies of Staff in Practical Care

During interviews, the caregivers and coordinators shared many coping strategies for improving the quality of care based on their personal experiences. These strategies are used to build personal connections with residents, provide motivations to engage in care and social activities, and calm, comfort, or stimulate clients as needed. We name these strategies the enabling factors within the care context. See Table 3.2.

The first identified factor is “Optimism and Empathy”, a general attitude expressed by staff and influenced by the care culture of Vitalis. This strategy addresses the person-centered care approach that emphasizes knowing the person, not just the disease of dementia. In particular, it describes the use of cheerful and encouraging languages, being enthusiastic when providing care activities, and showing sufficient empathy for residents’ conditions to motivate residents to better engage in care.

The following three strategies, including “Addressing Familiar Topics”, “Communicating in Short Sentences”, and “Confirmation of Reality”, are adopted to help facilitate effective verbal communications and engage residents in care and social activities. Addressing Familiar Topics advocates using conversational content that promotes familiar topics related to longer-term memories rather than short-term ones to avoid interpersonal frustration. The second - Communicating in Short Sentences - proposes the use of short sentences to lower cognitive needs and language barriers. Moreover, by phrasing the sentences with a potential yes or no answer, PWD is encouraged to express themselves better. Confirmation of Reality refers to a validation technique used by staff to reassure residents who are struggling to make sense of their surroundings by constantly giving confirmations to their perception of reality to help them thrive.

The fifth is a specific strategy that staff use in dementia care practices - “Touch”. Touch is a crucial gesture in care provision that can build rapport in relationships and help with message delivery and mutual understanding in communication. It can also soothe and calm PWD to deal with psychological distress such as anxiety. Receiving and giving touch in appropriate ways is particularly important for residents with more advanced stages of dementia. This sensual experience is often ignored in the LTC environment and might be the only sense that has not been lost.

The following two strategies – “Attention” and “Comfort” - focus on managing potential challenging behaviors by fulfilling individual attention-seeking needs and providing support, security, and reassurance. The first one focuses on providing interpersonal attention to individuals to occupy them proactively. At the same time, the latter is often used to reassure and comfort residents to de-escalate situations when they become restless or agitated.

Table 3.2 The 9 identified enabling factors within the context of Vitalis facility for PWD which describes the reported coping strategies that staff used for promoting quality of care.

Enabling Factors	Coping Strategies	Exemplar Quotations
1 Optimism and Empathy	Motivate residents to better engage in care activities by using optimism attitude, showing enthusiasm in care activities, and empathizing with their conditions.	*"We talk to each other in a higher pitch, well you know… They love the cheerful tone."* *"You bring them the energy, and laugh, so they laugh as well."*
2 Addressing Familiar Topics	Address topics that are familiar and avoid the use of short-term memories.	*"You talk to them using right questions… You do not ask them how they liked their family visit days ago. But something you know they will remember."*
3 Communicating in Short Sentences	Promote the use of short sentences with an answer of "yes or no."	*"You see what I did there? The short sentences really help with the communications."* *"We also use questions with the answer of yes and no, so they can engage in the conversation."*
4 Confirmation of Reality	Provide confirmation to their perception of reality.	*"When they speak, they are waiting for confirmation of the reality."*
5 Touch	Promote the use of touching in dementia care.	*"Touch is very important. When talking is no longer working, we take their hand. You could see that your message really 'reaches' them."* *"Feeling (touch) works very well for them. To feel is not only asking attention but letting you know that you are there."*
6 Attention	Provide personal attention to the individual.	*"They just need someone that gives them attention and say something back… Attention is the inner peace for them."*
7 Comfort	Soothing, calming, and reassuring to provide a feeling of security.	*"You notice that they get very busy when they receive too many stimuli. Then you need to calm them down, otherwise, they will take over."*
8 Go-along	Respond in individual's reality.	*"You need to go along with their experiences, respond in their reality. No one likes being told wrong all the time."*
9 Respect	Respect individuals with dignity and value personal opinions.	*"You always treat them like adult elderly people. No childish tone. Introduce your intention, ask for permission, and be polite."*

The following strategy is “Go-along”, which describes responding to residents’ realities and go-along with their conversations. There have been controversies about using this strategy due to its overlooking of reality. In practice, caregivers often use it to calm residents and avoid potential conflicts.

The last and most important one is “Respect.” Valuing PWD with respect and dignity is essential to fostering a positive interpersonal relationship between staff and residents. And a loss of dignity when performing care can lead to agitated behaviors or resistance to care. In practice, caregivers deliver dignifying care by paying attention to small details, such as asking for PWD’s opinions on what to eat and wear.

3.3.3 Concluding Remarks

The qualitative research journey aimed at gaining the sensitivity of target users within their real-life living context has generated key findings. These findings were summarized using the 8 inhibiting factors and 9 enabling factors. The inhibiting factors concluded the main challenges encountered from both the client-based perspectives and the staff’s point of view. And the enabling factors were summarized based on the staff’s care practices. Next, we discuss these findings in terms of what is already known in the literature and what our findings add.

Overall, the 8 inhibiting factors, in line with our previous literature reviews presented in chapter 2, confirmed an unsatisfied living situation resulting from the heavy burden of care from the staff’s side and the lack of meaningful engagement from the residents’ side.

From the perspective of staff, the practical challenges regarding care provisions, such as short of personnel and overloaded work, have been well documented in the literature. Moreover, heavy effort of discussion for promoting care qualities has been given to mitigating challenging behaviors of PWD and promoting staff-client relationship building. Also, the work of Karrer et al. (2020) concluded six staff-related factors that influence the effectiveness of intervention delivery, including team cultures; knowledge, experience and skills of staff; motivation and energy of staff; degree and clarity of responsibilities; degree of familiarity with the intervention; and focus of care. Our findings add to existing studies by showing that the personnel composition of the care staff team and insufficient exchange of information within the team could also negatively influence the staff-resident relationships and care qualities for PWD. Furthermore, as we already know that maintaining a routine of care provision and consistency of care strategies can be crucial for the quality of care for individuals, our findings indicate that such stability can also benefit staff. Thus, future activity design for PWD should consider the quality of stability of activity provision so that it is manageable by staff in practice. And the facilitation of activities should try not to interfere with or further complicate the care provision.

From the residents' perspective, the inhibiting factors confirmed the identified barriers reported in chapter 2. Specifically, the residents demonstrated unmet psychosocial needs within the environment of LTC; residents showed little initiative in participating in care, leisure, and social activities; the effectiveness of activity (whether for care or other purposes) is highly dependent on the quality of facilitation; and existing solutions implemented in Vitalis are not sufficient to address the needs for leisure and social purposes from a community-based level. Also, the state-of-the-art illustrates a considerable demand for meaningful activity provision targeting the psychosocial needs of PWD within LTC, especially for residents with advanced stages of dementia. Our findings build on the above, emphasizing the importance of proactive participation in changing the "wait for care" situation. Thus, future design should attempt to curate initiatives from PWD and motivate proactive activity participation. In addition, while the literature addresses the activity provision targeting effective social interaction, our findings show the importance of leaving space and opportunities for enabling personalized social interactions with close-tie relationships.

Meanwhile, the 9 enabling factors acknowledged that the appropriate attitude and effective communication of staff is crucial for providing quality care. Moreover, they provide great examples for demonstrating which approaches can be beneficial and how researchers could work and communicate better with PWD to motivate initiation and engagement in future.

These findings revealed a loop from the disengaged and inactive living situation of PWD to the display of challenging behaviors, from the difficulties when handling these challenging behaviors to reduced quality of care, and eventually from unable to provide high standard care quality to diminished quality of life of residents in LTC. Thus, the current situation calls for innovative approaches that can break the unfortunate loop. The findings give hits of possible design opportunities that can occupy PWD's attention; soothing, comforting, and reassuring PWD; promoting interests and motivations of engagement in care, leisure, physical exercise, and social activities; and addressing aspects of human existence such as the feeling of security, autonomy, and dignity.

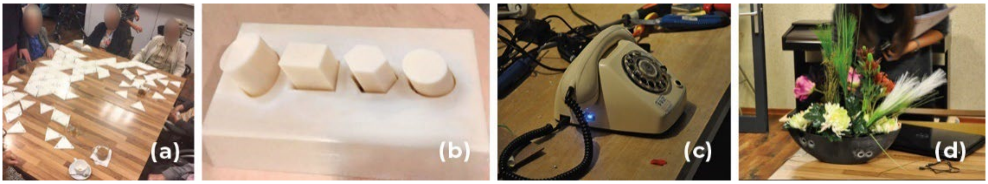

Figure 3.3 Prototypes developed for contextual inquiries with residents and caregivers living in Vitalis. (a) Prototype of the 2D-puzzle; (b) Prototypes of the 3D- and 4D-tangible puzzles; (c) Prototype of the reminiscence phone; (d) Prototype of the interactive flower bouquet.

3.4 Empirical Studies

To find out which qualities make the design of an interactive system meaningful for PWD within the specific context of LTC environments, we developed four prototypes and tested them with residents and caregivers of Vitalis. In the following, we present the design considerations, prototype building, and insights gathered through evaluative studies in a real-life living environment.

3.4.1 Tangible Puzzle - A Leisure Activity through Touch Manipulations

Design considerations. To provide leisure activity that can stimulate PWD to address inactivity and disengagement, we developed a set of three puzzle games using auditory and tactile senses. A puzzle is a common game in care facilities for stimulating cognitive abilities and leisure purposes. Inspired by the crucial role of sound and music in dementia care (Wesselink et al., 2020), we added sound effects to one of the puzzle games as a rewarding effect. The explorative play experiences within the arm-reach length were expected to motivate interests, promote the moderate physical exercise of arms and hands, and provide sensory stimulations.

Prototypes. Three types of puzzles were prototyped, including the 2D-Puzzle, 3D-Puzzle, and 4D-Puzzle. The 2D-Puzzle is similar to a standard puzzle game and is played by matching the shapes, see Figure 3.3 (a). The 3D-Puzzle, with the appearance of tangible bricks, is played by matching the shape of the brick with the hole cut in its base to enable touch manipulations, see Figure 3.3 (b). 4D-Puzzle is built based on the 3D-Puzzle and enhanced using sound effects. When the connection is correct, a short piece of music will start to play. See also Figure 3.3 (b). The prototypes of puzzles were made using 3d printing and programming using Arduino.

Insights. Prototypes were tested with 7 residents within a living room of Vitalis with two caregivers at present. Overall, the residents found the 2D-

Puzzle too difficult and with too many pieces. The spread pieces did not successfully facilitate collaborative play as we expected. At the same time, the 3D-Puzzle was with too few pieces (four different shapes), therefore, too easy for participants, and they quickly got bored with it. Besides, residents showed different responses towards the 4D-Puzzle. Some found the music cheerful and started to sing along with the music when it played. However, two other ladies found it childish and annoying. The caregiver also commented, "It will also be a problem that some of them will keep pieces of things that do not belong to themselves." The takeaway insights from this study are: 1) the play experience of cognitive games should be designed to match individual abilities to be able to have positive effects on PWD; 2) when designing with sensory materials such as music, individual sensory preferences need to be taken into consideration.

3.4.2 Reminiscence Phone – A Voice Message from Family for Addressing Sundowning Effect

Design considerations. The second prototype attempted to address the communication needs of PWD with their close-tie relationships, such as family members, to maintain their social skills, regain self-identity, and provide positive emotional experiences. During the interviews, we learned that residents would easily get anxious and emotional and ask to go home to their families during the time around sundowning of a day. Inspired by this phenomenon, we designed an artificial phone call experience with the function of an answering machine that records and plays voice messages between residents and their loved ones. The design was also expected to calm and reassure the residents during their high behavioral time of the day.

Prototypes. We named the phone - *Reminiscence Phone* due to two reasons. First, we used a nostalgia old phone and modified it into the prototype; second, the voice messages were supposed to trigger the reminiscence of happy memories that PWD spent with family members. The phone was designed to send and receive voice messages to/from their family members. We have recorded voice messages from the daughter of a lady living in Vitalis and used the messages as materials for testing. The prototype was implemented by adding a Bluetooth speaker to the phone receiver and programming using Arduino, see Figure 3.3 (c).

Insights. We tested the prototype with the lady whose daughter recorded the voice messages to see how she responded to the familiar voice. This specific user was chosen due to her frequent showing of anxiety and sad emotions during sundowning. The test was performed in the afternoon.

After consulting with the caregivers, we brought the prototype to the lady and asked her to pick up the phone, as her daughter had "left her a message." We observed a noticeable lift of mood when she recognized that this was her daughter's voice. However, despite the positive effect with the lady, this experience is very personalized and does not work every time. To quote one caregiver's comments: "They could feel even more anxious after receiving the phone call." Furthermore, "There is only one lady living in Vitalis that we can ensure she can recognize her family member's voice and know how to use telephone correctly." We learned from this inquiry that: 1) for this experience to work towards a positive influence, residents need to be able to recognize the voice from loved ones, which is beyond the abilities of the majority; 2) such bonding experience with a family member are very personalized and depends on their mood at that moment of a day. Further design should avoid the use of materials that could potentially lead to negative influences such as further confusion or extreme emotions.

3.4.3 The Interactive Flower Bouquet - A Center Piece on the Table for Attention Occupation

Design considerations. The third prototype aimed to address the attention-seeking needs and provide occupation of attention to reduce the reliance of caregivers and further influence on challenging behaviors. During our observations, we found that residents spent most of the time sitting beside the table in living rooms, and their conversations were highly concentrated on appreciation of the flower as a centerpiece of the table. This inspired the design of an interactive flower bouquet for drawing attention and facilitating potential discussions among residents.

Prototypes. We created a bouquet as a decoration of the table using artificial flower materials, see Figure 3.3 (d). The bouquet is interactive as some of the flowers were controlled by actuators and programmed to bend to resemble a dancing move. The vase was equipped with ultrasound sensors so it could sense if anything was approaching. Besides, it was also designed to show initiative when no one was interacting, and the flowers would also "dance" to draw attention.

Insights. We brought the prototype to a group of 7 residents within a living room of Vitalis with a caregiver at present. In general, the attention of residents sitting around the table could be successfully drawn by the flower bouquet. Some participants found it intriguing that the flower could move and gave a smile when they did. However, the findings also suggested that the interaction did not make any sense to them. Even when we introduced that waving to the flowers would trigger them to dance, none of them tried to interact with the flowers. The reflection of the failure suggests the interaction design for PWD should consider its connection with real-life experiences, and using gestures in the air may not be the best way for this group of users.

To summarize the insights derived from testing the proposed three design opportunities in real-life practice (3.4.1-3.4.3), we present the following implications **(i1-i3)**:

i1. Learned from the prototype - Tangible Puzzle, that when designing psychosocial activities, the challenges of the provided stimuli should match individual abilities and preferences to generate a positive impact on users. Thus, we proposed that sensory engagement could be a pathway to engage a community of users with dementia with various personal conditions.

i2. Learned from the second prototype – Reminiscence Phone, that designer needs to carefully consider the material used for emotional experiences to avoid the risk of negative influences such as extreme emotions. The customized design materials for reminiscence could be extended to the shared experiences of a community of residents living in Vitalis.

i3. Learn from the third prototype – the Interactive Flower Bouquet, that interaction design for PWD should consider its connection with real-life experiences. It should fit certain logic and be able to refer to their previous living experience to promote intuitive interaction.

3.4.4 *Dynamorph* – An Interactive Table Design for Collective Play Experiences[11]

Based on the above lessons, the fourth prototype of an interactive table design – *Dynamorph*, was developed to engage users in an explorative play experience through sensational touch that was often ignored by LTC facilities, see Figure 3.4. A table was adopted as PWD spend most of a day sitting around one so the interaction with the proposed design would not

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[11] **This study is largely based on**
1. Feng, Y., van Reijmersdal, R., Yu, S., Rauterberg, G. W. M., Hu, J. & Barakova, E. I. (2018) Dynamorph: Montessori inspired design for seniors with dementia living in long-term care facilities. In Proceedings of 9th International Conference on Intelligent Technologies for Interactive Entertainment, INTETAIN 2017. Springer Netherlands, LNICST; vol. 215, p. 49-58 10 p.
2. Feng, Y., van Reijmersdal, R. J. H., Yu, S., Hu, J., Rauterberg, G. W. M. & Barakova, E. I. (2017) Using observational engagement assessment method VC-IOE for evaluating an interactive table designed for seniors with dementia. In Proceedings of International Conference on Smart Health, ICSH 2017, Springer, vol. 10347, p. 26-37 12 p.

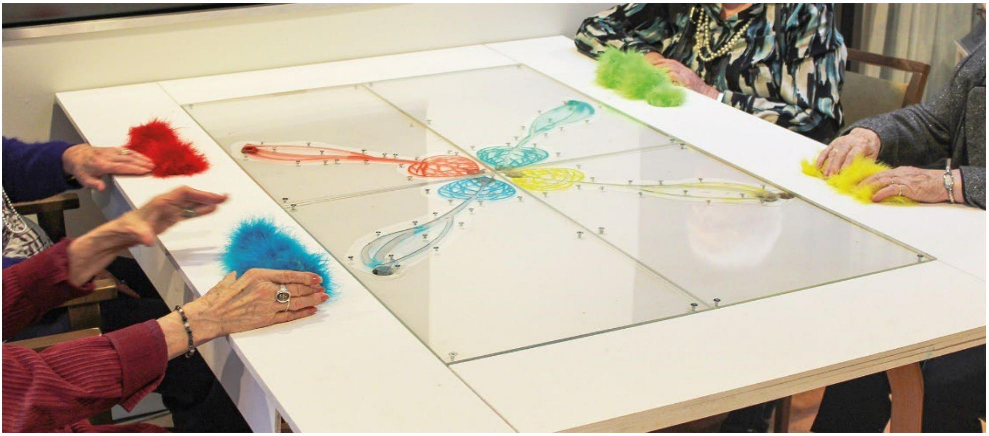

Figure 3.4 The *Dynamorph* interactive table design with four seniors with dementia from Vitalis interacting with it.

interfere with their daily routines. The table was designed to engage users in playful tactile interactions that were similar to petting an animal. It also aimed to promote proactive play, support self-exploring and a sense of autonomy with minimal facilitation requirements of caregivers. We extended the individual participation of previous prototypes to a small group of users to facilitate social interactions among residents. Moreover, this explorative study attempted to address unfolding evaluative research of a designed activity within the context of LTC through combined qualitative and quantitative data collection.

Design Considerations

Montessori approach for encouraging self-exploration. The "Montessori Method" was originally developed by Maria Montessori to teach cognitive, social, and functional skills to children (Montessori, 2004). The core spirit of Montessori is for children to explore how to engage in the activity by themselves in order to generate and magnify the corresponding rewarding effects. The same principle can be applied to PWD. Inspired by the Montessori method and developed Montessori-based activities for PWD, we proposed the idea of having a levelled interaction framework that breaks the whole interaction into steps and processes, from simple to complex, from concrete to abstract, where users can achieve the results by self-exploring, and control the interaction level with freedom, in order to fulfil different user conditions and a wider range of needs (Sheppard et al., 2016). See reference (Feng et al., 2018a) for the levelled interaction framework that was implemented in the design of *Dynamorph*.

Sensory engagement for maintaining PWD' abilities. Users with dementia, without reliance on logic, reasoning, or short-term memory, rely on their senses alone. Numerous research and design cases addressed that sensory stimulation plays an essential role in the well-being of PWD (Strøm et al., 2016). Engagement in sensational experiences can also help maintain cognitive and sensory abilities. There is one famous saying in dementia care as: "*Use it or lose it*." And this is supported by related neurology studies that the somatosensory area of the brain is shaped by the quantity and quality of the sensory messages received from different areas of the body (Tanner, 2017). When no sensory message is received, there is nothing for this area of the brain to process. And this will further lead to the loss of the neural connections essential to processing these sensory messages. Thus, the provision of proper sensory stimulation can help maintain abilities to a certain extent and therefore promote the quality of life of PWD.

Tactile exploration for addressing needs of touch in dementia care. Tactile experiences are particularly important for PWD, especially for those living in residential care homes. Touch is a bodily experience and a non-verbal form of communication. It helps us shape how we feel, keep us busy and occupied, gain a sense of control, and be safe and secure. During observations of residents in Vitalis, we noticed that residents sometimes naturally gravitate towards tactile stimulation by exploring the fabric of their clothing or the smoothness of the table in front of them. The cognitive impairment can alter one's experience of touch, not by changing the actual sensory experience, as holding hands should still be felt like holding hands, but the meaning of touch may be misinterpreted. As someone's perception changes, they can become more discriminating in giving and receiving touch, consequently leaving them in a desperate situation of needing touch. Literature also confirmed a lack of touch in dementia care enabled through human care and activities (Tanner, 2017). Thus, the design focuses on addressing this ignored emotional need for touch by providing rich and playful tactile interactions.

A table design for promoting social connectedness. The design is integrated into a table as it is one of the most common objects used in the residential care context. The table itself is already a physical connecting object since the person sitting around often forms a sense of connectedness. Objects placed on the table are likely to be seen, touched, or naturally initiate conversations. Furthermore, as the designed tangible manipulatives were embedded in a table, it saves the staff's effort to organize the activities, or even simply placing, collecting, or passing around the stimuli, therefore requiring little effort from care staff and reducing the risk of lack of use.

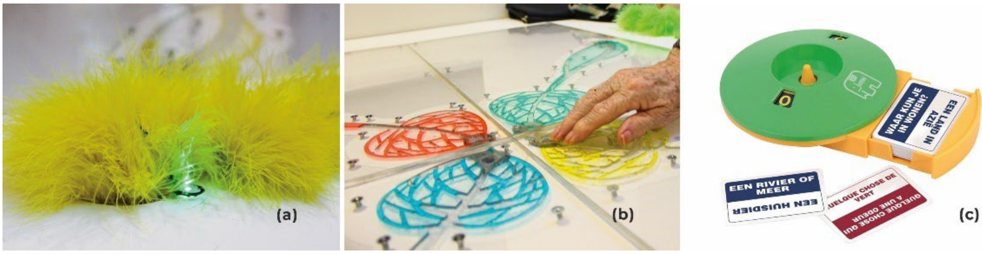

Figure 3.5 (a) Zoomorphic shapes of *Dynamorph* consisting of three separate feather balls were embedded on the table with a pulse sensory near them. (b) The leaf shape patterns of *Dynamorph* positioning in the center of the table with colored liquid inside. (c) The game Pim Pam Pet (PPP) adopted as a control activity for comparison study.

Design of Dynamorph

Dynamorph is an interactive table with tangible interfaces for activation of the play experience of PWD. The design consists of two essential elements: four zoomorphic shapes placing two on each long side of the table and four symmetric leaf shape patterns embedded in the center of the table. The table design can support at most four users interacting simultaneously, with each user having one zoomorphic shape and a hollowed route link to the center leaf shape pattern filled with colored liquid. Their daily sitting habits form the positioning of the zoomorphic shapes. The name of the design indicates the meaning of dynamic and morphing, as the design gives an implicit transformation of dynamic interactive behaviors into morphing shape interfaces by detecting the heart rate of users.

Design of zoomorphic shapes. Each zoomorphic shape consists of three individual feather balls made of attractive, vibrant colored goose down with a soft sponge core inside, see Figure 3.5 (a). The size of the core is designed to ensure comfortable grasping so that the seniors can squeeze and hold these artifacts, and the down offers a cheerful appearance, invites touch, and adds some animal fur feeling to it. Three feather balls are controlled by mechanics underneath the table separately so that together they can be programmed to mimic animal-like movements and respond to user gestures.

Animal-like feedback of tangible interaction. The zoomorphic shapes were designed to behave like animals to motivate user interests through something playful, surprising, and new. For instance, when they are moving up and down gradually, they may appear like pulsing or alive and breathing in the perception of users. The conductive wires hidden in the feather are programmed for sensing different ways of contact, combining with force sensing to distinguish possible gestures. Different gestural interactions are defined so that the ball set can respond correspondingly to provide an animal-like character. For example, when no engagement happens with the ball sets, they will show a provoking reaction popping out the table surface now and then and acting like a curious and shy animal. When positively engaged, such as stroking, holding, handling, or petting the feather balls, they will mimic a breath pattern by slowly moving. And when negatively engaged, such as slapping or hitting, they will react, hide, or dive back into the table to show a hurtful animal-like behavior. See reference (Feng et al., 2018a) for detailed responsive behaviors, system implementations, and adaptive system design.

Design of leaf shape patterns. Inspired by natural elements and organic shapes, the center leaf shape patterns were designed as an interface for biofeedback display of heart rate information detected using a pulse sensor embedded on the table, see Figure 3.5 (a) and (b). The pattern is transparent and, therefore, barely visible. When the sensor picked up signals from users' wrists, a pump started working to pump the colored liquid toward the center along with the rhythm of users' heartbeat. Instead of projection or lighting, the liquid was adopted in addition for a sound effect, as pumping with the heartbeat sounded like a rhythm and could help users better recognize the feedback.

Each zoomorphic shape and the connected leaf shape with liquid in its route were designed using cohesive color choice with high contrast to enhance the attractiveness, keep users' attention, and give them a personal playing role. It helps build a logical connection between the interactive ball sets and the patterns filled with the same-colored liquid. This modularized design aims to stimulate self-awareness and give the seniors possibilities to make comparisons, which supports their autonomy in controlling one set of the elements. When multiple users interact, the center area of the table will morph into a pattern with symmetric leaf shapes and different colors designed to be attractive. This way, the users are contributing to their own cohesive and attractive visual enjoyment. The dynamic pattern aims to enhance the tactile sensory experience by adding visual and auditory features and can have a calming effect. And creating the attractive pattern together would perhaps incur a sense of connectedness within the group.

User Study

Design and Participants

To evaluate the design's impact on PWD, we conducted an effectiveness study with four residents, a professional caregiver in a living room of Vitalis.

In addition, the game Pim Pam Pet (PPP) was adopted as a control activity, see Figure 3.5 (c). The game PPP is a typical activity used by caregivers in Vitalis and proved to have positive effects on seniors with dementia based on their former experiences. The game PPP consists of a set of cards with questions and a turntable with letters from the alphabet. A caregiver with extensive experience in dementia care as a facilitator to guide the game and read the questions on the cards, while participants take turns to roll the turntable then answer the questions on the cards starting with the letter from the turntable. For instance, if the question is “what can you have on bread?” and if a participant rolls a letter “P,” then “Peanut butter” should be one of the correct answers.

Four participants with a formal diagnosis of dementia were recruited from Vitalis. Residents with a functional level of auditory, visual abilities and physically able to sit and interact with different stimuli were eligible to participate. All four participants are female due to the majority population living in Vitalis being female. They are with an average age of 85, range from 75-93, and different levels of cognitive functioning according to a diagnostic four-stage rating scale used in Vitalis (P1 – stage 2, Moderate; P2 and P3 - Stage 2-3, Moderately severe; P4 – Stage 3 Severe).

Two activities (*Dynamorph* versus PPP) were performed during non-planned activity time within a living room of the Vitalis. In session with PPP, participated residents were invited to sit around a table and play the game for 20 minutes or lose interest. The length of the play session was determined based on previous experiences. In session with *Dynamorph*, the same group of participants were invited again to sit around the designed table, introduced to the design, demonstrated how it could be played, then encouraged to explore by themselves until they lost interest or left the table. The caregiver performed as the primary facilitator for playing PPP and as an observer mainly in interaction with *Dynamorph*. Both sessions were with the same four participants for better generating social connectedness and assessing collective engagement.

Method

Quantitative observations using VC-IOC for both activities. A video coding protocol - Video Coding Incorporating Observed Emotion (VC-IOE) (Jones et al., 2015) - was used to document engagement of participating residents in both activities. The whole interaction/game sessions of *Dynamorph* and PPP were video recorded.

The VC-IOE coding scheme was proposed by Jones and colleagues based on theory integration of the “Dual-channel” hypothesis (Lawton et al., 1996) and the Comprehensive Process Model of Engagement framework

(Cohen-Mansfield et al., 2011) and further integrated the social aspects of the engagement. The protocol emphasizes six dimensions of engagements, including *Emotional*, *Verbal*, *Visual*, *Behavioral*, *Collective Engagement*, and *Signs of Agitation*. Each dimension is assessed separately and then considered jointly for providing a more comprehensive overview of the engagement experience. Table 3.3 explains the video analysis protocols in detail.

The *Emotional Engagement* was assessed by observing facial responses and coded into three categories: *Pleasure*, *Negative*, and *Neutral*. The *Verbal Engagement* was assessed through conversations. It offers a context for understanding their engagement situations and behaviors toward the stimulus. *Visual Engagement* as an indicator of participated residents' non-verbal engagement was examined and coded according to the presence of the visual engagement, for instance, keeping eye contact with the stimulus or no eye contact with the stimulus. *Behavior Engagement* assessment was modified based on the relevant work of Cohen-Mansfield et al. (2011) and Kolanowski et al. (2011). Gestural interaction, including petting, stroking, handling the stimulus properly, were considered positive behavioral engagement, and hitting the table or pulling out the feather from zoomorphic shapes was considered negative behavioral engagement. Furthermore, *Collective Engagement* was assessed when participants showed collaborative behaviors such as introducing or instructing stimulus to others, encouraging others to interact with, or using stimulus as a communication tool for forming conversations. At last, *Signs of Agitation* is coded based on Cohen-Mansfield's related research on agitation and agitated behaviors involving both verbal and non-verbal aspects (Cohen-Mansfield, 1996). In addition, the missing data were coded as no engagement. See Table 3.3.

Qualitative analysis of verbal communications when engaging with the *Dynamorph*. To further understand participated residents' attitudes and focus of interests, we analyzed the verbal communications of four residents during the interaction session with *Dynamorph*. The content of verbal communications recorded was transcribed into text and then translated into English for thematic analysis. After sessions ended, the observed caregiver was interviewed for her expert opinions about the design, observations of the participated residents, and suggestions toward potential improvements. All the qualitative data collected during user study (verbal expressions of four participated residents) and afterward (caregiver's interview) was analyzed by first selecting quotes following the qualitative content analysis approach and then collaborative coding by

Table 3.3 Video coding protocol of VC-IOE including six dimensions of engagement and observational signs used in evaluations.

Engagement Dimensions	**Observational Signs**
Emotional engagement	
Positive emotions (Pleasure)	Smiling, laughing towards the stimulus
Negative emotions (Anger, Anxiety or fear, Sadness)	Physical aggression, yelling, cursing, drawing eyebrows together, clenching teeth, pursing lips, narrowing eyes; voice shaking, shrieking, repetitive calling out, lines between eyebrows, lines across forehead, tight facial muscles; crying, frowning, eyes drooped, moaning, sighing, eyes/head turned down
Neutral	Relaxed or no sign of discrete facial expression
Verbal engagement	
Positive	Appreciating, praising the stimulus, making jokes, expressing happiness, fun experience, and participating and maintaining conversation, verbally responding to the stimulus
Negative	Verbalizes the desire to leave, refuses to participate in the activity anymore, makes repetitive generalized somatic complaints, cursing and swearing
No verbal engagement	Not participating and maintaining the conversation. Not responding or talking to the stimulus or facilitators
Visual engagement	
Visually engaged	Appears alerted and maintaining eye contact with the stimulus, including eyes following or looking at the stimulus.
No visual engagement	Blank stare into space. Does not make eye contact with the stimulus.
Behavioral engagement	
Positive	Touching or attempting to touch the stimulus. Stroking, petting, holding and handling the stimulus appropriately
Negative	Hitting, shaking and slapping the stimulus inappropriately, including Shoving it away and pulling it out.
No behavioral engagement	No touching, physical contact and interacting with the stimulus
Collective engagement	
Evidence of collective engagement	Encouraging others to interact with the stimulus. Introducing stimulus to others. Using stimulus as a communication channel to interact and talk with others
No collective engagement	No sign of collective engagement
Agitation	
Evidence of agitation (Verbal, vocal, motor activity)	Restlessness, repeated/agitated movement, picking and fiddling with clothes; repetitive rubbing own limbs or torso; appears anxious. Repeats words or phrases, abusive or aggressive toward self or other.
No evidence of agitation	No sign of agitation as described above

two coders using the Dedoose[12] platform online.

Findings

Findings of Video Coding Analysis using VC-IOE

The total duration of each participated resident when engaged with the *Dynamorph* far surpasses the corresponding total duration of sessions with game PPP. Indicating the residents were willing to spend more time sitting around the designed interactive table and exploring by themselves than playing the game PPP led by the caregiver. The results of video coding analysis of six dimensions of engagement with two activities using VC-IOE are summarized in Table 3.4. The numbers represent the duration in seconds of each coded item of six dimensions of engagement. Due to the uneven total duration of each participant of two activities, the total durations are all mapped to 600 seconds, and coding results were converted accordingly. Thus, the converted results of subcategories (e.g., *Positive*, *Negative*, *Neutral*) of each dimension should sum up to 600 seconds.
The results of emotional engagement suggest a longer duration of both positive and negative emotional responses towards the *Dynamorph* than with PPP. Compared to PPP, *Dynamorph* succeeds in provoking their emotional expressions. However, the rise of negative emotions is not our intention of the design. This could be due to the overstimulation caused by sensory designs and animal-like behavior feedback. Moreover, residents engaged in *Dynamorph* spent relatively less duration of visual engagement than in PPP. However, the verbal and behavioral engagement is much higher when interacting with *Dynamoph* than with PPP. Meaning the design of *Dynamorph* also facilitated verbal communications. The higher display of behavioral engagement in the former activity could be explained by the different nature of the two activities: the *Dynamorph* aims to engage users in touch manipulations.

In addition, we have noticed that participants who had a longer duration of verbal expressions tend to have less behavioral and visual engagement. Their visual engagement is associated with behavioral engagement, as when they are manipulating the stimulus, they are often gazing toward the stimulus at the same time. Results also show that residents with more advanced stages of dementia (such as P2, P4) tend to be more engaged in behavioral engagement and find social involvement within collective engagement challenging. Regarding the collective engagement, activity

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[12] Dedoose online platform: www.dedoose.com

Table 3.4 Results of video coding analysis using VC-IOE of two activities including total duration of engagement sessions and converted durations of six dimensions of engagement.

	PPP				*Dynamorph*			
Participants	P1	P2	P3	P4	P1	P2	P3	P4
Total Duration	755	755	755	477	2832	1910	1399	1890
Mapped Duration	600	600	600	600	600	600	600	600
Emotional engagement								
Positive	25.36	7.13	3.17	1.26	76.06	16.65	107.22	7.62
Negative	1.59	0	0	0	5.08	13.19	2.14	11.11
Neutral	573.05	592.87	596.83	598.74	518.86	570.16	490.64	581.27
Visual engagement								
Visually engaged	529.46	397.09	493.79	435.22	261.86	394.87	208.00	330.16
Verbal engagement								
Positive	88.77	40.42	9.51	5.03	323.31	37.70	258.18	54.29
Negative	0	4.76	0	0	22.46	0	14.15	8.89
Behavioral engagement								
Positive	3.17	9.51	0	0	167.80	385.13	88.78	203.17
Negative	0	0	0	0	0	0.63	2.14	0
Collective engagement								
Evidence of collective engagement	13.47	2.38	0	0	61.02	16.65	96.93	19.37
Agitation								
Evidence of agitation	3.17	5.55	0	40.25	0	6.28	4.29	38.41

Dynamorph performed better in facilitating social collaborations, such as helping each other on how to interact with the zoomorphic shapes, making the liquid pumping work, and guiding each other's attention towards the stimulus. We did not find a difference in signs of agitation between the two games.

Findings of Qualitative Analysis

For around 20-40 minutes' interaction session with Dynamorph (different duration for each participant), seventy-six quotes of four participants were selected from the transcripts. The selection was limited due to the limited language expressions and their ability to express intentions clearly. The chosen quotes reflect participants' attitudes and focused interests toward the design. As a result of thematic analysis, six primary themes emerged, including: "Aliveness," "Aesthetics Appreciation" of the zoomorphic shapes and leaf pattern interface, "Reflection of Self," "Indication for Social Inclusion," "Positive Emotional Responses" and "Others."

Overall, participants showed significant interest in *Dynamorph*. The autonomous power of attraction without any instruction showed a successful concept as a designed intervention for PWD living in Vitalis.

Discussions about the design regarding the “Aliveness” and “Aesthetics Appreciation” made up the majority of conversations (50 out of 76 quotes). The aliveness is a crucial feature to initiate behaviors of users (29 out of 50 quotes). All four residents have implied to a certain extent that the zoomorphic shape is a “living” thing, referring to it as an animal or a pet. P3 named the design in front of her “Peter” and said “Goodbye, my friend” to it when she left. The designed responsive behavior also helped to sustain these interests and initiatives. For example, during the testing, the ball stopped its movement when no interaction proceeded. P3 reacted as “*Now it doesn’t do anything, I have to tickle it*.” There were also appreciations regards the aesthetic quality of the design. P3 commented, “*Beautiful, wonderful, yes! That is very beautiful, isn’t it?*” and P1 later confirmed this as, “*This is very beautiful (pointing to the leaf shape).*” The high color contrast and the texture also contribute to attention-drawing. The participants found the colors enjoyable and vibrant. The goose-down texture reminded them of the furry animals, which triggered them to pet. P3 said, “*Look at this. It becomes alive. Look at this. Hello? (to the ball)*”.

The rest of the discussion spread into “Reflection of Self,” “Indication for Social Inclusion,” “Positive Emotional Responses,” and “Others.” The users referred to the design of feather balls in front of them as “mine” or “my.” This might indicate a reflection of the belongingness of something they own. P3 said, “*Mine is moving, mine is alive. This one is working, and this one is not working anymore.*” In addition, one participant - P1, was able to comprehend the design of self-reflection through the collected pulse signal. P1 recognized that the liquid was pumping in a rhythm of her heartbeat without knowing how it worked. She commented, *“It does only work for you, not for me. How is that possible? I don’t have enough heartbeat.*”

Furthermore, many clues indicate the facilitation of social inclusion among participants (9 out of 76 quotes). For instance, P3 was very talkative during the session and asked questions to other users such as “*Don’t you like it? (Asking by P2), there are beautiful things attached. Don’t you think it’s beautiful? (Asking by P2)*”, “*Who would have done this?*”. The same person also demonstrated collaborative behaviors such as helping and instructing other participants. For instance, she said, “*See, you play it like this, you can touch It (to P2)*”. All four residents demonstrated positive emotional responses towards the design at a certain point of the user study. They laughed and made jokes about the design. P3 said, “*There might be a little guy in it.*” P2 also expressed her appreciation and said, “*It’s cozy. We are cozy. I haven’t had this for years*”. At last, it was worth noticing that during the study, we also found the personal memory was triggered by the feather textile of the design. P1 shared her hobby of sewing as "*This is beautiful. It is nice if you sew it somewhere else. I always sew, but nothing like this.*"

Findings through the in-depth interview with the caregiver confirmed residents' interests in the design and acknowledged that *Dynamorph* had provided users a meaningful engagement for the occupation of time. She also mentioned the aliveness of the interactive object as animal-like as: *"The colors on the table, super nice. Bright, invites, invites to touch, it's soft, cuddle-like, it often reminds them of a furry pet, and it is just fantastic."* Petting the object and being amazed by its movements, colors, and texture kept the residents busy, calm and avoided the situation that they started looking for confrontation or negative activities. Moreover, she emphasized the calming and positive effect *Dynamorph* brought to the seniors as: "*There are people sitting there (points to the table) petting for over 40 minutes. So, you are already giving them a form of inner peace otherwise they wouldn't sit down for that long time*". The peace and harmony that were not shown during their daily living situation were evident when interacting with *Dynamorph*. In addition, she did suggest that the abstract interaction and logic connection between the pulse sensing and liquid pumping interface was very challenging for users to grasp. This could be further addressed and improved in future works.

Conclusion

In section 3.4.4, we present the design of *Dynamorph* to engage a small group of residents around a table in sensational touch explorations and collective play experiences; and to explore how to evaluate design effectiveness with PWD in their living context comprehensively. The prototype was tested with four residents from Vitalis and a caregiver using quantitative observations of *Dynamorph* and a game activity PPP based on video coding protocol VC-IOE and qualitative analysis of verbal feedback. The findings showed sufficient positive evidence on provoked emotional responses, activated behavioral participation, increased verbal expressions, and increased social connectedness among participants. The rich tactile interaction design through the zoomorphic shapes proved can motivate user interests and initiative in active participation, support independent play, and provide meaningful occupation of time through self-exploring.

3.4.5 Concluding Remarks

At the end of section 3.4.3, we summarized the insights gathered through empirical studies of three developed prototypes within PWD's real-living environment. Next, we present implications extended on i1-i3 with explanations of how they gradually evolved into the qualities which make the design of an interactive system meaningful for PWD within our specific context of an LTC.

Extended on i1, we propose our first lesson learned: **Design that encourages engagement and fun through the sensory experience without the concerns of making mistakes could be a promising direction for designing for a community of users living in the LTC context.** Different from games that with an answer of right or wrong, like a puzzle or the game PPP, the explorative play through sensory engagement has the potential to benefit multiple users regardless of their level of cognitive abilities. Therefore, reduce the risk of frustration and agitation of PWD induced by the complexity of the activity, which naturally helps to maintain their interests and promotes the hedonic well-being of PWD in LTC.

Extended on i2, we propose our second implication: **Design for PWD within the context of LTC needs to strike a balance between the over-stimulation and under-stimulation of sensory experiences.** In our last study, we observed a rise in negative emotions in participants when interacting with *Dynamorph* compared to their experience with PPP. All four participants expressed negative feelings at a certain point toward the responsive behavior design of the zoomorphic shapes. When no interaction is detected, one of the feather balls will pop up and invite new user input. The constant searching for attention was suggested annoying by one participant. Based on our observations and analysis, we speculate that the negative emotions and agitated behaviors resulted from over-stimulation provided through the combined use of vibrant colors, responsive behaviors, and liquid pumping effects. Therefore, future studies are needed on the amounts and types of sensory stimuli a person experiences in order to address the under-stimulated living situation while avoiding over-stimulating PWD.

Extended on i3, we propose our third implication: **When designing for a community of PWD living in the LTC context, the use of features of "Aliveness", "Familiarity", and "Concreteness" could contribute to positive experiences.** We noticed from our last study that most comments of participating residents were around the theme "Aliveness." They were drawn to the feather textiles and animal-like responsive behaviors and searched for a feeling of familiarity compared to the interaction with an animal. This helped build a rapport between the designed artifacts and users with dementia that motivated their behaviors and promoted emotional responses. We have also learned that the abstract shape of the leaf pattern in the center of the table and liquid pumping feedback did not work as well as we expected, according to expert interviews and observation of users. This could be due to the abstractness of the design being beyond their ability to comprehend the logic connection. Thus, we summarized three features that could help motivate PWD and lower the cognitive ability barriers: “Aliveness”, “Familiarity”, and “Concreteness”. The first feature – the aliveness - is likely to motivate interests, draw attention, and build emotional connections; the second feature – the familiarity - can help the users to interact in a way that they could reference to long-term memories; and the third – the concreteness - could give a clear cue in the design intention and thus lower the requirement of complex logic thinking.

Additionally, we propose our fourth implication: **When designing for PWD within the LTC context, the involvement of public space could benefit residents by supporting easier access, independent use, and potential social inclusion of multi-stakeholders.** Compared to a designed artifact (such as the reminiscence phone or puzzles) or a game organized and given by a facilitator, the design embedded on a table provides users easier access and possibilities for social inclusion. Although the interactive table design was not ready for practical use, and the peer interactions were not promptly as expected, the affordance of a table inspired the future works, which future designs could be employed in a more public space to enable easier access, independent use, and social inclusion of multiple stakeholders.

Last, the evaluation of the last study shows that both qualitative and quantitative data collection could provide different knowledge aspects and complement each other. The qualitative analysis of the evaluation of *Dynamorph* provides detailed reflections of their subjective experience with the design. The reflections, however, were limited by their verbal expression abilities. And the analysis of non-verbal cues provides extra information for evaluating users’ engagement. It quantified to which extent interaction with *Dynamorph* is better than other activities, in our case, the PPP. However, due to a small sample of four participants, we did not perform further statistical analysis. Future studies should consider recruiting a sufficient sample for significance examinations.

3.5 Conclusion

The current chapter first introduces the research site of Vitalis residential care home as a close collaborator for unfolding design research works of this thesis. It demonstrates a qualitative explorative journey for understanding this specific living context and concludes identified inhibiting factors (challenges facing by both staff and residents) and enabling factors (coping strategies of caregivers) within a specific location of a complex and realistic LTC environment of PWD. Inspired by the main encountered problems and useful approaches suggested, we generated four design concepts and empirically tested them with residents and caregivers in Vitalis.

We developed 3 quick prototypes for contextual inquiry and gathering in-depth information regards how design can be used to address real problems in daily living for PWD living in LTC. Based on derived implications, we decided on a potential direction of sensory engagement and explorative collective play for engaging a small group of residents for social inclusion with limited facilitation effort from staff/caregivers. Thus, the fourth prototype *Dynamorph* was then developed and tested to evaluate its effectiveness and explore how evaluative research could be unfolded in real life with PWD.

The knowledge derived from the last design and evaluation process are: 1) engage PWD in playful and fun experiences through sensory stimulation that without being afraid of making mistakes to fit a larger community's abilities like LTC; 2) consider the balance between under-stimulation and over-stimulation from design for positive effects on PWD; 3) promote the use of familiar objects, aliveness content, and concrete form rather than abstract ones for motivation of engagement; 4) provide easy access, facilitate independent use, and potential social inclusion through affordance of a public space; 5) the use of qualitative and quantitative data collection for comprehensive evaluation of design's impact on PWD. These derived implications further clarify the qualities that make the designed activity meaningful through empirical explorations within real-life living contexts.

Finally, we conclude the identified qualities that could potentially contribute to a meaningful activity design for PWD within the LTC environment, as:

A psychosocial activity design that: provides multisensory engagement to comfort or stimulate residents; encourages explorative and playful experiences without the concerns of making mistakes; with rich interaction possibilities that are intuitive, familiar, and can use previous living experiences as references; with affordance that supports independent use, allows easy access, and enables social inclusion of multi-stakeholders within an LTC context.

Part 3
INVESTIGATION

Chapter 4 | Design of the *Closer to Nature*[13]

Enabling Multisensory Engagement with Rich Interaction

4.1 Introduction

In Part 2, we have proposed related qualities that contribute to the meaningfulness of activity provision within the LTC context. In this chapter, we implement those qualities and translate them into an implemented interactive system design that enables multisensory engagement with rich interaction – *Closer to Nature* to address the inactivity of PWD in the context of LTC.

The **objectives** of this chapter are to:

- Propose design approaches that correspond to identified qualities and are suitable for the institutionalized context, such as a small-scale community like Vitalis (see the end of Part 2).
- Elaborate on the possibilities of utilizing an installation design *Closer to Nature* for addressing the inactivity and the limited connection with the outdoor nature of residents living in LTC to improve PWD's well-being.
- Implement the design in the real-life living environment of Vitalis with the aim of long-term use for further design iterations and research investigations.
- Gather preliminary evidence on the effectiveness of *Closer to Nature* from multi-stakeholders (i.e., residents, visiting family members, and caregivers) of Vitalis.

In response to the first objective, we propose three approaches that we believe are suitable for the institutionalized context. Then, we present the interactive system design and its modification for long-term use as a permanent fixture within the Vitalis residential care. Lastly, we conducted a preliminary user study for gathering opinions from multi-stakeholders within our specific context.

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[13] **This chapter is largely based on**
Feng, Y., Yu, S., van de Mortel, D., Barakova, E., Rauterberg, M. & Hu, J. (2018) Closer to nature: Multi-sensory engagement in interactive nature experience for seniors with dementia. Proceedings of ChineseCHI 2018. ACM. Inc, Vol. Part F137135, p. 49-56 8 p.

4.2 Design Considerations

4.2.1 Connecting with Nature as a Meaningful Activity

Nature is well acknowledged for its therapeutic and restorative benefits on human health (Passmore & Howell, 2014). Studies have empirically shown that exposure to nature and outdoor spaces confers benefits for improving well-being emotionally, cognitively, and physically (Annerstedt & Währborg, 2011), (Capaldi et al., 2015). Viewing of actual nature scenes has been implemented in many clinical settings to help hospital patients with pain management and decrease depression and anxiety. Moreover, specific nature elements have also shown their benefits. A study in Japan found that wood and running water can positively influence stress levels (Tsunetsugu et al., 2010). Such phenomenon can be well supported In literature by theories including: the *Biophilia Theory* - a hypothesis that humans are keen to nature biologically due to the fact that our ancestor's well-being and survival depended on connecting with nature (Barbiero & Berto, 2018); the *Attention Restoration Theory* - that nature stimulation can help engage with involuntary attention, therefore, improves concentration, directed attention, and emotional functioning (Kaplan & Kaplan, 1989); and the *Stress Reduction Theory* – that exposure to non-threatening nature can have stress reducing responses, decreases arousal, and perceived stress levels (Ulrich et al., 1991).

Recent studies on nature-assisted therapy for PWD proved that digital content of nature (e.g., video or photographic images of nature) also holds effectiveness in reducing undesirable behaviors and improving engagement, see examples like (Eggert et al., 2015) and (Reynolds et al., 2018). Although contact with nature can be beneficial to PWD, they are often either not available or underused for those living in community dwellings despite easy access to outdoor nature spaces (Gonzalez & Kirkevold, 2014). Thus, it is promising to consider the adjunctive use of virtual nature experience to provide residents with some of the benefits afforded by nature. For PWD living in LTC, the viewing of natural settings is suitable for any variation of the stages and conditions of the residents without the risk of increased agitation due to excessive or inappropriate sensory stimulation. It is also an excellent fit for LTC usage, as it not only compensates for the limited outdoor activities for residents but could also benefit care staff by positively influencing their stress levels.

Connecting with nature was chosen as a suitable activity for LTC use in our research. The work presents in this chapter utilizes a landscape of a typical Dutch farm that is nostalgic to a generation of Dutch elderly, especially grown-up in Eindhoven. The familiar scenery serves as a shared experience that could speak to the majority of residents living in Vitalis, and potentially access their remote memories for reminiscence purposes.

4.2.2 Multisensory Stimulation for Benefiting Wider Stages of Dementia

Deterioration in the senses is expected as part of the aging process. The risk of sensory deprivation for PWD is even higher due to the neuronal losses caused by the disease. The shift towards an unstimulated or wrongly stimulated LTC environment makes the situation even worse, resulting in normal stimuli becoming confusing and consequently leading to increased challenging behaviors (Cadieux et al., 2013). To address this, Collier et al. (2017) proposed the Multisensory Stimulation (MSS, or Snoezelen) method, and it is becoming increasingly popular in dementia care. It aims to help stimulate the remaining functions and maintain cognitive abilities by stimulating multiple senses. MSS offers an alternative approach to cognitive-oriented activities to cope with diminished learning ability. As this approach does not need complex reasoning, it allows a broader range of users to benefit from these stimulating activities.

There are two theoretical constructs in the literature that explain the underlying mechanism of the therapeutic effects of MSS. The first explanation is supported by the *Kovach Model of Imbalance in Sensoristasis*, which suggests that the imbalances in "the pacing of sensory-stimulating and sensory-calming activities" affect behaviour, instrumental and social functioning (Kovach, 2000). To better understand this, it is common that residents within the context of LTC may either experience too little sensory stimulation or too much inappropriate stimulation (e.g., complaints or screaming from other residents) due to environmental and personal factors. Therefore, MSS either offers stimulating sensory events or calming relaxations according to the need of residents, which further influence their behaviours positively. The second explanation is supported by studies of automatic reinforcement in the field of developmental disabilities (Staal et al., 2003). MSS is believed to be effective as reinforcement because it uses classes of automatic stimuli (sensory experiences) matched to the preferences of the person. The reported effects of the MSS with PWD may be the result of the cumulative effects of sensory reinforcement and related positive affect on the individual. The above two theories suggest a potential way of successful use of MSS for PWD, that the proposed design needs to be "adaptive for sensory needs and preference". Thus, in this chapter, our work provides two statues accommodating both the needs of sensory-calming and sensory-stimulating of PWD in LTC.

The typical application of MSS is the Multisensory Environment (MSE, also known as Snoezelen rooms) (Jakob & Collier, 2017a), in which visual projections, soundscapes, light or tactile materials are commonly available for self-exploration by users. Empirical evidence from research has confirmed that such an environment can enhance feelings of comfort, support communication, and maximize a person's potential to focus (Sposito et al., 2017), (Maseda et al., 2018). However, despite these advantages, the planned activity and the passive role of PWD in MSE were suggested as not motivating enough with little involvement from social or communication aspects, therefore, difficult in achieving expected therapeutic effects. Moreover, it has been reported that many existing MSE seems to fail to address the specific user needs due to inadequate design and poor facilitation resulting in such spaces being underused (Baker et al., 2003). Researchers and designers therefore need a proactive strategy to actively engage PWD in MSS sessions using properly designed artifacts and facilities.

4.2.3 Interactive Public Display for Social Inclusion

Dementia has not only brought barriers for life in functional aspects such as a decrease in sensory information receiving and processing, but also brings forth a new set of challenges in social interactions. Due to the compounding conditions, seniors with dementia spend much less time than their peers engaging in social activities. The decrease in mobility, hearing, and visual functions may disorient PWD further, leaving them feeling vulnerable and more emotional. These feelings can lead to a search for reassurance and attention from caregivers and others, which may further result in a reduced quality of care. Structured and planned activities are one of the common solutions for addressing social needs within LTC. However, as a first limitation, they only compose a small part of daily life. PWD still need to find other ways to occupy time and mitigate boredom. As a second, the passive following of such activities could not fulfill their higher needs of feeling in control and was simply not motivating enough for those with conditions that result in a lack of internal interests like apathy.

To address the limitations above, one promising approach – interactive public display has been used in elderly research to improve the social connectedness and well-being of residents in a shared community. It has shown potential as a medium for story sharing between generations (Lin et al., 2016), to increase family bonding (Kang, 2019), and displayed other benefits due to the placement in a public domain (Leonardi & Zancanaro, 2011). Several explorations have already demonstrated the positive impact within the context of residential nursing homes for the elderly with and without dementia (Gaver et al., 2011). One example is *OutLook* (Kang et al., 2018). *Outlook* uses a series of displays placed in a public space of an elderly care home that aims to enhance social interactions and improve the feeling of connectedness. A group of three screen monitors was embedded on the wall near a cafeteria to show real-time images of their living city. Users could save and print their preferred views on a postcard using a tangible button to share with others. The evaluation shows evidence for positive impacts, such as the quality of easy access, improvement of social interaction, and a sense of connectedness to the locations shown on displays. The trial also revealed an interesting finding that compared to images with people, the participants preferred to print postcards with nature and animal appearance. In a different design for PWD living in LTC - *VENSTER*, which is translated into English as "window", an interactive art installation in the form of a window was used to offer the experience of looking out (Luyten et al., 2018). The installation can show pre-recorded calming content such as a park, activating content such as a person outside the window, or interactive content such as snowing (enabled via touchscreen). A string for a window blind is attached to the window frame to allow switching between scenes. The explorative evaluation suggests *VENSTER* can successfully facilitate communications through passive engagement. Both *OutLook* and *VENSTER* provide users with free access to the installation, involve the living environment as part of the design, and create the possibilities of social interactions. They show great potential as a medium for increasing PWD's autonomy and engagement in social activities for the betterment of their quality of life. However, more interactive features could perhaps further enable physical engagement.

4.3 Design of the *Closer to Nature*

Grounded on the advantages of the above approaches, in this section, we present the design, modification, and real-life implementation of the interactive installation *Closer to Nature*. This project started with an initial prototype developed to connect nursing home residents with dementia (who have to stay inside) with the outdoors due to their limited contact with real nature (Valk et al., 2017). The design explores how simulated farm viewing and animal watering experience could connect users with their previous farming life, give a sense of nostalgic feeling, and fulfill a sense of responsibility by nurturing the animals. Simple tactile interaction enabled by an actual water pump with a low engagement threshold was adopted to match and stimulate the users' reduced cognitive abilities. The prototype shows pre-recorded sceneries of a typical Dutch farm on a screen display. In front of this, an actual old-fashioned water pump that pumps water into half of the animal feeding water trough, which was built as an extension of the virtual farm content. When the system detects a user interacting with the pump, it shows a video feed of the animals appearing and being fed from the trough, then wander off after a while.

The design concept was inspired by reminiscence therapy and positive empirical evidence of nature and animal viewing on PWD. Reminiscence therapy aims to assist in creating interpersonal connections using remote memories and familiar objects (Lazar et al., 2014), thus enabling intuitive interaction using pre-existing knowledge. The design addresses several aspects that are familiar to a generation of elderly Dutch people that respond to one's deepest and earliest memories in order to trigger reminiscence and evoke positive emotional responses. First, since almost all residents had either grown up on a farm or had significant experience of farming, video footages of typical farm scenery with farm animals were used as the main media content. Besides, half of the water through was built with an actual old-fashioned water pump mounted on top to create an augmented simulation of providing the animals with water. The prototype aims to immerse residents with dementia in enjoyable sensory engagement and meaningful reminiscent activities through physical and virtual interactions.

4.3.1 Installation Built as a Permanent Fixture in Vitalis

In literature, numerous design research within dementia care has been empirically tested with and for PWD. However, few cases have been implemented in the real-living environment to explore how such designs work in natural settings for a longer term. We consider this real-life implementation crucial for designing for PWD. Therefore, modifications have been made from the prototype to the current *Closer to Nature* installation, shown in Figure 4.1. The screen display resembles a real-life like window with an outlook on the farm. With the collaboration of Vitalis nursing home, the installation was rebuilt in the public domain on a shared space as a permanent setting. Figure 4.2 explains step-by-step how the system could be interacted with.

We have chosen this location since residents living in Vitalis are restrained in a closed environment due to safety concerns with passcode control to outside. In addition, the common area within this location was chosen due to the following reasons: 1) This space is connected to their private rooms where they could freely walk to; 2) The common area is located

Figure 4.1 The installation *Closer to Nature* as part of the permanent fixture in Vitalis.

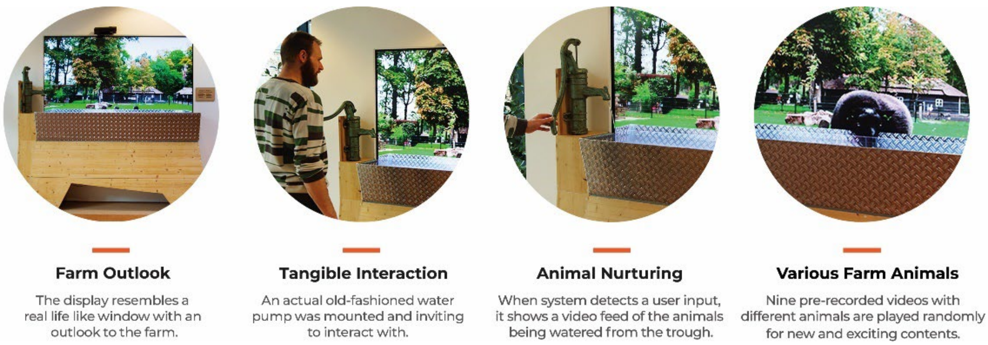

Figure 4.2 A step-by-step instruction on how to interact with the *Closer to Nature* installation.

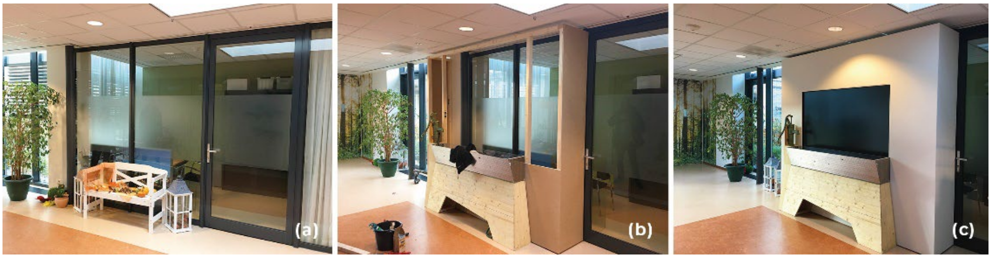

Figure 4.3 (a), (b), and (c) Transformation of one wall of an office into the *Closer to Nature* installation.

near the activity room, which increases the frequency of visit as their schedule is planned to participate structured activities in a daily basis; 3) The location is also near the nursers' offices where their activity could be easily noticed and facilitated when need; And last 4) this place also provides opportunities for social interactions as it connects to the entrance door, where they could greet or say goodbye to their relatives and friends when being visited. Figure 4.3 shows how the glass wall of the nurse's office was transformed into the wall that the installation was embedded.

See Figure 4.4 for the layout of the area where residents of PWD live in Vitalis. Moreover, although the facility design provides easy access to two well-designed botanic gardens, there are barriers such as the weather, temperature change[14], and safety hazards[15] that present challenges and leave little opportunity for residents to freely go outside unless being accompanied. Research indicates that the physical and social environment of LTC can have a huge influence on the well-being of PWD (Vogt et al., 2012). Thus, by transforming this space into an enriched sensory environment with preferred videos of nature, the living quality of residents could potentially be improved.

For long-term use, several improvements to the appearance, system, and structure have been made:

- **Appearance:** an appearance design was made so the whole installation could fit the general interior design of the residential cares' common area. We built a clean wall with the same details of the nursing home decoration, with a hidden inner structure for supporting and securing the ultra-high-definition display (BenQ, 87'), and a weight structure for safety concerns and to make sure it is

[14] People with dementia may not be sensitive to temperature change, which may result in having a cold.

[15] Safety hazards such as unnoticed falls or staying outside too long could further lead to dehydration, fatigue, muscle sore, etc., and eventually result in challenging behaviors like agitation.

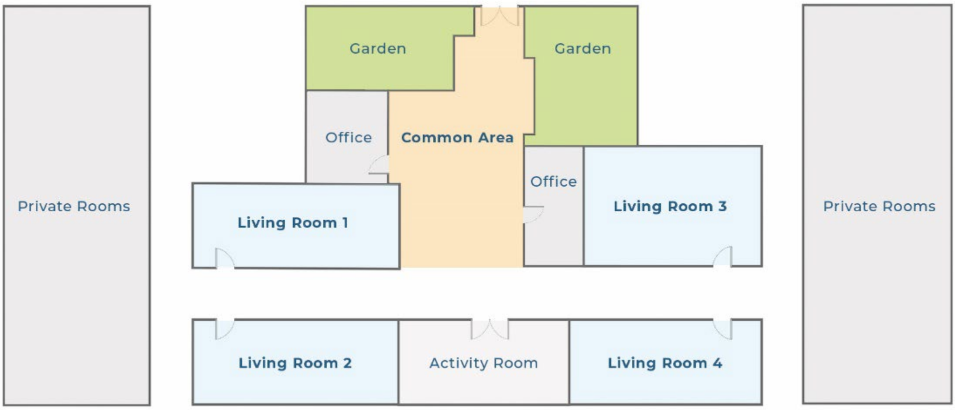

Figure 4.4 The schematic layout of the area where inhabitants with dementia live in Vitalis. The common area is located in the center and connects to an activity room, two offices, two gardens, four living rooms, and multiple private rooms.

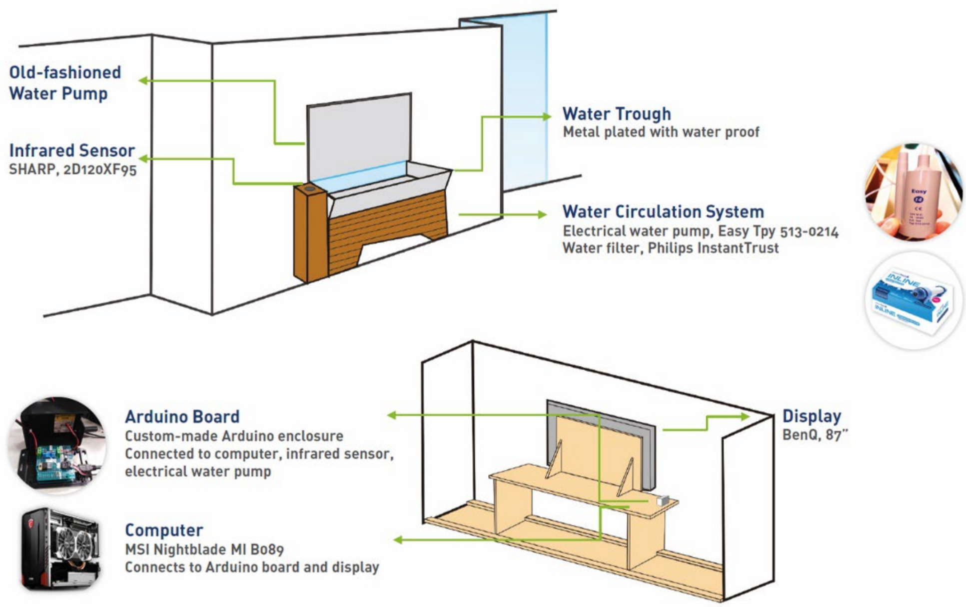

Figure 4.5 Illustration of the technical implementation of the *Closer to Nature* installation.

always firm and steady during any interactions. Shown in Figure 4.5.

- **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 scenes. Additionally, the back of the trough that stands against the display is made of transparent polycarbonate.
- **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) that connects to an electrical water pump (Easy Tpy 513-0214) to maintain the water's quality to a drinkable level, as the residents may touch directly or accidentally drink from it.
- **Sensor system:** an infrared sensor (Sharp, 2D120XF95) inside the pump was relocated for a accurate reading of the distance change.
- **Software:** the threshold of pumping gestures was also adjusted so that it can detect continuous pumping and give corresponding video feedback. We used the Processing software as the programming environment to ensure the stable and long-term running of the system and set up an alarm to monitor the running state using a watchdog via a web server to reduce unnecessary on-site maintenance. The computer connects to the Wi-Fi provided by Vitalis for remote control or to update software. Locally, the interaction triggers were logged to avoid the same video being repeatedly shown on display. Nine different pre-recorded videos with different animals are selected randomly when the system detects user input from the pump.
- **Controlling hardware:** an always-on computer (MSI Nightblade MI B089) is situated in between the walls (newly built and original wall of the facility) for video image processing. It connects to a custom-made Arduino enclosure (Arduino Uno with an extension board) that reads an infrared sensor and regulates the water circulation system. A remote connection is available for reading out logs and updating, so the residents would not often see on-site maintenance.

4.4 Preliminary User Study

4.4.1 Study Design and Participants

To explore the effectiveness of *Closer to Nature* within the specifically designated setting of Vitalis. A preliminary user evaluation with 21

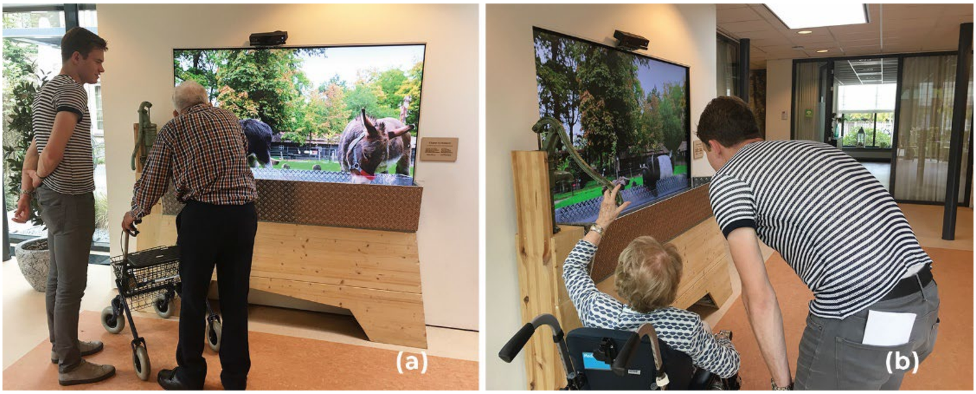

Figure 4.6 (a) A resident from Vitalis who was invited for an interview session with the facilitator. (b) Another participant from Vitalis who was sitting in the wheelchair and interacting with the water pump of *Closer to Nature* installation.

participants was conducted using semi-structured interviews. The same facilitator participated in all evaluations to guide through the interviews. Twenty-one participants, including fifteen residents living in the Vitalis, four family members of the residents (all children of participating residents, female, n = 1; male, n = 3) and two professional caregivers working there (female, n = 2) were invited for the interviews after four weeks of free exploration with the installation being operational around the clock. All participating residents have a formal diagnosis of dementia with ages ranging from 79 to 97 (M = 87, SD = 5). They were inhabitants for over six months, according to the staff report.

4.4.2 Method

Participating residents were invited according to their wishes for a 10-minutes interview one by one by an experienced facilitator, see Figure 4.6. If any family members at present, they were also invited to come along. The facilitator explained the intention of the study and introduced the design concept, then asked for opinions towards the installation design. The interview questions for participating residents focus on 1) general impressions of the installation design and interaction experiences; 2) participants' personal experiences related to the aesthetic design, including the content showing on display and animal water experiences; and 3) their previous interaction experience during past weeks. The interview questions for family members and caregivers focus on 1) general impressions of the installation design; 2) perceived user experiences of PWD during past weeks; 3) PWD's personal experience that related to the installation design; and 4) suggestions for improvements and concerns raised. All the interviewing sessions were recorded for further thematic analysis. Notes of each direct observation were also taken to supplement the data collection of qualitative interviews.

4.4.3 Data Analysis of Interviews

The content of the interviews was first transcribed then translated by the Dutch interviewer. It was coded using thematic analysis to identify the key information that 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, P1 (Participating resident 1), F2 (Family member 2), and C2 (Caregiver 2).

4.4.4 Result of Participants' Feedback

Feedback from Residents

Overall, all participating residents expressed their appreciation for the beautiful scenery showing on display and demonstrated positive emotional responses towards the experience. According to the observation notes, almost all residents (14 out of 15) displayed a lift of mood, even surprised when they saw the animals come for drinking water after interacting with the water pump. During the interviews, when encouraged to interact, 7 out of 15 residents successfully initiated pumping interaction without help.

The qualitative results also showed that the installation could facilitate verbal expression and memory sharing. During the interviews, many residents (12 out of 15) shared their own stories around topics like child memories, pets, and occupations. P2 is a lady grown 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.*" P9, 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 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 the cognitive games, singing songs, or other task activities during their regularly scheduled activities from the previous experience. P8 shared more personal stories beyond talking about farms or farm animals. She showed the facilitator her family photo album from her stroller and emphasized the story about her dog named

"*Sinta*". P6 shared her occupation as a telephone operator, her hobby of philately, and her favorite music band.

In addition, the findings also revealed a sense of connection with the outdoor environment. For example, P7 recognized the display resembles 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."*

When asked if they could remember their previous interaction experience during past weeks with the installation, only four participants said they were able to recollect their thoughts on previous user experiences. In particular, one participant – P9, demonstrated his "impeccable memory" with the installation. When invited to come over to the installation for an interview, P9 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. He remembered the goats very well and said he even came back to look 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."* Observations of interviews also showed that not all the residents could initiate interaction without help from others. P5 expressed her concern as: *"Oh, no, it is made of metal which is too heavy for me."* Additionally, we found that P10 added her imagination to the scenery that did not exist: *"See, the washed clothes were hanging there to dry."* We could not know whether the imagination was her beautiful wishes or an indicator of hallucination that is one of the symptoms of dementia.

Feedback and Suggestions from Family Members

In line with findings from interviews of residents, all family members reached an agreement that their parents, in general, responded positively to the installation. They stated that their parents experienced 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. F1 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 F2 as *"She (her mother) is addicted to the pump." "My mother grew up on a farm in Eindhoven. She became very talkative when I mentioned how she fed the animals, telling vivid stories about the baby goat."* F2 also suggested that *"It would be nice if they can have a real goat after this, something to carry away, a doll or something."* F3 expressed her concerns that excitement may fade away if the installation stayed unchanged for a very long time.

Feedback from Professional Caregivers

In general, the professional caregivers appreciated the attractive visual appearance and reported the soothing effect of the installation. They both 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 C1 as, *"The installation gives them a feeling of being in the control and meaningfulness."* During interviews, both 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. [C2]" "It recalls their nurturing nature as most of the residents we have here are women. [C1]"* C1 also mentioned residents' improvement in cognition as *"They start to remember things from the past, which holds great value for them."* C2 stated the value between the residents and their relatives as *"It provides great bonding for the family and the residents."* Both interviewed professional caregivers also pinpointed that because of the location of the installation. 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, C2 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."*

4.5 Implications, Limitations, and Future Work

There are two takeaway messages from the preliminary study. First is the importance of real-life implementation for an empirical field study with multi-stakeholders. Implementing designs in real-life settings holds great value for engaging users and multi-stakeholders (e.g., residents, family members, professional or non-professional caregivers, even volunteers) in a research process within the context of LTC (Compagna & Kohlbacher, 2015). This provides possibilities for a deeper understanding of the user needs, long-term effectiveness studies, and an iterative design process. Second, the importance of promoting "in the moment" enjoyment for PWD, especially those suffering from severe conditions. Ingrained memories such as personal experiences, characters, and interests, play an important role in generating positive effects on PWD (Kolanowski et al., 2001). Thus, engaging users in relatable experiences are more likely to promote positive emotional responses and facilitate “in the moment” enjoyment.

Moreover, we identified several limitations according to the qualitative findings. As one major limitation, the current design could not physically engage participants sitting in wheelchairs due to the position of the water pump is too high from the ground. Therefore, a future design iteration is needed to accommodate the needs of those who are wheelchair-bound. Our findings also revealed an interesting finding that although nearly half (8 out of 15) of the participating residents did not initiate interaction when they were first introduced to the installation, they enjoyed watching the animal feeding video when the facilitator interacted with the pump. Therefore, future work could compare passive nature watching experience with active interaction to identify the contributing role of tangible augmentation in promoting user engagement of PWD. Additionally, during the study, we noticed that participants sometimes would touch the screen and try to reach the virtual animals. Thus, future designs could consider adding tactile interaction to contribute to an interactive experience with more sensory modalities engaged. Last, since the qualitative interviews used in this can only acquire limited insights due to residents’ language limitations, a future effectiveness study with more comprehensive assessments and a larger group of users could be employed. The recently developed observational-based explorative studies through behavior analysis could be beneficial for a better understanding of user experience and engagement (Perugia et al., 2018).

4.6 Conclusion

This chapter presents an interactive installation design *Closer to Nature* for addressing inactivity and limited connection with outdoor nature to improve the well-being of residents with dementia living in a Dutch residential care home. It aims to engage PWD in a relaxing nature experience through multisensory engagement and rich interactions. The design was implemented in a real-life environment, and a preliminary user study using qualitative interviews was conducted with multi-stakeholders within the research context. The findings suggest that our design successfully provided a soothing outlook for residents and brought out positive emotional experiences by encouraging recollection of memories. The rich interaction motivates moderated physical exercise of arms and hands through low threshold pumping actions and brings a sense of meaningfulness through nurturing animals. The feedback also indicates that the installation served as a useful bonding tool for facilitating communications and promoting social interactions.

Despite the above presented positive evidence, the current design also has its limitations in terms of low accessibility for wheelchair users. Furthermore, we have noticed a divided preference that some participants would prefer to actively initiate interaction while others are engaged in a more passive way – enjoyment in watching media contents while the facilitator demonstrated the interaction with the pump. Therefore, in the next chapter, we decide to explore whether the “rich” part of the interaction would have a significant impact on the experience of PWD, and if so, to what extent. Furthermore, in order to capture user responses more comprehensively and robustly, we adopted two categories of quantitative measures. One is the measure commonly used in clinical trials for evaluating the effectiveness of therapeutic interventions through clinical rating scales; another is video-based coding analysis for behavior analysis. This shall be further addressed in chapter 5.

Chapter 5 | Exploring the Role of Tangible Rich Interaction

Effects on Enhancing User Engagement and Managing Challenging Behaviors of PWD

5.1 Introduction

In Chapter 4, we have shown the design considerations and implementation of the interactive system - *Closer to Nature*. The qualitative user study has demonstrated preliminary positive evidence of improved mood, bonding with nature and family members, and a recollection of memories for benefiting residents in the LTC setting. In the current chapter, we continue to explore the impact of the rich interaction design of *Closer to Nature* brought by the tangible extension of the installation on PWD's engagement, and challenging behaviors accompanied. Specifically, we conducted an experiment to investigate the effects of adding tangible augmentation to the screen-based installation on enhancing interaction-triggered engagement and reducing participants' apathy and agitation. Our research goal can be translated to the following main and sub-research questions:

RQ2.a: *To what extent can interactive systems with rich tangible interaction enhance engagement and reduce challenging behaviors of PWD living in the specific context of an LTC facility - Vitalis?*

Specifically, this chapter answers the following questions:

i. What are the effects of adding tangible augmentation based on the digital multimedia presentation of *Closer to Nature* in enhancing user engagement, in terms of regaining attentiveness, provoking positive emotional responses, and facilitating communications?

ii. What are the effects of adding tangible augmentation based on the digital multimedia presentation of *Closer to Nature* in reducing PWD's challenging behaviors (i.e., agitation and apathy) displayed during the interaction?

In response to the research questions, the following variables are used in this study:

- **Independent variables:** with and without tangible augmentation of the installation *Closer to Nature* as the representation of with and without rich interaction.
- **Dependent variables:** user engagement and observed challenging behaviors (i.e., apathy and agitation).

5.2 Method

5.2.1 Experiment Design and Setting

This study was conducted in the real-life living environment of a Dutch nursing home - Vitalis. A repeated measures design with the same participants taking part in each condition of the experiment design was adopted. In total, there were two experimental conditions and a control condition. Corresponding to the independent variables, the two experimental conditions were: with and without tangible augmentation of the installation *Closer to Nature* as the representation of with and without rich interaction, shown in Figures 5.1 (a) and (b). The former condition was addressed in the following content using the abbreviation CTN (i.e., *Closer to Nature*). In the condition CTN, a physical presence of tangible augmentation is displayed. And the latter condition is addressed as VCTN (i.e., Virtual *Closer to Nature*) since only the virtual interface is displayed for triggering the interactive video of water feeding the animals. The same video content with nature viewing and animal feeding was used in both experimental conditions. The virtual interface was a video layer edited to the original video materials using the Adobe After Effects software. It contains the looped video of an old-fashioned water pump being used and the water coming through the pump to half of the metal water bin, then stops. The aim was to recreate the animal watering experiences using only the video materials for experiment control purposes.

Additionally, we employed a control condition to differentiate whether the potential effects were due to the tangibility nature of stimuli and whether the interactive cues can better engage PWD. Thus, we employed a one-on-one interaction session with the facilitator using a selection of tactile stimuli composed of daily objects (e.g., tetherball, blanket, sponge, pillow, fur materials, and other tangible prompts). Figure 5.1 (c) demonstrates an example of one of the study sessions. These tactile stimuli were chosen as they were used in previous studies with PWD to occupy time, stimulate senses, and study PWD's engagement in activities (Cohen-Mansfield et al., 2010a), (Cohen-Mansfield et al., 2011).

Figure 5.1 (a) Experimental condition CTN with tangible augmentation including an old-fashioned water pump, half of a metal water trough, and a wooden frame with a water circulation system inside; (b) Experimental condition VCTN without the tangible augmentation but a virtual video layer of water pumping and animal feeding instead; (c) A snapshot of an interaction session from the control condition.

5.2.2 Participants

Residents from the Vitalis nursing home were approached for participant recruitment. To recruit as many participants as possible, we held a family meeting with the manager, residents, and their legally authorized representatives to introduce the purpose of this study and acquire informed consent. Moreover, written descriptions and digital consent were sent to non-attending legal representatives by email.

Twenty-four residents with documented formal diagnosis of dementia and aged 65 or above agreed to participate with written informed consent obtained. They underwent eligibility screening with the inclusion and exclusion criteria. The inclusion criteria were: a Mini-Mental State Examination (MMSE) score lower than 24; and a physical ability to respond to basic commands and interact with the presented stimuli. MMSE is a test used to assess the cognitive impairment of people who may have dementia. The total possible score on the test is 30 points, and a score lower than 24 indicates impaired cognition. The lower the score is, the more severe the cognitive impairment. See Appendix B for full detail of the examination.

The exclusion criteria were acute visual or auditory impairment reported by staff. Eventually, fifteen participants (n = 3 males, n = 12 females, age ranged 79-97) took part in the study. We could not acquire more participants due to the limited capacity of this facility. Demographic information, including gender, age, type and severity of dementia, MMSE test scores, reported restraints by staff, and length of stay in the residential care, was collected from documented records of participants, see Table 5.1.

Table 5.1 Demographics of participating residents.

Participants	Gender	Age	Type of Dementia	Severity of Dementia	MMSE Score	Reported Restraints	Length of Stay
P1	F	86	VD	Severe	3	L	>=12M
P2	F	93	MD	Mild	21	None	>=6M
P3	F	82	AD	Moderate	12	L/E	>=12M
P4	F	83	MD	Moderate	2	L/W	<6M
P5	F	91	MD	Mild	22	None	<6M
P6	F	94	MD	Severe	5	L	>=12M
P7	F	84	AD	Moderate	14	None	<6M
P8	F	97	AD	Moderate	10	None	<6M
P9	M	87	AD	Moderate	16	None	>=6M
P10	F	79	VD	Moderate	13	L/W	<6M
P11	F	80	MD	Mild	21	None	>=6M
P12	M	82	MD	Severe	6	L	>=6M
P13	F	87	AD	Severe	3	L/W	>=6M
P14	M	89	VD	Moderate	15	None	>=6M
P15	F	88	AD	Mild	22	W	<6M

Note: Abbreviations, Type of Dementia: AD is an abbreviation for Alzheimer's dementia, VD for vascular dementia, MD for mixed dementia; Reported Restraints: L stands for limitation of language expression, L/E for limitation of language and emotional expression, L/W for limited language and mobility abilities; Length of stay: <6M is Less than 6 months, >=6M is 6 months or more but less than a year, >=12M stands for 12 months or more.

5.2.3 Experiment Schedule and Environment

To counterbalance influences, fifteen participants were randomly allocated into two groups (using a random number generator). Participants in group 1 started with the condition CTN and group 2 started with the condition VCTN. We repeated the sessions twice for more prolonged exposure to the conditions and to ensure more data was collected. The study sessions were administered once a week for each participant and lasted for 5 weeks in total. Participants were first invited to participate in the control condition during week 1, then were invited again to participate in two experimental conditions alternatingly during weeks 2-5, see Figure 5.2.

All study sessions of experimental conditions were performed in the common area of Vitalis nursing home, as shown in Figure 5.3. The common area connects to four living departments (each department composed of a living room and 6-8 private rooms) so that residents can walk freely. Three cameras were placed to document the experimental sessions from different angles. The primary camera (C1 in Figure 5.3) was installed right above the installation facing directly towards the participant.

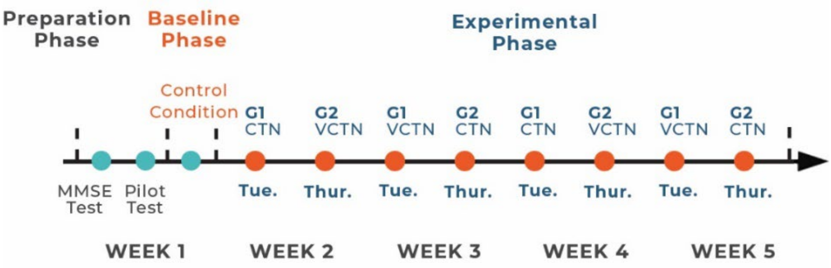

Figure 5.2 Experiment schedule.

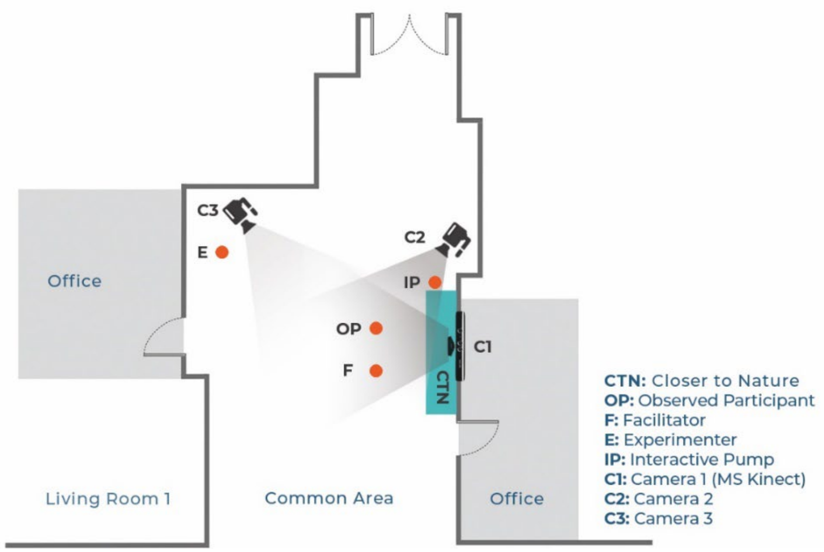

Figure 5.3 The experiment environment located in the common area of Vitalis with the position of stimuli, participant, facilitator, experimenter and three cameras marked.

We placed two supporting cameras: a GoPro camera (C2 in Figure 5.3) recording from the left side of the screen display and a digital camera (C3 in Figure 5.3) from behind the participants.

Sessions of the control condition were conducted in their living rooms where residents' most daily activities (e.g., having meals, watching TV, or listening to music) took place to reduce unfamiliar influencing factors. The installation was shut off when no experiment sessions were planned.

5.2.4 Measures

To address **RQ2.a-i** and to comprehensively assess PWD's engagement while manipulating, interacting, watching, or talking about the provided test stimuli, two categories of measures are used to quantify and document user responses – the observational rating scales and video coding analysis. The former has been widely used as a golden standard for measuring engagement during therapeutic interventions developed for PWD (Jones et al., 2015). Such rating scales are effective tools to get a broad idea of the engagement state, however, only at a global level. The latter has been used for more comprehensive and accurate documentation of engagement-related behaviors through video annotation. Together, these two approaches reflect the state-of-the-art regarding understanding observable facets of engagement in the context of dementia. Due to the majority of participants were from moderate to severe stages of dementia and with cognitive and language impairments, we did not assess engagement from the experiential dimension using subjective measures such as self-reports.

To answer **RQ2.a-ii**, dementia-related challenging behaviors - agitation and apathy are measured through the People Environment Apathy Rating Scales – Apathy subscale (PEAR-Apathy) (Jao et al., 2016) and Cohen-Mansfield Agitation Inventory (CMAI) (Cohen-Mansfield, 1996), respectively.

Assessing Engagement of PWD

We employed two widely used and validated rating scales - OME (Cohen-Mansfield et al., 2011) and OERS (Lawton et al., 1996) for engagement assessment. PWD's engagement concerning attention, attitude, and duration of a session is assessed through the OME scale; and participants' affective states are assessed through the OERS. Rating scales of OME and OERS were rated by the facilitator through direct observation and completed when each session ended. Moreover, a recently developed video coding scheme - the Ethnographic and Laban-Inspired Coding System of Engagement (ELICSE) - was adopted for quantifying engagement-related behaviors. This method can associate identified engagement-related behaviors with certain meanings in order to perform analysis according to specific research goals (Perugia et al., 2018). This is further explained in the following content. The video coding analysis was performed when all data collection was completed.

Observational rating scale of OME. OME was developed by Cohen-Mansfield and colleagues (Cohen-Mansfield et al., 2011) and has been widely adopted as a direct observation measure of activity engagement in PWD. See a more detailed description of OME in section – "Understanding Engagement in PWD" of Chapter 2. In this study, we utilized a short version containing three main subcategories that reflected user engagement in terms of *Duration*, *Attention,* and *Attitude*. The *Duration* of engagement refers to the time in seconds for which participants engaged with the stimulus. *Attention* measures the amount of attention the participant is paying to the stimulus during the engagement. It can be behavioral (e.g., manipulating the stimulus even if looking away), visual (e.g., gazing at the stimulus even if not interacting with it), or conversational (e.g., talking about stimulus-related experiences). *Attention* was scored using a seven-point scale ranging from "very attentive" to "very disruptive". *Attitude* to the stimulus during engagement involves a wide perspective of expressiveness, including the positive or negative facial expressions (e.g., smiling or frowning), verbal content (e.g., excitement in voice), and physical movements towards the stimulus (e.g., hugging or hitting). This subcategory was scored on a seven-point scale ranging from "very negative" to "very positive". Both *Attention* and *Attitude* were assessed on two levels - *Most of the Time* and *Highest Level*. The former reflects the attention and attitude towards the stimulus in an average situation, and the latter represents the highest level of attention. The scale OME and the description of terms for practical use are shown in Appendix C - OME.

Observational rating scale of OERS. OERS is another observation-based five-point Likert scale that was developed based on Lawton's "dual-channel" model of engagement (Lawton et al., 1996). It aims to measure the extent of emotional expressions using five affective states: *Pleasure*, *Anger*, *Anxiety/Fear*, *Sadness*, and *General Alertness*. These items can be scored using a fixed time duration or intensity. We used intensity in this study. See Appendix C – OERS for the scale used in this thesis. A higher score indicates a greater effect.

The ELICSE Coding Scheme for Video Coding Analysis. The ELICSE coding scheme was developed to measure engagement in PWD through observational behaviors (Perugia et al., 2018). It was built on a qualitative analysis of bodily movements that related to engagement of PWD and combined with the use of available software use (i.e., Noldus Observer XT) for video annotation (Perugia et al., 2020).

The method was inspired by two approaches that describe human behaviors - the ethnography and Laban/Bartenieff Movement Analysis (LMA) framework. Ethnography refers to the description and assessment of behaviors through ethograms. And ethograms within the context of dementia are inventories of engagement-related actions observed in context and used to annotate videos, examples see (Olsen et al., 2016), (Jøranson et al., 2016). Additionally, the LMA framework provides an underlying structure to explain how changes in body shape express attitudes toward the environment (Morita et al., 2013). As a result, the

ELICSE coding scheme is composed of two dimensions: *Behaviors* and *Modifiers*. The *Behaviors* identify actions of PWD that are engagement-related and aim to measure changes in the direction of attention; the *Modifiers* define whether former behaviors are associated with positive, neutral, and negative affective nuance. The final coding scheme used in this study is presented in Table 5.2. Furthermore, the coding scheme with detailed operational descriptions is listed in Table D1 of Appendix D.

In ELICSE, *Behaviors* are grouped and listed by the bodily parts that express behaviors involved in engagement (i.e., *Head/Gaze Behaviors*, *Arms/Hands Behaviors*, *Torso Behaviors*). Furthermore, each bodily part is directed to a cluster of targets to demonstrate their focus of attention. As shown in Table 5.2, the attention focuses within each behavior group are directed toward: *Facilitator (F)*, *Installation/Stimulus (IS)*, and *None of the target behaviors*. Specifically, the IS in the control condition refers to the presented manipulative stimuli. In the condition CTN, IS refers to the *Closer to Nature* Installation, including the interactive pump, the screen display, the water trough, and the wooden frame. And in the condition VCTN, IS refers to only the screen display with the video content shown on it.

Considering the original coding scheme only addresses the observed bodily behaviors, we added verbal behaviors - *Conversations* - as an extra aspect for evaluating how the content of verbal expressions varies in different conditions. Moreover, the *Modifiers* assigned to conversational behaviors are determined by whether participants expressed in a way that was simply describing or repeating what they saw (descriptive conversations); or using their memories to tell a story or reflections of their past experiences, job, hobbies, etc. (associated conversations).

Assessing Challenging Behaviors of PWD

Observational rating scale of PEAR-Apathy Subscale. Diagnostic criteria define apathy as “a disorder of lack of motivation, demonstrated in a lack of goal-directed activities in cognitive, behavioral, and affective dimensions, and a lack of response to internal or external stimuli” (Robert et al., 2009). In this study, we used a four-point Likert scale - PEAR-Apathy subscale to assess apathy in PWD. PEAR was constructed by “PEAR-Environment subscale” and “PEAR-Apathy subscale” for quantifying apathetic states and examining the association between apathy and environmental stimulation (Jao et al., 2016). The PEAR-Apathy subscale evaluates the symptoms of apathy in cognitive, behavioral, and affective domains through six ratings: *Facial Expressions*, *Eye Contact*, *Physical Engagement*, *Purposeful Activity*, *Verbal Tone*, and *Verbal Expression*. A

Table 5.2 The coding scheme used in this study for video annotation of all sessions of control and two experimental conditions.

Behaviors	Modifiers
Head/Gaze Behaviors	**Signs of Affection**
Gaze toward the Facilitator (Gaze_F)	With positive signs of affection (_Pos)
Gaze toward the Installation/Stimulus (Gaze_IS)	Without signs of affection
None of the target gaze behaviors	With negative signs of affection (_Neg)
Non-visible gaze behaviors	
Arms/Hands Behaviors	**Quality of Reach Out**
Reach out to the Facilitator (Reach_F)	Warmly reach out (_Pos)
Reach out to the Installation/Stimulus (Reach_IS)	Neutrally reach out
None of the target hand behaviors	Negatively reach out (_Neg)
Non-visible hand behaviors	
Torso Behaviors	**Without Modifier**
Lean in the Facilitator (Lean_F)	NA
Approaching/Lean in the Installation/Stimulus (Appro/Lean_IS)	
None of the target torso behaviors	
Non-visible torso behaviors	
Conversations	**Quality of Talk**
Talk about the Facilitator (Talk_F)	Descriptive conversations (_Des)
Talk about the Installation/Stimulus (Talk_IS)	Associated conversations (_Asso)
None of the target conversations	
Silence	
Not understandable conversations	

Note: Behaviors marked in italic style are assigned with modifiers. Detailed operational descriptions are listed in Table D1, Appendix D.

higher rating of each domain indicates a higher level of apathy among participants, see Appendix C – PEAR-Apathy Subscale.

Observational Inventory CMAI. The CMAI is an inventory of identified behaviors that are associated with agitation states of PWD. It was Developed by Cohen-Mansfield and Billig and was widely used to assess the frequency of manifestations of agitated behaviors among PWD during intervention sessions (Cohen-Mansfield & Billig, 1986), (Cohen-Mansfield, 1996). There have been several versions of CMAI with full or shortened listed behaviors, different rating points, or additional information ratings (e.g., disruptiveness) to fulfill different research goals. In this study, we used the CMAI-short with 29 listed behaviors further categorized into four sub-types: *Physical Aggressive* (contains 11 behaviors), *Physical Non-Aggressive* (contains 10 behaviors), *Verbal Aggressive* (contains 3 behaviors), and *Verbal Non-Aggressive* (contains 5 behaviors), see Appendix C - CMAI. In CMAI-short, each behavior is rated on a 5-point scale of frequency ranging from “never” to “several times within 5 minutes”. Therefore, the rated sore of each sub-type can range from 11 to

55 for *Physical Aggressive*, from 10 to 50 for *Physical Non-Aggressive*, from 3 to 15 for *Verbal Aggressive*, and from 5 to 25 for *Verbal Non-Aggressive*. Higher scores indicate greater agitation displayed.

5.2.5 Procedure

The experimental study had three phases: the preparation phase (during week 1), the baseline phase (during week 1), and the experimental phase (during weeks 2-5). See also Figure 5.2. A facilitator and an experimenter (i.e., the author) were on-site to ensure proper facilitation and data collection. The facilitator is a hired research assistant who has experience with dementia care. He was intensively trained using pre-experiment presentations, written guidelines, and received regular personal supervision throughout the study to get familiar with the procedures. To control the influence caused by the quality of facilitation, the same facilitator facilitated all sessions, including experimental and control conditions. The experimenter oversaw three roles, including preparing the experiment equipment (cameras for video recording of experiment sessions) and environment as required by each condition; consulting the care staff regarding participant’s personal conditions and their mood at the moment; and asking for participant’s agreement before each session again to ensure their voluntary nature of the participation.

The study was arranged during non-planned activity times (i.e., 10:00 - 12:30 and 14:00 - 16:00) to accommodate daily care schedules and to control the high behavioral time of the day (e.g., the Sun-downing effect, which describes the time of a day before dinner when challenging behaviors often appears). Each individual session was scheduled for up to 20 minutes, which was long enough to observe behavioral changes across time and short enough to not be interrupted by nursing care or visitors. It ended when the participants started to lose interest and focus, expressed to quit, or sessions reached the maximum time limit of 20 minutes.

The preparation phase: This phase focused on demographic data collection and participants’ eligibility screening using the MMSE tests. Recruited participants (n = 24) were invited to take an MMSE test one by one with the help of the facilitator. Afterward, all eligible participants (n = 15) were involved in the next phases of data collection.

The baseline phase: This phase focused on data collection of the control condition. Sessions were performed in each participant’s living room with all manipulative stimuli laid out on their dining table. And the facilitator invited participants one by one for a free play session with the stimuli. Participants were asked for their opinions and preferences when they picked up a certain stimulus. All sessions of the control condition were recorded using a camera facing directly towards the participant. The session ended when the participants expressed their willingness to quit or reached the maximum time limit of 20 minutes. After the session ended, the facilitator accompanied participants back to their personal units, thanked their participation, and then came back to finish the OME and OERS scales rating.

The experimental phase: In this phase, study sessions were conducted under two experimental conditions (i.e., CTN and VCTN) with alternative orders. Before each session, the facilitator was instructed first to introduce himself to the participants with a warm handshake. Then he invited the participant for an interaction session upon his/her agreement. Participants were picked up from their personal units or the living room and walked to the common area where the study took place. After they arrived, the experimenter then turned on all three cameras to record. During the study session, the facilitator first presented a short introduction of the installation and its intention, and then facilitated the session with verbal encouragement. Questions such as participants' previous farm experiences, animal feeding experiences, pets, and occupations were prepared to prompt conversations about the engagement experience. The facilitator would also demonstrate how the installation can be interacted, if needed. The study session ended once the participants expressed their wishes to quit, lost their interests, or interacted for longer than 20 minutes. The experimenter then switched off all cameras and stopped the recording. Afterward, the participants were accompanied back to their units by the facilitator and thanked for their participation. The facilitator filled in the rating scales of OME and OERS after each session was completed.

5.2.6 Ethical Considerations

The research was approved by the Board of Vitalis WoonZorg Groep care center. It was permitted and conducted in accordance with the requirements of the Eindhoven University of Technology. Written informed consent was obtained from all participants or their legal guardians. We obtained written consent from their legal guardians in cases: if participants could not write and sign but verbally gave consent with their legal guardians present and agreed, the principal investigator was not sure if the participants fully understood the statement of informed consent, they could not clearly express their willingness, and their legal representatives agreed and considered beneficial to participate in. Before each experiment session, participants were reminded again that their participation is entirely voluntary, and they are free to withdraw at any time without their care being affected. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

5.3 Data Analysis

The rating scales of OME and OERS were rated by the facilitator on-site through direct observation. However, the PEAR-Apathy Subscale and the CMAI were rated by a trained researcher (different from the facilitator and addressed as “the rater” in the following content) based on video recordings of the study sessions. The choice was made because of practical limitations of time scheduling between study sessions. Moreover, the validity and reliability of using videos for indirect observation-based ratings were supported by previous studies, and examples see (Kolanowski et al., 2011), (Jao et al., 2016). The rater also completed the video coding analysis of all study sessions (i.e., all control and experimental sessions) using the Noldus Observer XT 14.0 Software (Noldus International Technology, Wageningen, the Netherlands). He was blinded to the objectives of the study and received training in the use of rating scales (PEAR-Apathy Subscale and the CMAI), the ELICSE coding scheme, and the software Observer XT. Before the formal analysis started, three random sessions were used to discuss discrepancies together with the experimenter.

The data rated/scored by the facilitator and the rater were used for further data analysis. Data entry and statistical computation of all measures were completed using IBM SPSS Statistics Version 24. The critical *p*-value was set at 0.05 (= 5% alpha error). Initially, there were 75 study sessions planned (n = 15, Control; n = 15*2 = 30, CTN; n = 15*2 = 30, VCTN). However, there were 12 drop-out sessions because participants expressed wishes of not participating on the day their sessions were planned, or personally not suitable for participation due to medication use or body discomfort. Thus, the final completed sessions were n = 14, Control; n = 25, VCTN; n = 24, CTN. Concerning the missing data, we analyzed the repeated measured data of within-subject design as between-subjects and used analysis of variance (ANOVA) tests for examining statistical differences.

In addition, data examination of OERS suggested a very low occurrence of rated affective states: *Anger*, *Anxiety/Fear*, and *Sadness*. Therefore, these three items were merged into one item as *Negative Affect* for data analysis. This method of data aggregation was the same as in the previous study of (Cohen-Mansfield et al., 2012a). The rest data collection of OME, OERS, the PEAR-Apathy Subscale, and the CMAI were analyzed and presented by each rating item.

For Inter-Rater Reliability (IRR) validity purpose, the experimenter rated and coded partially sessions (25.4%, 16 out of 63 sessions, randomly selected) independent from the rater or the facilitator to calculate the IRR. On the one hand, the IRRs between two coders of each rating item of all rating scales were calculated using Cohen's Kappa, and they ranged between 0.64-0.77. According to Fleiss (Fleiss et al., 2013), a Kappa value between 0.40-0.60 was considered a fair agreement, between 0.60-0.75 a good agreement, and above 0.75 an excellent agreement. Therefore, they are considered between good and excellent. On the other hand, the IRR of ELICSE was calculated on bodily behaviors and associated modifiers using the "Reliability Analysis" option of Observer XT software with Cohen's Kappa statistic. When calculating IRR, the software took both the matching of scored behaviors by two coders and the overlap of time into consideration. We utilized the "Frequency/sequence" method of the comparison and set 3 seconds tolerance for reliability analysis. The IRR results of 16 paired sessions ranged from 0.72-0.87 with an average Kappa of 0.80.

5.3.1 Video Coding Analysis using the ELICSE Coding Scheme

Preparation of Video Materials and the Coding Platform

Video recordings collected from different cameras were used for video annotation to complement missing details from a single view. Since these recordings of each session were initially with different lengths and starting/ending points, they were synchronized using the Adobe Premiere CC software. Recordings of the main camera were used as the primary sources for video annotation as they had the clearest view of facial expressions and body movements. Recordings from the other two cameras were used to support video annotation. For instance, videos from the second camera provided a better sound quality and a better angle for determining behaviors/modifiers associated with the interactive pump. Therefore, these videos were used for annotating *Arms/Hands Behaviors* and *Conversations*. Additionally, recordings from C3 were used for supporting the scoring of *Torso Behaviors* when needed. Figure 5.4 shows three representative images of the screenshot from three camera angles.

Meanwhile, the coding platform was set up by the experimenter prior to the video annotation procedure by the rater. The experimenter first created a project using the Observer XT platform, defined the coding

Figure 5.4 (a) A screenshot of the recordings from the primary camera (C1); (b) A screenshot of the recordings from the second camera (C2); (c) A screenshot of the recordings from the third camera (C3).

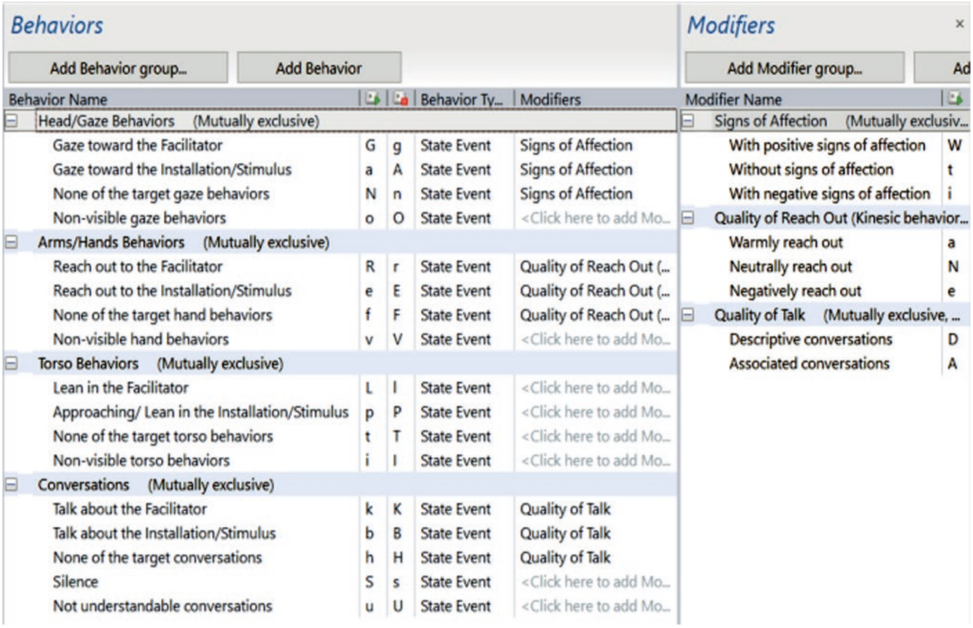

Figure 5.5 The final coding scheme shown in the Observer XT software with Behaviors and Modifiers defined by the experimenter.

scheme according to Table 5.2 (see Figure 5.5), and then filled in necessary information within the software. Synchronized video recordings of three angles were then imported into a single "Observation" (the created scoring session in the Observer software) for further video annotation.

Video Annotation

A total of 63 "Observations" were created in the software with an average duration of 10.75 minutes. The rater was instructed to first watch the whole video for a general overview before the video annotation started, then annotated each behavior group of *Head/Gaze Behaviors*,

Figure 5.6 An example of video annotation visualization of one of the observation sessions.

Arms/Hands Behaviors, *Torso Behaviors*, and *Conversations* separately. Within the behavior group, each cluster of behaviors was scored as mutually exclusive with a continuous sampling technique, see Figure 5.6. After video annotations of all sessions were completed, the original data were analyzed using the “Behavior Analysis” option of Observer XT software. The analysis output - a data set of the percentage duration of each scored behavior and its modifier using scores ranging from 0 to 100 - was then exported for further data aggregation and pattern examinations. The percentage of duration was chosen instead of frequency due to the uneven duration of each session.

Data Aggregation

The data aggregation was performed for further interpretation and statistical examination of the data collection using ELICSE. We performed theory-driven data aggregation similar to the works of (Perugia et al., 2020). As explained in the earlier section of “Measures”, the observable facets of engagement measured through ELICSE are composed of two essential components: *Attention* and *Valence*. The scored *Behaviors* of ELICSE represent changes in the direction of attention, and *Modifiers* reflect the extent of valence. Therefore, we aggregated the scored items of *Behaviors* into metrics associated with *Attention*, and *Modifiers* into metrics associated with *Valence*. The aggregated metrics demonstrated the extent to which the participant is engaged with the activity. The detailed data aggregation computation is presented in Table 5.3.

On the one hand, we aggregated scored observable items of *Behaviors* into metrics associated with *Attention*. We considered scored behaviors that have focused attention directed towards the facilitator and the stimulus (i.e., IS) as expressing attention, and the rest scored behaviors (i.e., None of the target behaviors and non-visible behaviors) as not attentive. Thus, the group of behaviors of expressing attention was aggregated into four metrics according to different bodily parts: *Gaze Activity* (GAct), *Reach out Activity* (RAct), *Torso Activity* (TorAct), and *Talk Activity* (TAct). The value of each metric was computed according to the formulas as presented in Table 5.3. Data aggregation of *Behaviors* used a computed value to indicate attention that ranged from 0 to 100. And a higher value of a certain aggregated metric indicates a higher level of denoted attention.

On the other hand, we aggregated scored observable items of *Modifiers* into metrics associated with *Valence*. In this study, the scored *Modifiers* of *Head/Gaze Behaviors* and *Arms/Hands Behaviors* were associated with positive, neutral, and negative nuance. Thus, unlike data aggregation of *Behaviors*, the scored values of *Modifiers* of *Head/Gaze Behaviors* and *Arms/Hands Behaviors* were mapped on an axis with two directions, with associated positive valence given a positive number and negative valence a negative number. To get a value that represents the overall valence state of a certain category, we subtracted the modifiers expressing negative valence (e.g., SignAff_Neg) from those expressing positive valence (e.g., SignAff_Pos). The results of *Gestural Support* (SignAff) and *Quality of Reach Out* (QuReach) are scores ranging between -100 and 100, where a negative number means negative valence was predominant, and vice versa. The formulas are shown in Table 5.3. A higher value indicates a higher level of affective states for that specific metric.

In addition, data aggregation of the *Modifiers* of verbal behaviors was different than non-verbal behaviors. The *Modifiers* of verbal behaviors - *Quality of Talk* (QuTalk) were annotated using *Descriptive Conversations* (QuTalk_Des) and *Quality of Talk using Associated Conversations* (QuTalk_Asso). We aggregated these two separately to investigate whether the tangible augmentation would have an impact on memory recollection and the way of language expressions.

Table 5.3 Data aggregation computation of scored behaviors and modifiers of the ELICSE coding scheme.

Aggregated Items	Data Aggregation Computation
Attention	
GAct	= Gaze_F + Gaze_IS
RAct	= Reach_F +Reach_IS
TorAct	= Lean_F + Appro/Lean_IS
TAct	= Talk_F + Talk_IS
AttenSum	= GAct + RAct + TorAct + TAct
Valence	
SignAffect_Pos	= Gaze_F_Pos + Gaze_IS_Pos + Gaze_None_Pos
SignAffect_Neg	= Gaze_F_Neg + Gaze_IS_Neg + Gaze_None_Neg
SignAffect	= (Gaze_F_Pos + Gaze_IS_Pos + Gaze_None_Pos) – (Gaze_F_Neg + Gaze_IS_Neg + Gaze_None_Neg)
QuReach	= (Reach_F_Pos + Reach_IS_Pos) – (Reach_F_Neg + Reach_IS_Neg)
QuTalk_Des	= Talk_F_Des + Talk_IS_Des
QuTalk_Asso	= Talk_F_Asso + Talk_IS_Asso
Engagement	
EngSum	= AttenSum + SignAffect + QuReach

Next, based on the aggregated metrics calculated, we further aggregated these metrics into sums to represent user attentiveness (AttenSum) and user engagement (EngSum) to compare among conditions. In specific, we computed a value to reflect the latent variable of *Attention* (AttenSum) by summing up the aggregated items of GAct, RAct, TorAct, and TAct. And AttenSum, SignAff, and QuReach together into a sum value of *Engagement* (EngSum). Also shown in Table 5.3.

Statistical Examinations

The computed results of data aggregation listed in Table 5.3 were then exported to SPSS for pattern examinations. During which, outliers were first excluded, and normality tests were performed. ANOVA with post hoc comparisons was carried out to examine statistical differences across conditions. The partial eta-squared was used for reporting the effect size due to the limited sample size. The suggested norms for partial eta-squared are $\leqq$ 0.01 considered as small, ≈ 0.06 as medium, and $\geqq$ 0.14 as large (Cohen, 2013).

5.4 Results

5.4.1 Effects on User Engagement of PWD

We investigate the impact of rich interaction through adding tangible augmentation based on the digital multimedia presentation of *Closer to Nature* on user engagement in terms of regaining attentiveness, provoking positive emotional responses, and facilitating communications. The results concerning our research question **RQ2.a-i**, measured by OME, OERS, and ELICSE, are presented in the following.

Results of Rating Scales OME and OERS

To answer **RQ2.a-i**, statistical analysis using ANOVA tests was performed with three conditions (i.e., Control, VCTN, and CTN) as independent variables and data collection of rating scales items of OME and OERS as dependent variables. The results were summarized using descriptive statistics with means (M) and standard deviations (SDs) listed in Table 5.4. The findings of statistical analysis showed significant differences among three conditions on two items: *Duration* of OME F (2, 62) = 7.111, p = .002, η^2 = .194, and item *Attention – Most of the Time* of OERS F (2, 62) = 3.495, p = .037, η^2 = .104. Findings indicated that participants were engaged in each activity of three conditions with significantly different average total duration and were demonstrated significantly different attentiveness most of the time.

Results of post hoc tests revealed that participants were engaged in the CTN condition CTN condition (M = 406.54, SD = 149.68) significantly longer compared to the Control, (M = 249.36, SD = 321.33, p = .005); and considerably longer to condition VCTN, (M = 249.36, SD = 321.33, p = .053), see Figure 5.7 and Table 5.4. The results of post hoc tests also showed that participants were rated with significantly higher attentiveness (Atten_M) in condition CTN (M = 5.21, SD = 0.98) than in VCTN (M = 4.56, SD = 0.77, p = .039). Although the average mean of Atten_M was rated higher for condition Control (M = 4.64, SD = 1.01) than VCTN (M = 4.56, SD = 0.77), no statistical significance was found.

No other significance was discovered for the rest of the rating items. The above findings suggested that when the tangible design of the installation was employed, participants had a significantly higher average engagement duration than two other conditions. Moreover, compared to condition VCTN, participants engaged in CTN showed significant positive improvements in attentiveness during most of the time of a session. And there was no effect found on participants' emotional responses across conditions based on results of OERS.

Results Based on Video Coding Analysis of ELICSE

We performed one-way ANOVA with post hoc tests using three conditions (i.e., Control, VCTN, and CTN) as independent variables and scored items

Table 5.4 Results of ANOVA tests with post hoc comparisons on all rating scales items of OME and OERS.

Scale Items		**Conditions**			**ANOVA**	**Post Hoc p-value**		
		Control (n=14)	VCTN (n=25)	CTN (n=24)	p-value	Control vs. VCTN	Control vs. CTN	VCTN vs. CTN
OME								
Duration	M	249.36	321.33	406.54	**.002****	.190	**.005****	.053
(in seconds)	SD	128.63	98.10	149.68				
Atten_M	M	4.64	4.56	5.21	**.037***	.960	.161	**.039***
	SD	1.01	0.77	0.98				
Atten_H	M	5.21	5.32	5.83	.113	.947	.171	.185
	SD	1.19	0.95	0.96				
Atti_M	M	4.00	4.43	4.46	.276	.326	.302	.944
	SD	0.96	0.75	1.06				
Atti_H	M	4.64	5.05	5.04	.437	.600	.589	.985
	SD	1.27	0.59	1.04				
OERS								
Pleasure	M	1.79	1.86	1.92	.779	.956	.782	.885
	SD	0.58	0.57	0.58				
Alertness	M	3.57	3.64	4.04	.112	.962	.178	.175
	SD	0.65	0.86	0.75				
Neg_Affect	M	3.29	3.19	3.08	.298	.967	.488	.302
	SD	0.61	0.40	0.28				

Note: Significance in Bold. Significance level *p < .05, ** p < .01.
Abbreviations, Atten_M, Attention Most of Time; Atten_H, Attention Highest Level; Atti_M, Attitude Most of Time; Atti_H, Attitude; Alertness, General Alertness; Neg_Affect, Negative Affect.

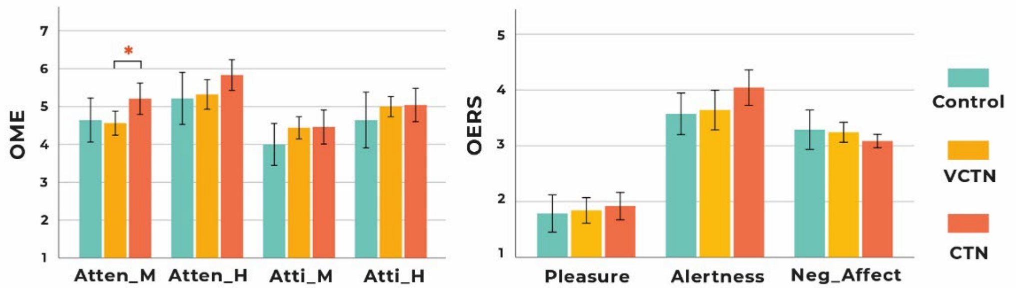

Figure 5.7 Results of rating scales OME and OERS.

of behaviors, modifiers, and aggregated metrics of ELICSE as dependent variables. The results are shown in Table 5.5. Statistical analysis disclosed significant differences on directly observed items of ELICSE, such as Gaze_IS F (2, 62) = 3.200, p = .048, η^2 = .096, Reach_IS F (2, 62) = 6.753, p = .002, η^2 = .184, Talk_Asso F (2, 62) = 3.141, p = .050, η2 = .092; and aggregated metrics of ELICSE, such as RAct F (2, 62) = 5.169, p = .008, η^2 = .147, AttenSum F (2, 62) = 3.971, p = .024, η^2 = .117, SignAffect_Neg F (2, 62) = 3.421, p = .039, η^2 = .102, and EngSum F (2, 62) = 3.646, p = .032, η2 = .108. Table 5.5 presents the descriptive statistics with means and SDs and results of ANOVA tests with critical p-values.

Table 5.5 Results of ANOVA tests with post hoc comparisons on percentage data of each scored behavior, modifiers, and aggregated items of ELICSE.

ELICSE Items		Conditions			ANOVA	Post Hoc *p*-value		
		Control (n=14)	VCTN (n=25)	CTN (n=24)	p-value	Control vs. VCTN	Control vs. CTN	VCTN vs. CTN
Behaviors								
Gaze_F	M	29.61	24.14	19.28	.163	.576	.143	.547
	SD	16.47	16.83	15.29				
Gaze_IS	M	48.93	47.04	61.42	**.048***	.962	.188	.053
	SD	22.97	20.74	20.43				
GAct	M	82.12	71.53	80.70	.103	.170	.967	.160
	SD	14.75	19.12	16.64				
Reach_F	M	2.67	1.28	5.56	.478	.941	.767	.455
	SD	4.99	2.13	19.20				
Reach_IS	M	26.59	7.12	11.35	**.002****	**.006****	**.017***	.629
	SD	27.46	6.38	14.03				
RAct	M	29.26	8.40	17.70	**.008****	**.043***	.396	.115
	SD	28.36	6.81	21.43				
Lean_F	M	0.84	1.72	2.47	.567	.837	.541	.836
	SD	2.24	4.50	5.55				
Appr/Lean_IS	M	5.42	2.98	3.44	.656	.644	.745	.978
	SD	13.46	5.31	6.20				
TorAct	M	15.64	11.03	7.21	.648	.869	.624	.876
	SD	36.32	27.89	19.71				
Talk_F	M	2.07	1.83	1.05	.618	.977	.660	.717
	SD	4.92	3.69	2.18				
Talk_IS	M	40.14	44.05	56.68	.104	894	.141	.208
	SD	28.63	20.17	28.73				
TAct	M	42.21	45.88	57.73	.139	.907	.181	.255
	SD	30.08	19.99	28.48				
AttenSum	M	154.35	128.11	159.60	**.024***	.145	.922	**.024***
	SD	52.00	33.29	40.59				
Modifiers								
SignAffect_Pos	M	5.23	9.72	4.66	.260	.470	.987	.269
	SD	9.81	15.67	5.76				
SignAffect_Neg	M	2.64	0.05	0.00	**.039***	.385	.372	.584
	SD	7.10	0.23	-				
SignAffect	M	1.72	4.17	4.66	.228	.339	.206	.942
	SD	5.25	3.36	5.76				
QuReach_Pos/ QuReach	M	0.10	0.58	0.25	.451	.475	.929	.610
	SD	0.38	1.68	0.93				
Talk_Des	M	39.64	35.59	45.72	.268	.875	.767	.175
	SD	29.98	16.43	22.24				
Talk_Asso	M	2.57	10.29	12.01	**.050***	**.024***	**.018***	.887
	SD	5.91	11.29	14.31				
EngSum	M	156.17	132.86	164.50	**.032***	.326	.872	**.015***
	SD	53.60	32.89	42.43				

Note: Significance in bold. Significance level *p < .05, ** p < .01.

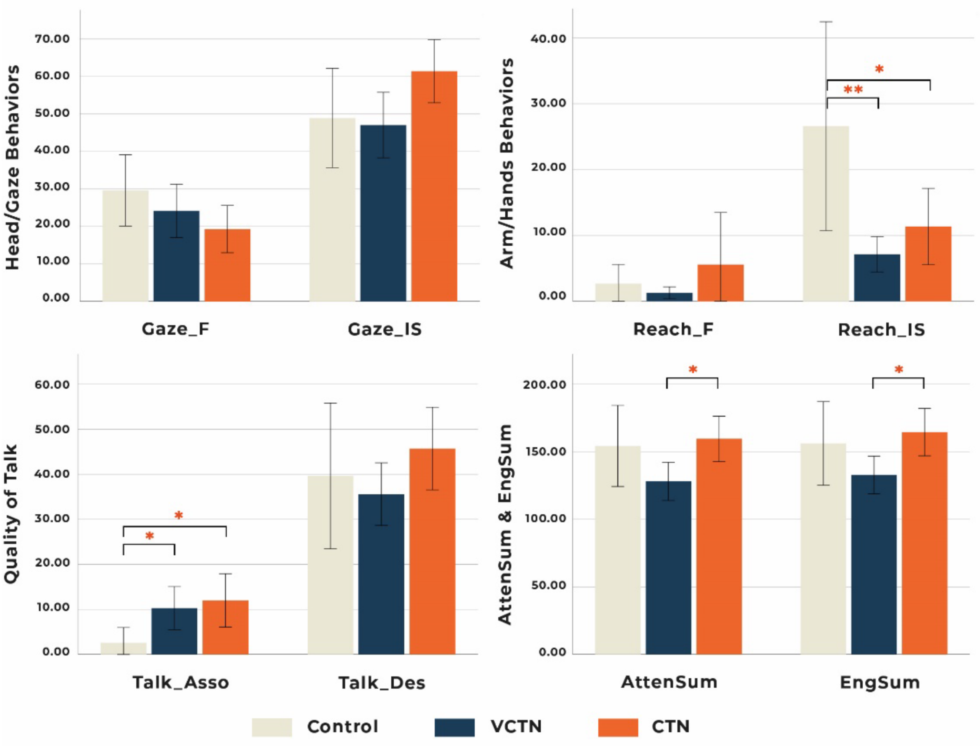

Figure 5.8 Results of items and aggregated metrics of ELICSE.

Further post hoc tests revealed multiple statistical significances between condition CTN and VCTN, see Figure 5.8. In condition CTN, participants demonstrated significantly higher scores on items: Gaze_IS (*MD* = 14.378, *SE* = 6.04, *p* = .053), AttenSum (*MD* = 31.481, *SE* = 11.68, *p* = .024), and EngSum (*MD* = 31.637, *SE* = 11.98, *p* = .015) than in condition VCTN. These results aligned with findings from data collection of the rating scales and showed that participants were rated with higher attentiveness while interacting with the installation with the tangible augmentation.

In addition, results of post hoc comparisons also revealed that participants' manipulative and reach out behaviors towards the stimulus (Reach_IS) composed a significantly higher percentage of duration when engaged in the Control than the other two conditions: VCTN (*M* = 7.12, *SD* = 6.38, Control vs. VCTN *p* = .006), CTN (*M* = 11.35, *SD* = 14.03, Control vs. CTN *p* = .017). This fits our expectations given the nature of the provided activity in the control condition. Similarly, the computed aggregated item RAct has a significantly higher average mean in Control (*M* = 29.26, *SD* = 28.36) than in VCTN (*M* = 8.40, *SD* = 6.81, *p* = .043), however, not than in CTN (*M* = 17.70, *SD* = 21.43, *p* = .396). Regards verbal behaviors assessed using

ELICSE, the conversational expressions using associated memories of participants (Talk_Asso) are significantly higher when engaged in CTN (M = 12.01, SD = 14.31, Control vs. CTN p = .018) or in VCTN (M = 10.29, SD = 11.29, Control vs. VCTN p = .024) than in Control (M = 2.57, SD = 5.91). Indicating the content of the installation triggered participants' reminiscence successfully. The highest average mean of Talk_Asso of condition CTN also suggests this particular condition performed the best in memory recollection and sharing for our participants.

Results of Concurrent Validity

To test the concurrent validity of ELICSE against the validated measures of OME and OERS, we performed the Spearman Rank correlation test between the 12 metrics of ELICSE (computed according to the formulas listed in Table 5.3) and the items of OME and OERS. As shown in Table 5.6, the results suggest that the metrics of ELICSE that related to user attentiveness (i.e., AttenSum and EngSum) were significantly highly correlated with rating scale items that assess user attentiveness. For instance, AttenSum of ELICSE with Atten_M of OME (p = .040); and EngSum of ELICSE with Atten_M (p = .021). AttenSum with *General Alertness* of OERS (p = .034); and EngSum with *General Alertness* (p = .019).

And metrics of ELICSE that denote *Valence* such as SignAffect_Pos and QuReach were significantly highly correlated with item *Pleasure* (p = .038, p = .011 respectively); and SignAffect_Neg with item *Negative Affect* (p = .010). Besides, *Gaze Activity* (GAct) was highly correlated with *General Alertness* of OERS (p = .013); *Torso Activity* (TorAct) with *Attitude – Most of the Time* (Atti_M) of OME (p = .023); Talk_Asso, and QuReach of ELICSE with all OME items, see also Table 5.6. These results confirmed that two categories of measures are highly correlated in terms of Attention and Valence aspects of engagement. Therefore, we considered our measures of engagement and data aggregation valid.

5.4.2 Effects on Observed Challenging Behaviors of Apathy and Agitation

To answer **RQ2.a-ii**, we tested whether the participants' agitated and apathetic behaviors differed across conditions during the study sessions. The results of each item of the PEAR-Apathy Subscale and CMAI were presented in Table 5.7. Statistical analysis of one-way ANOVA and further post hoc test (HSD) did not reveal significant results. The average means of scale items of the PEAR-Apathy Subscale demonstrated a trend of decreasing score of Control > VCTN > CTN (except for items *Facial*

Table 5.6 Results of concurrent validity between items of validated rating scales and ELICSE.

		GAct	RAct	TorAct	TAct	SignAffect _Pos	SignAffect _Neg	SignAffect	QuReach	Talk_Ass o	Talk_Des	AttenSu m	EngSu m
OME													
Atten_M	r(s)	.156	.236	.113	.231	.171	.212	.172	**.322****	**.328****	.131	**.259***	**.268***
	p	.222	.062	.378	.069	.181	.095	.192	**.010**	**.009**	.306	**.040**	**.034**
Atten_H	r(s)	.092	.172	.068	**.248***	.122	-.126	.166	**.338****	**.407****	.079	.221	.228
	p	.473	.178	.597	**.050**	.341	.326	.192	**.007**	**.001**	.537	.082	.073
Atti_M	r(s)	-.124	.157	**.287***	.122	.119	-.173	.178	**.429****	**.284***	-.052	.126	.128
	p	.334	.220	**.023**	.342	.352	.176	.162	**.000**	**.024**	.685	.323	.318
Atti_H	r(s)	-.067	.202	.123	**.267***	.174	-.217	.227	**.310***	**.297***	.138	.241	.255*
	p	.602	.112	.337	**.034**	.171	.087	.073	**.013**	**.018**	.282	.057	.043
OERS													
Pleasure	r(s)	.230	.188	.186	.275*	.262*	.067	.063	**.320***	.137	**.271***	**.306***	**.318***
	p	.070	.139	.144	.029	.038	.604	.626	**.011**	.284	**.032**	**.015**	**.011**
Alertness	r(s)	**.311***	.103	.113	**.318***	.055	-.147	.102	**.361****	**.350****	.221	**.290***	**.295***
	p	**.013**	.422	.377	**.011**	.669	.250	.424	**.004**	**.005**	.081	**.021**	**.019**
Neg_Affect	r(s)	.097	.000	.055	.001	-.046	.323**	-.143	-.198	-.062	.050	.050	.035
	p	.451	.998	.668	.997	.719	.010	.263	.119	.631	.697	.698	.785

Note: Significance level *p < .05, ** p < .01.

Table 5.7 Results of ANOVA tests with post hoc comparisons (HSD) on all rating scales items of PEAR-Apathy Subscale and CMAI.

Scale Items		Conditions			ANOVA	Post Hoc p-value		
		Control (n=14)	VCTN (n=25)	CTN (n=24)	p-value	Control vs. VCTN	Control vs. CTN	VCTN vs. CTN
PEAR–Apathy								
Fac_Exp	M	2.36	2.38	2.63	.610	.956	.630	.736
	SD	0.92	0.87	0.82				
Eye_Con	M	1.79	1.67	1.46	.373	.812	.360	.644
	SD	0.58	0.79	0.66				
Phy_Eng	M	3.00	2.95	2.79	.569	.967	.797	.551
	SD	1.04	0.92	0.97				
Pur_Act	M	3.00	2.48	2.42	.179	.291	.169	.923
	SD	0.88	0.87	1.10				
Ver_Ton	M	2.43	2.33	2.33	.859	.999	.918	.862
	SD	0.65	0.73	0.76				
Ver_Exp	M	2.43	2.05	2.38	.402	.478	.978	.502
	SD	0.65	0.81	0.82				
CMAI								
Phy_Agg	M	11.00	11.00	11.00	-	-	-	-
	SD	-	-	-				
Phy_NonAgg	M	10.64	10.67	10.75	.924	.955	.917	.991
	SD	0.93	0.73	0.85				
Ver_Agg	M	3.14	3.00	3.04	.135	.114	.334	.770
	SD	0.36	-	0.20				
Ver_NonAgg	M	5.36	6.10	6.25	.429	.615	.400	.904
	SD	0.63	2.30	2.44				
Total	M	30.14	30.76	31.04	.545	.755	.514	.887
	SD	1.29	2.58	2.89				

Note: Abbreviations, Fac_Exp, Facial Expression; Eye_Con, Eye Contact; Phy_Eng, Physical Engagement; Pur_Act, Purposeful Activity; Ver_Ton, Verbal Tone; Ver_Exp, Verbal Expressions; Phy_Agg, Physical aggressive agitated behaviors; Phy_NonAgg, Physical non-aggressive agitated behaviors; Ver_Agg, Verbal aggressive agitated behaviors; Ver_NonAgg, Verbal non-aggressive agitated behaviors.

Expression and *Verbal Expression*), indicating participants were rated with less apathetic behaviors towards condition CTN. However, no significant differences were yielded across conditions. In summary, the observed challenging behaviors of the participants related to apathy and agitation did not seem to be significantly affected by the type of stimuli provided.

5.5 Discussion

5.5.1 Effects on User Engagement and Challenging Behaviors

To summarize the main findings, our statistical analysis demonstrated significant positive impacts in motivating participants' interests (reflected through average attendance duration), restoring attentiveness, and facilitating memory recollection when adding the tangible augmentation of installation design. The findings also showed a trend of increased positive emotional responses and reduced apathy, however, without the support of statistical significance. Next, we further discuss these results with explanatory interpretations.

Tangible Rich Interaction for Promoting Attention Aspect of Engagement of PWD

Our study yielded interesting findings on the impact of adding tangible augmentation to the digital multimedia presentation of installation *Closer to Nature* on enhancing PWD's engagement. In particular, the statistical analysis using two measures - rating scales and video coding analysis using ELICSE - suggested that the rich interaction design of this study is significantly more effective in enhancing the *Attention* aspect of engagement. Here we offer the possible explanations of the results.

First, we discuss why the employed tangible rich interaction could significantly improve PWD's *Attention* aspect of engagement in this study. The results presented in the above section have shown that the interaction with condition VCTN was rated with the lowest average mean of Atten_M using the OME compared to two other conditions: the control condition with tactile manipulatives; and the CTN condition with tangible augmentation of the installation. Thus, one possible interpretation is that the tangibility of the provided stimuli has a significant impact on the user's attention. This is also in line with previous research that the use of kinesthetic/tactile modalities could improve users' attention and memory during learning activities (Minogue & Jones, 2006), (Fan et al., 2017). In this study, the materials of the wood trough, metal water pump, and running water give a unique tactile and sensory experience for manipulation and exploration, thus likely contributing to directing participants' attention toward the stimuli and sustaining such exploration with focused attention.

A second interpretation is that the multimodality of the provided stimuli (multimodal sensory experiences) could also have a positive impact on PWD's attention during the interaction. The human brain is capable of simultaneously processing and integrating information from multiple sensory channels (Garner, 1974). Furthermore, literature has suggested a link between multimodal interaction and cognition, and the positive effects of multimodal interaction originate from a reduction of cognitive load due to a distribution of information processing (Sigrist et al., 2013). Therefore, for PWD with a relatively short attention span due to the cognitive impairments of the disease, this reduction of cognitive load may help with sensory processing and sustained attention.

And for the third possible explanation - the interactivity enabled by system design could also help explain the improved attention of engagement. This is due to the positive correlation between properly designed "interactivity" and increased user engagement (Rozendaal, 2007). Being able to interact may facilitate active user participation. And compared to passive experiences, active participation of PWD could better attract, engage, and delight users with dementia (Raglio et al., 2015). In sum, we provide three possible interpretations regarding features of tangibility, multimodality, and interactivity of the system design that could help explain the increased user engagement, especially the *Attention* aspect.

Next, we discuss the reasons for the lack of significance regards the *Valence* aspect of engagement (e.g., item Atti_M of OME, *Pleasure* of OERS, SignAffect_Pos/Neg, and QuReach of ELICSE) **between conditions CTN and VCTN.** Despite the fact that the overall rating suggests an increase in average mean of items *Attitude* and *Pleasure* following CTN > VCTN > Control, no significant difference in observed facial expressions, *Signs of Affection*, *Quality of Reach Out* behaviors were found among all conditions and further comparations between every two conditions.

We provide two possible interpretations of these results. As a first interpretation, the lack of statistical significance could be due to the employed experimental design of conditions. For conditions CTN and VCTN, the variations of the two conditions were focused on the with or without tangible rich interaction. The expected designed content to provoke PWD's emotional responses, such as reminiscing content of farm, animal viewing and nature connecting, remains the same for both conditions. In addition, the design of *Closer to Nature* aims to bring a soothing, calming, and relaxing experience for residents living in LTC with the intention of trying to avoid the circumstances of over-stimulating those with hyper-sensitivity.

A second explanation may lay in the limitations of our study: 1) We did not further consider participants' demographic characteristics due to a relatively small sample size adopted in this study. Some participants, reported by staff, had challenges in expressing emotional responses. And this would influence the measure of observational facial and bodily behaviors that express emotions. 2) Furthermore, we have analyzed the repeated measure using a between-subject way (reasons explained in the previous section - 5.3 "Data Analysis"). It is likely that the number of dropouts from participation sessions and the between-subject analysis may have an influence on the power of statistical analysis. Therefore, this high incidence of participants' dropping out should be considered for future studies when designing experiments with PWD. 3) Lastly, we have used percentage data for video coding analysis of ELICSE. The percentage data describes the proportion of a particular behavior/modifier of the whole attendance duration. Since we discovered significant differences in attendance duration across three conditions, the percentage data analysis did not take into account the total duration of a session. Thus, this could also be a reason for unobserved significance and potential bias.

5.5.2 Positive Impacts on Reducing Apathy and Agitation

The results did not reveal any effect on participants' apathy and agitation during interaction across three conditions. We have two potential reasons for understanding these results. The outcome measures of CMAI and the PEAR-Apathy Subscale were initially developed to evaluate the effectiveness of clinical interventions (such as non-pharmacological interventions) on behavior management in dementia care. Such clinical interventions were often offered on a regular basis for an extended period. Thus, the first interpretation could be that the sensitivity of these scales for assessing the design's effectiveness within a short-term interaction period needs further validation. Second, the extent of intervention exposure could also affect the effectiveness assessment (Wang et al., 2018). Given consideration of the average attendance duration of three conditions lower than 10 minutes, it could also be that the lack of sufficient exposure to such designed intervention caused insufficient behavior changes instead of the inherent applicability of the stimuli type.

The literature has shown that many previous studies have adopted challenging behaviors of PWD as a standard for evaluating a designed product, system, or agent's impact on users. References such as (Moyle et al., 2015), (Libin & Cohen-Mansfield, 2004), and (Wilkinson et al., 2017). However, given the display of challenging behaviors is more individual-based, the use of these measures could be better supported with other user engagement assessments for evaluating a design's impact on dementia users during a short interaction session.

5.5.3 Limitations

Besides the limitation mentioned above regarding the statistical analysis, this study has other limitations. The main limitation lies with the small sample size with various conditions of each individual. The individual difference was unavoidable given the participants were recruited within a specific location of the residential care home of PWD. The participants were composed of different etiologies, severities, language skills, motivational disorders (i.e., level of apathy at a baseline), medication use, mobilities, personalities, background, and preferences. These features will influence our evaluations, and consequently, the results. Therefore, we could not make a strong claim based on this. However, our quantitative research using mixed methods enabled us to gain a deeper understanding of users' observable facets of engagement, and the findings are encouraging. As the second limitation, the evaluation of engagement and challenging behaviors were focused on interaction-triggered short-term evaluations instead of longer-term ones. Therefore, further extended studies with a larger scale of participants from different locations with both short-term and long-term engagement evaluations should be performed. The third limitation concerns the learning effect when being repeatedly exposed to the installation. The participants may lose their interest after several experiences with the installation and watching the animals come to drink water. However, we assume that most of the participants would not remember their previous participation, given the relatively low frequency - once in a week - of participation, and moderate to severe memory deteriorations of the majority of the participants.

5.6 Reflections

5.6.1 Tangibility, Multimodality, and Interactivity: To What Extent Could Each Feature Impact Engagement of PWD?

In our discussion, we proposed three features that are associated with investigated tangible rich interaction and could potentially, to some extent, influence user engagement of PWD – the tangibility, multimodality (in terms of output of a system design), and interactivity. Since we have only explored with or without tangible rich interaction in this study, it is interesting to extend the study further and investigate to what extent these features would have an impact on user engagement. This topic will be further addressed in chapters 6 and 7.

5.6.2 Tangible Benefits for the Cognitive and Mental Well-being

As reviewed in Chapter 2, tangible assistive technologies composed a major body of work for promoting the quality of life and well-being of PWD. Using a tangible user interface or tangible interaction has many reported benefits (Shaer & Hornecker, 2010), (Iversen, 2015), (Marshall et al., 2007). It represents an increasingly popular approach for 1) addressing technology accessibility challenges that allow more intuitive interaction through affordances; 2) promoting physical body movement and maintaining mobility due to its nature of physicality; 3) facilitating reminiscence activities due to the concreteness and relatable quality of physical artifacts. All above could be summarized as “Tangible Benefits” that provide valuable insights when designing for user groups such as PWD. In addition, the literature suggests the “tangible benefits” also cover its advantages on social interaction for the elderly (Bong et al., 2018). Different from all the above embodied, physical, and social aspects of the tangible benefits, this study has derived another layer of tangible benefits for the cognitive and mental well-being:

Tangible rich interaction for PWD not only promotes embodied, physical body involvement, and social collaboration, but could also benefit mental and cognitive aspects such as increasing attention, focus, and concentration.

It is not surprising that tangible interaction has been widely employed in designing for PWD, as embodiment and cognition are closely linked. The findings of the study have shown a potential influence of tangible rich interaction in promoting the attention aspect of engagement in dementia care. Further extended work could bring tangible interaction and cognition science together to help better reveal the underlying mechanism.

5.6.3 Passive vs. Active Experience: Do We Need a Multisensory Experience to be Interactive for PWD?

Nakatsu et al. (2005) proposed a framework for categorizing human activities in relation to entertainment experience using a dimension of two poles: passive versus active experience. The passive experience emphasizes a series of internal mental activities (e.g., watching a movie), while active experience addresses active participation in a dynamic situation (e.g., playing a sport). And the integration of passive and active experiences was suggested to be more enjoyable than each separately could achieve. Consistent with this finding, our study compared two experimental conditions – CTN versus VCTN. The results revealed a certain level of superiority of CTN over watching a virtual hand pumping and feeding the animals regardless of individual conditions. However, unique personal conditions do need to be taken into consideration. For example, a participant with poor verbal skills and low mobility could benefit largely from a lean-back sensory experience. For a design that faces a community of users, it would be valuable to provide varying levels of experiences through dynamic adaptive design that takes care of various needs, including those that are wheel-chair bond, sensory impaired, and physically deteriorated. Therefore, future work could see to exploit how to design interactive systems to meet various levels of needs of users with dementia living in a specific context of LTC.

5.7 Conclusion

Answering the research question – **RQ2.a**: To what extent can properly designed interactive systems with rich interaction - tangible augmentation of *Closer to Nature* - have an impact on enhancing user engagement and help to manage challenging behaviors such as apathy and agitation for PWD living in the specific context within LTC? We have conducted an experiment with two experimental conditions – with and without tangible rich interaction, and one control condition – manipulative tactile stimuli interaction, with 15 residents living in Vitalis nursing home. A mixed method of video coding analysis and observational rating scales were used for quantitatively assessing user engagement and challenging behaviors (i.e., apathy and agitation). The statistical analysis demonstrated significant positive impacts of adding tangible rich interaction on enhancing user engagement in terms of attention aspect and enabling recollection of memories through verbal communications. The findings also indicate a trend in promoting positive user emotions and reducing apathetic behaviors.

To interpret our findings, we offered explanations regarding the significant positive impact on the attention aspect of the engagement. Three potential contributing features of interactive system design were addressed, namely tangibility, multimodality, and interactivity. Further extended studies are needed to explore to what extent these features could influence user engagement of PWD. In addition, to understand the lack of significant impact on users' emotional aspect of engagement, we propose that future provocative strategies for promoting positive emotional responses are needed.

In summary, these findings have contributed to the related field by:

1. Deepened the understanding of why rich interaction is needed when designing for PWD.
2. Addressed how tangible interaction could benefit PWD besides its advantages in promoting accessibility, physical movement, and social interaction, but also in a mentally and cognitive way that holds great potential to help with attention, focus, and concentration.
3. Moreover, it raised the reflection of dynamic adaptivity of system design to cope and support various levels of PWD's needs within the context of LTC.

Chapter 6 | Design of the *LiveNature*[16]

Enhancing Affective Engagement through Social Robot-Assisted Rich Interaction

6.1 Introduction

The qualitative and quantitative evaluations of *Closer to Nature* presented in the previous two chapters provide valuable insights and key design recommendations for guiding our next step of research. The preliminary user study of chapter 4 indicates that participants who are wheelchair-bound are reluctant to use the water pump considering the position and height of the pump (Feng et al., 2018b). Thus, interactions that require a lower threshold of motor effort are required to meet their needs. Furthermore, chapter 5 investigated how the "rich" part of interaction would impact the engagement and behaviors of PWD. Overall, the statistical findings through a mixed method of video coding analysis and rating scales in Chapter 5 confirmed the contributing role of tangible rich interaction on user engagement. Results also revealed that the rich interaction through tangible augmentation had a significant positive impact on the PWD's *Attention* aspect of engagement. However, no statistical difference was found on the *Valence* aspect. In order to further enhance user engagement, proactive strategies that provoke affective responses of PWD should be addressed.

Therefore, based on lessons learned from the research performed in Chapters 4 and 5, this chapter attempts to address the following objectives:

- Propose design approaches for enhancing affective engagement, adapting to various user needs within the context of LTC, and strengthening the "rich" quality of the interaction.
- Present new design iterations based on previous work of *Closer to Nature* as a meaningful activity for PWD living in Vitalis; and implement this version of the design prototype in the real-life living

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[16] **This chapter is largely based on**
Feng, Y., Yu, S., van de Mortel, D., Barakova, E., Hu, J. and Rauterberg, M., (2019) LiveNature: Ambient Display and Social Robot-Facilitated Multi-Sensory Engagement for People with Dementia. In Proceedings of Designing Interactive Systems Conference (pp. 1321-1333). ACM.

environment for further investigations.

- Gather preliminary feedback on the effectiveness of implemented new prototype from multi-stakeholders within the LTC environment, including participating residents, visiting family members, professional caregivers (i.e., caregivers), and volunteer caregivers (i.e., volunteers).

The current chapter presents the design approaches, iterative design process, implementation, and qualitative user evaluation of a newly developed concept – *LiveNature*. *LiveNature* is an iterated design based on the existing installation of *Closer to Nature* (described as the augmented reality display in the below content), and in addition involves an animal-like social robot. The design aims to provide a vivid and holistic multisensory environment by enabling rich interaction possibilities.

6.2 Design Approaches

6.2.1 Animal-assisted Therapy and Animal-like Social Robots in Dementia Care

Animal-assisted therapy (AAT) was investigated over the last few decades in well-being research for rehabilitation of different pathologies, including PWD. This particular approach aims to promote social behaviors, motivation, and learning through contact with real animals. Sufficient anecdotal evidence suggests that AAT has short and long-term effects on mental and physical abilities (Lai et al., 2019). It was reported can alleviate mood, bring relaxation, pleasure, and contentment (Filan & Llewellyn-Jones, 2006), help with communication, attention, memory, and concentration (Peluso et al., 2018), and reduce anxiety, sadness, and loneliness (Koukourikos et al., 2019). However, AAT was often reported lack of use in residential facilities, as it raises safety hazards (e.g., allergies, infection, or injury) and overburdens caregivers (e.g., extra work of cleaning and taking care of the animals) (Beck, 2000). To avoid such issues in practice, many animal-related stimuli such as plush toys, animal sounds or videos, and animal-like social robots were adopted as substitutes for acquiring similar benefits when being accompanied by real animals.

Social robots have been widely researched and adopted within dementia care to evoke positive human emotions and motivate communications (Broekens et al., 2009), (Mordoch et al., 2013). Unlike humanoid robots (with the appearance that resembles a human), the animal-like social robot is one major area that has been intensively researched. Such robotic pets are designed to provide companion and social support and demonstrate similar positive effects as AAT for improving PWD's quality of life (Wada et al., 2008), (Broekens et al., 2009). Initial evidence of empirical studies has confirmed the therapeutic effects, including enriching social interactions, improving affect, providing companionship and motivation (Chen et al., 2018), (Bemelmans et al., 2012), (Góngora Alonso et al., 2019), (Khosla et al., 2019). Within animal-like robotic research, most effort has been made on PARO, a commercially available baby seal robot with its attractive white appearance, furry texture, and eye/tail movement (Wada et al., 2008). PARO was researched worldwide and proven can improve communication and regulate anxiety, depression, and agitation (Moyle et al., 2017b), (Takayanagi et al., 2014), (Chang et al., 2013), (Valentí Soler et al., 2015), (Hung et al., 2019). The therapeutic sessions were successful for all stages of dementia. Since the interaction process is familiar (e.g., stroking an animal), they can use pre-existing knowledge of how the animal reacts as a reference for shaping the interaction when encountering a robot. Other cases that were used in dementia-related research, include AIBO® (Sony Corporation, Japan), a robotic dog (Kramer et al., 2009); NeCoRo® (Omron Corporation, Japan), a robotic cat (Libin & Cohen-Mansfield, 2004); Huggable (Stiehl et al., 2006) and CuDDler (Moyle et al., 2016), robotic teddy bears; and Pleo (Ugobe Corporation), a robotic dinosaur (Fernaeus et al., 2010), (Perugia et al., 2017a). All the above robots are equipped with multiple sensors, designed with a cute and inviting appearance, and behave to evoke positive human emotions.

Regarding the objectives of robotic research on dementia care, the majority of efforts have been invested in gathering evidence to prove the effectiveness of interaction with off-the-shelf robots in promoting social engagement (McGlynn et al., 2017), (Šabanović, 2010), supporting care activity (Bemelmans et al., 2012), and regulating challenging behaviors such as anxiety (Góngora Alonso et al., 2019), depression (Chen et al., 2018), and agitation (Moyle et al., 2017b). Other researchers looked into how to improve robotic designs to serve the emotional and mental needs of PWD better. And these works were well discussed with ethical reflections on robot use for the elderly in general (Frennert & Östlund, 2014), (Sharkey, 2014), (Lazar et al., 2016c). Although social robotic studies have presented promising evidence in engaging PWD, reports show that facilitating a human-robot interaction (HRI) session with PWD can be challenging in its initial phase during practice (Frennert & Östlund, 2014), (Hung et al., 2019). One challenge is that caregivers typically need to create a story narrative to explain why they are bringing this "animal" to the residents (Whelan et al., 2018). Moreover, recent studies of these robots as interventions for PWD emphasize not only an understanding of revoked emotions and behaviors, but also potential influences from social contexts (Chang et al., 2013), (Salam et al., 2015), (Hoffman et al., 2016), (Hendrix et al., 2019). Therefore, in order to maximize its positive effects, the context of use and proper facilitation of these social robots need to be properly designed and guided during an interaction.

In our case of the *LiveNature* design, we propose the extended use of animal figures and the involvement of an animal-like social robot to promote positive emotional responses of PWD. The use of an animal-like agent as an element of nature appears to be a reasonable choice and means that social robots naturally blend into the simulated nature connecting experience. It reinforces the multisensory experience by adding tactile interactions through the furry textile covered on the robot and well-designed audio and behavioral feedback. The system design and the robot implementation will be explained in later sections. The utilization of a social robot in the final iteration design of *LiveNature* will be further explained by the iterative design process.

6.2.2 Ambient Display with Social Robot for Peripheral-Proximal Interaction

As a second approach, we propose a combination of peripheral interaction and proximal interaction through the combined use of the ambient display (i.e., augmented reality display) with a social robot to potentially help sustain user's interests, adapt to various user needs and preferences while "in the moment" of an activity.

Peripheral interaction describes a scene in which users can interact with the designed interactive system at the periphery of their attention. This interaction may also shift to the center of their attention when relevant (Bakker et al., 2015). We encounter many cases of peripheral monitoring of information in daily life, such as checking clocks and windows. Ambient displays, as a subset of peripheral displays, provide continuing displayed information that can be monitored by users without requiring their focused attention. These displays sit at the periphery of attention and provide relevant information such as the time or weather. Ambient displays as enhanced computational artifacts can easily blend into the environment, offering a natural method of interaction (Mankoff & Dey, 2003). They provide continued access to users, are available to a broad audience, and have the ambitious goal of presenting information without distracting or burdening them. In an application for PWD, such ambient displays are usually in the form of a calendar, a digital family portrait, a window, or ambient lighting (van Hoof et al., 2009), (Consolvo et al., 2004). They function as a way of presenting useful information to support daily living, reminiscence activity, or relaxation through calm technology.

Researchers in HCI have also constructed tools and techniques for tangible, sensing-based ambient displays as a way of combining the peripheral monitoring of information with embodied interactions. Examples are VENSTER - an interactive window for a simulated outlooking experience of PWD (Luyten et al., 2018), and Ambient Activity Technology unit - a wall-mounted installation with a tangible interface for personalized reminiscence (Wilkinson et al., 2017).

Inspired by peripheral interaction and ambient displays, we consider a shifting role of our previous design - the augmented reality display that provides nature connecting experience to a narrative context for the HRI. In *LiveNature*, we attempt to create a scenario in which peripheral attention is applied to allow PWD to enjoy a multisensory experience from the ambient nature soundscape and natural scene on a screen, whilst their center attention is focused on interacting with the therapeutic social robot. Since the HRI is designed to trigger feedback from both the augmented reality display and the robot, we consider the loop of input on the robot and output from the ambient display as peripheral interaction, and input and output from the robot as proximal interaction[17]. The interaction between the user and a social robot is mediated by touch, which by nature requires the user to be close to the social agent. This physical spatial proximity is believed can naturally influence the social bonding experiences of PWD (Morrissey et al., 2016). Adopting both peripheral and proximal interaction in our work allows the system to offer multiple ways of engagement through self-exploration and interpretation. Thus, it is more likely to engage a broader spectrum of users and maintain attentiveness as they could shift their attention between different agents to remain in a flow.

In the next section, we show how we unfolded design in practice through the iterative design process, further explain the reason for adopting a social robot and present the final design of *LiveNature*.

6.3 Iterative Design Process towards the *LiveNature*

6.3.1 First Design Iteration

The iterative design process involves co-creation with key stakeholders to gather essential knowledge and insights. The first design iteration addresses the issue of how to initiate user engagement better. We learned from the previous user study of *Closer to Nature* that although residents

[17] Proximal, as the opposite of distal, here describes a close physical distance between the user and a social robot.

enjoyed the surprising experiences when the animals appeared, they tended to forget what triggered this appearance and sometimes even the existence of the installation itself (Feng et al., 2018b). Therefore, we placed some figures of farm animals, such as decorations and plush toys, within their living environment to remind residents of the installation, see Figures 6.1 (a) and (b). We also added a video to the installation, which appeared every 25 mins when no interaction was detected (with footage of a sheep that tries and fails to drink water and then leaves) to motivate interaction, see Figure 6.1 (c). The feedback from caregivers suggests that the influence of these animal figures was too subtle and was seldom noticed by PWD. However, the added footage of the activating scene worked well, as expected, as it captured residents' attention and provoked interaction.

6.3.2 Second Design Iteration

We noticed from our previous study with *Closer to Nature* that participants would sometimes reach out toward the screen display as if to pet the animals. This generated the second design iteration, in which a physical model of a goat was employed to extend the virtual animal into the physical world for the completeness of the multisensory environment through tactile stimuli. As shown in Figure 6.1 (d), a goat prototype covered with furry textiles and woven patches of conductive sensors was developed. The prototype is a mediator for the connection between the visual farm scene and the physical context of the residents. In addition, videos equipped with nature soundscape replaced the original background noise. The nature soundscape (including birds singing, wind, and animal sounds) blended into the indoor acoustic environment and was expected to be pleasant, calming, and relaxing for residents (Yu et al., 2016). We also set a timer in the processing program to dim video's brightness at night. Hence, the installation could also operate as a reminder to distinguish between day and night routines for residents. The feedback on this iteration suggested that the interactive goat prototype offered modest promise in terms of its usefulness without the expected bonding effects. The users viewed it as too statue-like and perceived it as "dead". And this further leads to the utilization of a sheep appearance robot that responds to user input. The other two changes (the additional sounds and the tactile exterior of the goat) were helpful in practice and successfully created an immersive sensory experience.

6.3.3 Third Design Iteration – the *LiveNature*

The above work led to the third iteration - an interactive system design of

Figure 6.1 (a) and (b) Examples of the distributed decorations of farm animals in the first design iteration; (c) A snapshot of the video of a sheep that tries and fails to drink water; (d) The second design iteration, in which an interactive goat covered with conductive sensor patches was developed.

Figure 6.2 Design of *LiveNature*, as implemented in Vitalis including the ambient display unit and an interactive robotic sheep.

LiveNature (Feng et al., 2019). *LiveNature* engages PWD in a holistic “living in nature” experience through the combined use of an augmented reality display mounted on the wall and an interactive robotic sheep. The augmented reality display attempts to provide an immersive multisensory experience through dynamic media content and tangible augmentations.

The interactive robot strives to reinforce the tactile sensations for the completeness of the multisensory engagement and provide rich interaction through embodied interaction from HRI (Bainbridge et al., 2011). See Figure 6.2.

The robotic sheep works as a tangible interface to interact with multisensory media content. The dynamic context was responsive, as the interaction with the robotic sheep triggers both motion and sound feedback of the robot and visual-audio responses from the display. When it senses touch input from users, the robotic sheep moves its legs, neck, head, and tail and makes happy sounds to evoke human emotions. Additionally, the content on display will change status from a more static (e.g., sheep lying on the ground) to an active one (e.g., sheep herd becoming more alert and active, gathering in front of the display and curious about user's behavior). The designed activity aims to provoke the playful experiences of "sensation", "relaxation", and "reminiscence", and those three were suggested to be suitable for the capacity of a larger audience of PWD regardless of the severity of their condition (Anderiesen, 2017). The system design of *LiveNature* responds to interactions with both the old-fashioned water pump and the robotic sheep.

System Implementations

Controlling hardware. The system design was modified based on the implemented *Closer to Nature* situated at the same location of Vitalis, with the controlling software re-programmed using the software Processing. The controlling hardware includes a computer (MSI Nightblade MI B089) located in between the newly built walls (for embedding the screen display) and the original wall of the Vitalis facility for video content processing; and a custom-made Arduino enclosure (Arduino Uno with an extension board) to control the sensors and actuators. The computer also connects to the Wi-Fi provided by Vitalis for remote control.

Media content. Unlike the *Closer to Nature* installation that plays a farm scene without animals or close shot of animal feeding videos when the system detected an interaction. We replaced the video content with a more serene view of a grass field with a herd of sheep to simulate a window outlook experience, see Figure 6.2. The role of farm animals in providing relaxation, reducing anxiety and depression, generate valued relationships is a relatively new area of research (Pedersen et al., 2012). Recent research looked at the values of specific animal species on well-being and suggested lambs in spring are attractive and the ultimate expression of joy (Hassink et al., 2017). Thus, we played the typical Dutch farm scenery of a herd of sheep with the nature soundscape using the 87-

inch high-definition screen display (BenQ, 87'). The nature media content and soundscapes were adopted to emulate nature-assisted therapy's soothing effects and avoid over-stimulation of senses in the LTC environment (Howell et al., 2011).

Embedding the Robotic Sheep

The robotic sheep extends the idea of a physical animal figure and provides tactile interaction with a lower threshold of motor effort (petting and holding), thus addressing users' needs in wheelchairs. Previous research regarding robotics design suggests that such soft and furry features can initiate users to touch, cuddle, and hug it (Bradwell et al., 2019). A model of the sheep was chosen, as its fur has a denser and fuller textile quality. The robotic sheep prototype was developed by appearance transformation using a vivid lamb (i.e., baby sheep) toy and re-programming the Pleo robot using the Pleorb Development Kit (PrbDK), see Figure 6.3 (a).

Appearance transformation of the robotic sheep. We disguised the appearance of the Pleo as a lamb and equipped it with a furry textile and a soft stuffing material underneath, so it felt soft upon hugging and touching. The reasons for choosing the Pleo robot are:

1. After the appearance transformation, the size of the robotic sheep (length ± 50 cm, width 17 cm, height 27 cm with legs outstretched) and weight (approximately 4 kg) is similar to a real lamb, as shown in Figure 6.3 (b).
2. The Pleo robot has well-developed recognizable emotional behaviors available by the producing company (e.g., happy, sad, tired, angry, hungry, and miscellaneous) that were shown to provoke human emotional responses. Figures 6.4 (a) and (b) show example behaviors when a touch input is sensed.
3. It allows customization within the context of its operating system, Life OS. Researchers could change the way Pleo behaves and sounds. Moreover, it is equipped with multiple embedded sensors (e.g., capacitive sensors, ground sensors, force feedback sensors, microphones, a color camera, an infrared interrupter, infrared transmitter, tilt/shake sensors, and motors) for the possibility of re-programming.
4. The mechanical sound caused by the motors of the Pleo is at a tolerable level. Therefore, it is more likely to be perceived as an animal than a machine by the elderly adults given the hearing impairment.

Figure 6.3 (a) The appearance transformation of the Pleo robot using a lamb toy; (b) The interactive robotic sheep with size and weight similar to a real lamb; (c) User evaluation in Vitalis with a participating resident.

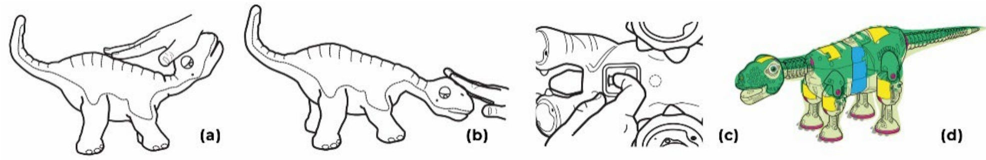


Figure 6.4 (a) and (b) Example emotional behaviors of the Pleo robot available by the producing company; (c) The micro-SD card slot for re-programming the Pleo robot which is located inside the battery slot of the Pleo robot; (d) An illustration of the Pleo robot with sensors located throughout the body for lifelike movements. Touch sensors are marked using yellow.

Re-programming the Pleo robot. We re-programed the Pleo to allow the robot to behave and sound more like a real lamb. This was achieved through three steps: 1) program using the PrbDK environment; 2) load the program files to a micro-SD card; 3) insert the micro-SD card in the card reader located inside the battery slot of the Pleo robot, see Figure 6.4 (c). Given considerations of potential tactile interaction that requires a lower threshold of motor efforts such as petting and holding, we utilized pre-embedded capacitive touch sensors to program purposeful movements. See areas in Figure 6.4 (d) marked yellow. When a touch input is detected, we invoke different pre-existing motions of Pleo categorized as “happy” emotional behaviors via the programming for potential positive affective engagement.

6.4 Adaptive System Design of the *LiveNature*

LiveNature is a system consisting of an augmented reality display and a robotic sheep. The augmented reality display focuses on presenting ambient sensory content using users’ peripheral attention. The robotic sheep emphasizes promoting social connection through emotional interaction via focused attention. We believe that through this

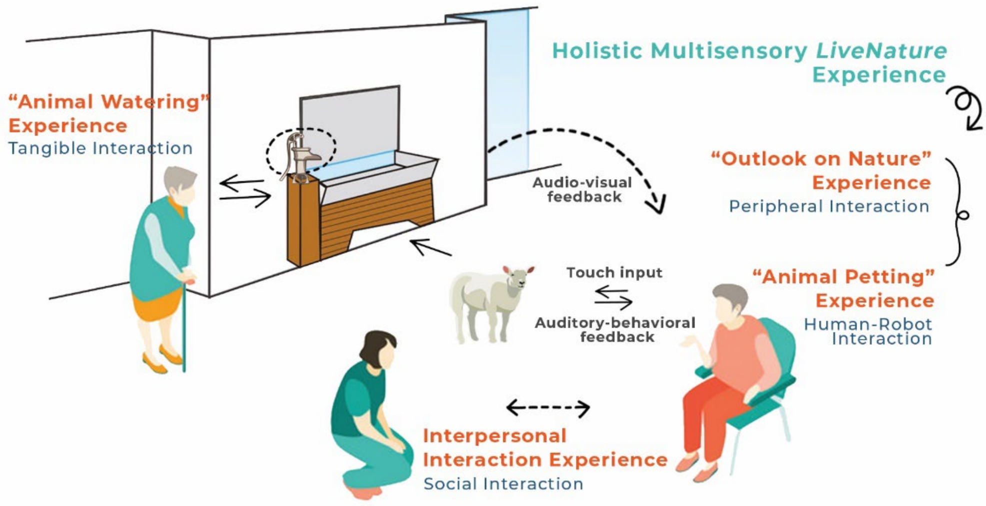


Figure 6.5 An illustration of 5 avenues for engaging residents living in the Vitalis care facility through the design of *LiveNature*.

combination, *LiveNature* can (1) offer users long-term access to the installation design; (2) sustain attention and interest during engagement by providing multiple feedback from both the robot and the screen display; and (3) create a context for improving the acceptance of the HRI for PWD (Leite et al., 2017). In addition, (4) through this combination, we believe that users are more likely to experience positive emotions and achieve the expected therapeutic effects than with a singular sensory stimulated experience or an interaction session with a social robot.

The final system design of *LiveNature* aims to address varied user needs through dynamic adaptive system design. It provides multiple avenues for engagement experiences through self-exploring enabled interaction possibilities, as shown in Figure 6.5:

- **The holistic multisensory *LiveNature* experience.** In the best use scenario, the system provides an immersive multisensory experience that maintains the user's flow of attention, shifting between watching the display and interacting with the robotic sheep, and with the display through the robotic sheep. The acoustic environment, interactive video content, and tactile interaction contribute to the completeness of the multisensory engagement.
- **"Animal petting" experience.** In the case where the user concentrates only on the interaction with the robotic sheep, reflecting the later stages of dementia in which some tend to live in their own world, the system performs as a typical social robot for the

enjoyment of an “animal petting” experience.

- **“Animal watering” experience.** In cases where the user ignores or refuses to interact with the robotic sheep, they are still offered the animal watering experience using the old-fashioned water pump.
- **“Outlook on nature” experience.** When no interaction occurs, the system will continue to provide a relaxing “outlook on nature” experience, and encourages “in the moment” enjoyment, whereby users are able to watch an ambient relaxing video of a farm with a flock of sheep or listen to a nature soundscape of birds singing and the wind blowing.
- **Interpersonal interaction experience.** The system also performs as a bridge to increase social bonding. It encourages the involvement of other key stakeholders (i.e., caregivers, volunteers, family, and visitors) in the interaction.

6.5 User Study

6.5.1 Study Design and Participants

We conducted a field study to evaluate the overall experience of *LiveNature* using qualitative interviews and gather insights from three types of users: residents living in Vitalis, family members, and staff, including caregivers and volunteers. Two evaluation settings were adopted in this study, with setting 1 – tangible interface augmented installation interaction (interaction with *Closer to Nature*); and setting 2 – robot-assisted installation interaction (interaction with *LiveNature*). Setting 1 was used as a baseline for a comparison study.

Twenty participants, including nine residents, five family members (two spouses, two daughters, and a son), two caregivers (one male and one female), and four volunteers (all female) participated in the user study. The inclusion criteria for residents with dementia are the physical ability to sit, hold and interact with the robotic sheep. The exclusion criteria are acute visual or auditory impairment reported by staff. Nine residents (female n = 7, male n = 2, age range 78 - 92) were invited one by one for interaction sessions accompanied by a trained facilitator. Then, this was followed by a 10-minute interview. All residents participated in both two experiment settings at separate times. If their family members were at the location for visiting, they were invited for the interaction session and interviews. Caregivers and volunteers were interviewed independently. Demographic information of the participating residents was collected

Table 6.1 Demographics of participating residents.

Participants	Gender	Age	Stage of dementia	Type of dementia	MMSE Score	Reported restraints by staff
P1	M	90	Moderate	VD	12	None
P2	F	92	Moderate	MD	12	None
P3	F	89	Mild	AD	21	None
P4	F	81	Severe	MD	0	L/E
P5	F	80	Severe	AD	0	L/E
P6	F	78	Severe	VD	7	L
P7	F	80	Moderate	MD	18	None
P8	F	81	Severe	MD	9	None
P9	M	86	Mild	AD	23	None

Note: Abbreviations, Type of dementia: "AD" is an abbreviation for Alzheimer's dementia, "VD" for vascular dementia, "MD" for mixed dementia; "Restraints" is short for restraints reported by staff, "L": limitation of language expression, "L/E": limitation of language and emotional expression.

based on staff reports, as shown in Table 6.1.

6.5.2 Method

The interview questions for participated residents focused mainly on: 1) general impressions of the installation design; 2) interaction experience with the robotic sheep 3) participants' personal experiences related to the interaction experience; and 4) potential suggestions for improvements. The interview questions for family members, caregivers, and volunteers cover topics of 1) perceived user experiences of PWD with the installation; 2) daily leisure/care activities with family members/clients; and 3) suggestions, comments, and concerns for improvements. Qualitative data, including audio recordings of interview sessions and notes taken by an observer, were collected through semi-structured interviews and direct observations. Data of qualitative interviews were transcribed, translated, and analyzed in NVivo using thematic analysis (Braun & Clarke, 2006).

6.5.3 Results

Feedback from Participating Residents

Common feedback from the study of both evaluation settings included **expressed enjoyment**, **recollected memories**, and **facilitated verbal communication**. Communicated positive experiences and enjoyment were recorded for the majority of participants (6 out of 9, 3 participants were limited by language expression) in both study settings. Participants commented on how much they liked the beautiful scenery in the display, how they appreciated the installation, and how they enjoyed sharing the experiences with the facilitator. Phrases such as "*this is nice*," "*this is beautiful*," "*I like sitting here with you*," and "*I can do this all day long*" often arose during study sessions. The qualitative results also showed that both settings could help recollect memories and perform as tools for facilitating communication. Many participants shared their prior experiences on a farm as well as stories about their occupation, hobbies, residence, and pets. The designed settings succeeded in encouraging conversations with an unfamiliar person (the facilitator) about their personal experiences, which rarely happens during regularly scheduled activities or daily social interactions. The findings below are described using example quotations with the coded representations of participation.

The results from the qualitative data also indicate differences between the two study settings in terms of restoring communications. The setting of *LiveNature* generated a broader spectrum of conversation topics than *Closer to Nature*. Participants talked mainly about themselves in *Closer to Nature*, while several participants (P1, P2, P7, P8) extended the topic of conversation to their children or grandchildren in the *LiveNature* setting. P7 said the sheep reminded her of children; she used to be a babysitter and would bring them to a farm to feed the animals. P1 spoke about his children as if they were still young and expressed his feelings towards the robotic sheep politely, saying, "*…the children would love it, you know*".

The involvement of the robotic sheep in the *LiveNature* setting provoked different emotional reactions toward the interaction. Figure 6.6 shows examples of participants interacting with the robotic sheep. Most participants (except P1 and P4) displayed pleasure towards the robotic sheep, appraising it as looking cute, adorable, and soft, and even naming it. P2 said, "*It is nice even just holding it. It feels soft—oh, it is moving towards me.*" Some were surprised when they realized that robotic sheep was a robot and could respond to their touch behaviors. P3 discussed with the facilitator about how to enable the sensors and expressed pride after finally figuring out where to touch to trigger sound and movements. P8 was confused by the realistic movement and sound effects of the robotic sheep and thought it was a real sheep. When it was suggested that she return the robotic sheep, she said, "*I can't give this to you; it costs money, you know.*" Some participants (P5, P6, and P7) were also surprised by the feedback through the screen display when interacting with the robotic sheep, as the relative static content of sheep herd resting and eating grass has shifted to a more activating scene with sheep gathering towards the virtual water bin. P5 turned the robotic sheep towards the display when sensing the feedback and said, "*Look, you need to look.*" (P5 suffered from language expression disorder and did not usually speak). There were other findings from participants. For instance, the robotic sheep was considered rather large and heavy. Participants P3, P7, and P9 appreciated the role of

Figure 6.6 Examples of participants interacting with the *LiveNature installation with the robotic sheep*. (a) A participant who was holding and kissing the robotic sheep. (b) A participant who turned the robotic sheep towards the screen and showed the content on display to the robotic sheep. (c) A participant who was figuring out where to touch to enable the sound and movement feedback.

the facilitator in the social interaction and the opportunity to join the sessions, as they had someone to talk to who would listen to their stories. It was also discovered from P4 that the bird sounds in the soundscape were distracting, as she started to look for the birds at one point.

Perception from Family Members

It was generally agreed by all family members that the installations were well designed and that the sensory experience was valuable for their family members. Some highlighted the sensitive fact that they no longer knew what to talk about when visiting. During the interview, a daughter of P6 said, "*It is hard to let her go into a nursing home and see her condition getting worse every day. The disease developed quite rapidly and severely*"; "*I used to come here and read newspapers with her—now all I do is push her out for a walk*." When she observed P6 in the *LiveNature* setting with the robotic sheep on her lap, she felt that her mother "*woke up*" when seeing the animals and started responding to her, for which she felt very grateful. P1 was visited by his daughter and two grandsons, and they were therefore invited to participate in the study together. His grandchildren used to arrive, say "*hello*", and then leave, but now they come to *LiveNature* and play together with the grandfather. The daughter of P1 said, "*It works really well as a starting point for a conversation.*" The attitudes towards the robotic sheep of the spouses were less positive than those of the children; they were emotional and did not accept that their husbands happily played with a toy-like robot. However, they confirmed the benefits of companionship; as one interviewed spouse said, "*He would really enjoy the company of a dog. As you can see, there are not many animals around here, for safety reasons, I guess. It would be nice to have a companion for the elderly here.*"

Feedback and Suggestions from Caregivers and Volunteers

The feedback from caregivers and volunteers also acknowledged the benefits of the sensory experience, its attractive visual appearance, the tangible interactive components, and its potential positive influence in their everyday lives. They commented that both settings made the environment calming and enjoyable for inhabitants. Two caregivers mentioned the challenges of constantly fulfilling the patients' attention-seeking needs and dealing with their impaired language expression abilities. They commented that both *Closer to Nature* and *LiveNature* made it easier to make a connection with the residents in the shared space. The activation scene worked very well, as it generated curiosity and the interactive experience was beneficial in exercising motor skills. The user study of *LiveNature* also addressed feedback on the robotic sheep. One caregiver explained that they used to have a PARO for robot interaction sessions to engage residents. And then, she compared the use of the robotic sheep with the PARO from the perspective of facilitation. The other caregiver stated that the overall experience of *LiveNature* created a natural introduction for the involvement of the robotic sheep. *LiveNature* provides access to a user scenario that makes facilitation much easier in practice. There were also suggestions for the design of *LiveNature*, for instance, greater movement of the robotic sheep and a louder soundscape from the display to compensate for hearing-impaired users.

6.6 Implications and Future Work

The implications arising from the findings and design research process are discussed here to highlight directions for future work and knowledge sharing with related personnel working in this field.

Design for holistic sensory enrichment. Engaging PWD in activities can be challenging. Therefore, sensory stimulation that speaks to their remaining abilities becomes extremely important. MSS can be used to compensate for sensory deterioration, stimulate remaining functions, or access memories. The holistic sensory experience with visual, audio, and touch explorations can benefit PWD with sensory impairments, mobility constraints, or expression constraints. Therefore, it plays a crucial role in the success of the design to a broader spectrum of PWD. The time span for exposure to sensory stimulation is also significant. Large-scale public displays are an effective approach for providing continued sensory experience, therefore, have great potential in contributing to the overall benefits and longer exposure to sensory enrichment for PWD.

Design strategies for active engagement. Design for PWD aims to actively involve and engage this group of people in meaningful activities. Through the iterative design process, we developed four strategies for designing interactive systems towards active engagement: 1) enable intuitive interaction through design affordance of things PWD are familiar with; 2) capture user interest by using activating scenes/content; (3) maintain user attentiveness through combined peripheral and proximal interaction; (4) expand possibilities for interaction through the dynamic adaptivity of the system design. The first of these focuses on how to initiate interaction through quality aesthetic design, while the second emphasizes fostering engagement through stimulating content. The third aspect addresses system design through a spatial environment, and the last aims to create an adaptive system to meet the needs of a range of users and offer social inclusion.

Reminiscence objects for a new experience. Design for dementia often attempts to access remote memories through reminiscence for therapeutic effect. We aim not only to allow the user to remember the past and live in those happy memories but also to open broader opportunities for different experiences that are stimulating and new. The adoption of reminiscence objects provides tools to facilitate communication in order to enable new experiences of sharing and social bonding with others. This helps us understand how to design and offer new types of interactive systems for promoting well-being in dementia.

User-centered vs. family-oriented. It is essential to reflect on who we are designing for within a specific context of an LTC facility. This process is user-centered; meanwhile, all stakeholders are involved. It is unrealistic to fulfill only the needs of PWD without considering caregivers or to ignore practical institutional constraints. Moreover, should design also consider the perceived impression when people observe the use? During the evaluation, we found that one resident immensely enjoyed the companionship and interaction with the robotic sheep. At the same time, his wife was not excited to see her loved one with a toy-like artifact. This raises our reflection on whether the design for dementia should also consider the perceived impression when users are no longer able to think for themselves anymore (Neven, 2010).

Ethical implications. Since this vulnerable user group is, in most cases, unable to make logical decisions and to express agreement or disagreement, we conclude two ethical implications of this study. First, empirical field studies with PWD should consider the protection of the users' autonomy, privacy, and dignity (Sharkey, 2014), (Wallace et al., 2012). We set up clear protocols for obtaining signed, informed consent and for data collection, storage, and access. Second, the nature of care should still be human care (Vallor, 2011). Concerns over the employment of robots in dementia care are often raised, as this tends to replace human relationships with technology (Sharkey & Sharkey, 2012), (Sparrow & Sparrow, 2006), (Turkle, 2017). The design of *LiveNature* does not serve as a replacement for human care, but forms a bridge connecting PWD with caregivers or families. We seek to ensure that a facilitator (or caregiver) is present when *LiveNature* is used in order to ensure qualified, reflective and ethical implementation and use of the interactive system design.

Further study of the following aspects would be valuable. Although the findings suggest that the robotic sheep succeeded in provoking user emotions and facilitating social interactions, the design and implementation of the robotic sheep still require further work to improve the weight, size, movement, and auditory feedback. Moreover, as the robotic sheep is designed to give feedback only when it senses touch input, future work on the provocative behavior of the robotic sheep is needed to help initiate user interaction and maintain user attention. Additionally, a long-term effectiveness study could be valuable to explore the influence of the installation on cognitive and behavior changes. The experimental setting and design of this study only addressed the comparison between *LiveNature* and *Closer to Nature* without further explorations regarding the role of the social robot on PWD. Thus, future studies could be conducted to confirm the benefits of collaboration on the design approaches of the augmented reality display and the social robot. Finally, since our preliminary findings of the qualitative interviews can only provide a general impression of user engagement, further studies through observational behavioral analysis may be beneficial for a more comprehensive understanding of engagement.

6.7 Conclusion

Starting a new life in a nursing home is a difficult choice for PWD and their loved ones. Residents of LTC facilities face challenges arising from environmental and psychosocial factors that make their condition even worse. We aim to make positive changes in their situation through an iterated design called *LiveNature* implemented in their real-life living environment. *LiveNature* used a sheep appearance social robot to promote emotional and social aspects of engagement. It offers holistic multisensory experiences and rich interactions to stimulate multiple senses, and helps maintain cognitive and sensational functions. The design emphasizes social interaction in which technology serves as a medium for facilitating human interaction. It has been proven to help residents living in Vitalis enact embodied behaviors through multiple possibilities for interaction, perceive and express emotions in a tailored context, restore attentiveness and communication, and establish relationships by encouraging communication. Therefore, the system can contribute to an enhanced quality of care and improved quality of life for PWD living in Vitalis.

Chapter 7| Exploring the Role of System Interactivity and Multimodal Stimuli[18]

Effects on Enhancing Engagement of PWD

7.1 Introduction

Engaging in meaningful activities is the key to promoting PWD's quality of life. Previous chapters looked into how interactive system mediated activities could be designed towards an increased level of engagement for PWD from a user-centered perspective. In the current chapter, we aim to address this goal from a system-oriented perspective and investigate two system features that have a potentially positive impact on engagement.

For decades, researchers within the HCI community have been exploring how unique system features can influence user engagement. The "Richness, Control, and Engagement" framework proposed by Rozendaal (2009a) addressed the role of experienced richness and control in determining user engagement. The notion of richness was described as "the range of possibilities afforded by an interactive medium in terms of perception and action". It was influenced by system features at sensorial level - the variety of external sensory stimulation; behavioral level - degree of various behavioral movements enabled; and mental level - curiosity and ambiguity through thought process (Rozendaal, 2007), (Rozendaal et al., 2009b). "Control" emphasizes the balance between personal experiences/skills and system provided challenges.

The experienced richness is suggested by literature accumulated by a system afforded feature named "Interactivity", and the representational richness of a medium named "Vividness" (Rozendaal et al., 2007). Interactivity - which is central to interactive system design - has been well studied for decades and has been defined in many ways. The concept has many varied interpretations according to different perspectives. Interactivity, defined by Steuer (1992), combines both the possibilities of the system and the human action that is needed to bring about these possibilities. With more possibilities to manipulate the system in order to

[18] **This chapter is largely based on**
Feng, Y., Perugia, G., Yu, S., Barakova, E.I., Hu, J., Rauterberg M., 2022. Context-Enhanced Human-Robot Interaction: Exploring the Role of System Interactivity and Multimodal Stimuli on the Engagement of People of Dementia. International Journal of Social Robotics, 14(3), 807-826.

achieve higher goals, the interactivity is therefore increased. For an interaction experience, interactivity has the ability to influence the feeling of control and increase richness at a behavioral level, which consequentially affects the physicality of interaction, while the presented sensory feedback could affect richness at a sensorial level. Therefore, together, they are likely to contribute to enhanced user engagement.

However, few studies extend this research of engagement to dementia users. For PWD with diminished cognitive and functional abilities, and impaired sensory information processing and integration skills, their perceptual and behavioral experience may vary from a general understanding of how user experiences were shaped. In this chapter, we took the research of experienced richness and how it influences user engagement to a specific target user group - PWD. In particular, we investigate how system features of system interactivity and multimodal presentations could impact the engagement of PWD in the specific context of LTC.

To achieve this objective, we conducted a field study with 16 residents from Vitalis based on the interactive system design of *LiveNature*. Participants were engaged in sessions with varying levels of system interactivity and multimodal stimuli implemented through different system design configurations. We present the knowledge acquired from this study and discuss how it could benefit future activity design within dementia care. This chapter contributes by revealing the relationship between experienced richness and engagement of dementia users; and providing new insights about the impact of multimodal stimuli and system interactivity on user engagement which will help design interactive systems for PWD in LTC.

The research questions related to the study aim are:

RQ2.b: *To what extent can the features of rich interaction in terms of the system interactivity and the multimodal stimuli influence the engagement of PWD living in the specific context of an LTC facility - Vitalis?*

Specifically, this chapter answers the following sub-questions:

i. To what extent can different multimodal stimuli provided by system design based on the *LiveNature* influence the engagement of PWD living in the specific context within LTC?

ii. To what extent can the level of system interactivity provided by system design based on the *LiveNature* influence the engagement of PWD living in the specific context within LTC?

iii. To what extent can the interaction effect of multimodal stimuli and the level of system interactivity provided by system design based on the *LiveNature* influence the engagement of PWD living in the specific context within LTC?

7.2 Method

7.2.1 Study Design and Setting

The field study was conducted within the real-life setting of an LTC for PWD with four experimental conditions and one control condition in total. The study design of experimental conditions followed a two-by-two mixed factorial experimental design with one within-subject variable - multimodal stimuli - and one between-subject variable - level of system interactivity. The system interactivity was considered increased when more interaction possibilities were enabled, and the level of multimodal stimuli was considered higher when external stimulation of more sensory channels was provided. The system configurations of *LiveNature* were modified to create different experimental and control conditions. Specifically, the levels of system interactivity (abbreviation as I) were divided according to whether the robotic sheep could be used as a tangible interface for triggering contextual interactions from the augmented reality display; and the levels of multimodal stimuli (abbreviation as M) were defined by whether auditory feedback was presented besides visual-tactile stimuli from both the robot and the display.

In total, there were two levels of experimental conditions within each independent variable (named I1, I2, and M1, M2, respectively), and as the number increases, the level of independent variables increases. The experimental conditions with varying levels are presented with detailed descriptions in Table 7.1. In addition, we adopted a control condition for examining the group difference of engagement at baseline. During the control condition, participants were engaged in interaction with the augmented reality display only.

The prototype was situated at the same location of Vitalis as in previous chapters. Two seats were positioned in front of the display (for one-on-one interaction sessions of a participant and a facilitator) to create a comfortable atmosphere and accommodate wheelchair users, see Figure 6.2. All experiment sessions were recorded with one primary camera (C1, a Microsoft Kinect camera) and two supporting cameras (C2 - a GoPro camera, C3 - a digital camera). See Figure 7.1 for experimental settings.

Table 7.1 Detailed descriptions of four experimental conditions with the level of multimodal stimuli as a within-subject variable and the level of system interactivity as a between-subject variable.

	Multimodal Stimuli Level 1 (M1): Visual-tactile stimuli provided	Multimodal Stimuli Level 2 (M2): Visual-auditory-tactile stimuli provided
System Interactivity Level 1 (I1): The robotic sheep was disconnected from the system	Condition M1I1 The robotic sheep was turned Off and disconnected from the system; Visual content was presented on display.	Condition M2I1 The robotic sheep was turned Off and disconnected from the system; Visual-auditory content was presented on display.
System Interactivity Level 2 (I2): The robotic sheep was connected to the system	Condition M1I2 The robotic sheep was turned On with tactile-motion feedback; HRI triggers visual feedback from display.	Condition M2I2 the robotic sheep was turned On with tactile-motion-sound feedback; HRI triggers visual-auditory feedback from display.

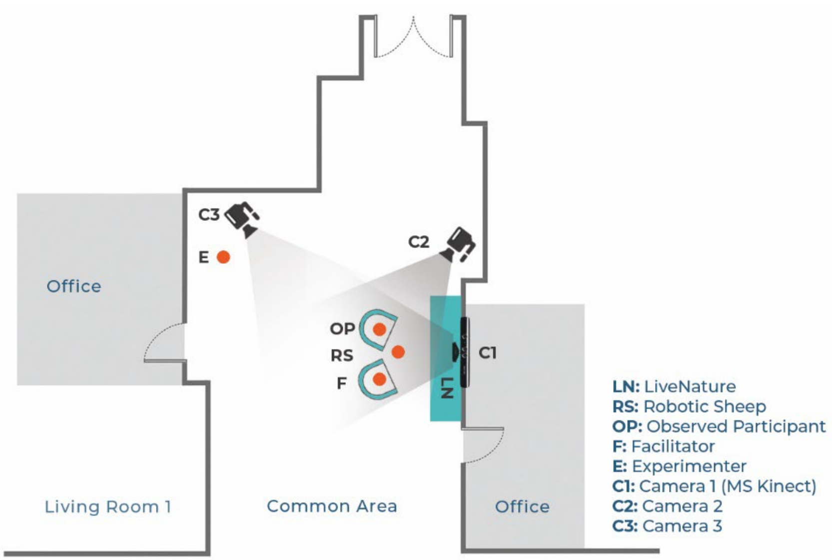


Figure 7.1 Experiment settings with participants, stimuli, and cameras.

7.2.2 Participants

A total of 24 residents were recruited from the Vitalis nursing home. To estimate the required sample size of this study, we performed a priori statistical power analysis using the software package GPower (version 3.1.9.7) (Erdfelder et al., 1996). With effect size set at 0.40 (considered to be large according to Cohen's criteria), an alpha of 0.05, and power = 0.80, the projected sample size needed with this effect size is approximately N = 16 for this within-between interaction comparison. Thus, we recruited more than 16 participants at the beginning of the participant recruitment to make sure the sample size was adequate for the main objective of this

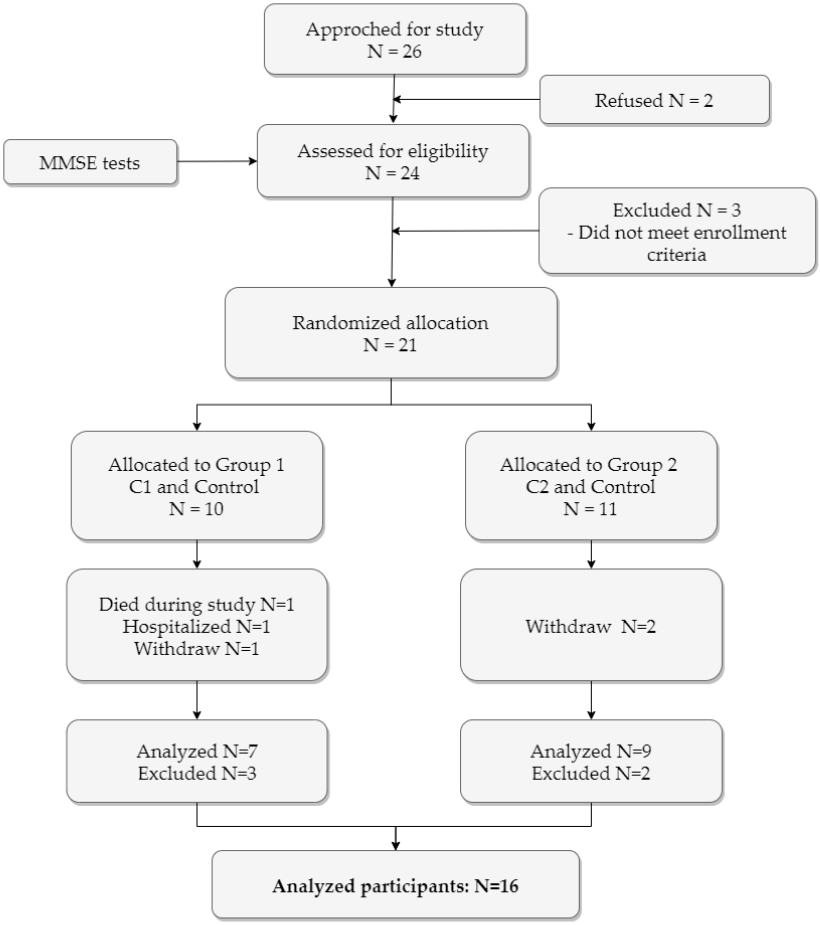


Figure 7.2 Flow diagram of recruitment, enrollment, allocation, and the number of participants.

study. We could not recruit more participants due to the limitation of the capacity of residents living in Vitalis, which is further discussed in the limitation section.

The inclusion criteria were: (1) an MMSE score lower than 24 (25-30 was suggested as normal cognition, and below 24 as cognitive impairment); (2) signed informed consent of participants or their legal guardians. The exclusion criteria were: (1) acute visual or auditory impairment reported by the caregivers; (2) inability to sit, hold or interact with an interactive artifact. Twenty-one participants met the inclusion criteria and were therefore enrolled in the study. Participants were stratified according to their cognitive abilities and randomly assigned to 1 of 2 groups. The initial sample size decreased to 16 during the experiment period due to participants' death (n = 1), hospitalization (n = 1), and dropouts because of other reasons (n = 3). The final sample used in the analysis consisted of 16 participants (4 male, 12 female, M = 85:2, SD = 4:8, age range 78-92 years), with group 1 consisting of seven participants and group 2 of nine participants (uneven number of participants are due to uneven dropouts). See Figure 7.2 for a flow diagram of participants' recruitment, enrollment, and allocation.

Detailed demographic information provided by the medical staff of participants is presented in Table 7.2. We ran t-tests with the group as an independent variable and the sociodemographic and clinical characteristics of the group members as dependent variables. The results suggested no significant differences between the two groups on each characteristic (see Table 7.2). Each participant took part in three sessions in total (including one control condition and two experimental conditions) with one session per week. For instance, group 1 would participate in the control condition, condition M1I1, and condition M2I1; and for group 2, the control condition, condition M1I2, and condition M2I2. The participation order was randomly chosen from all six possibilities of the permutation of three conditions to control counterbalancing effects and assigned to each participant before the whole session started.

7.2.3 Measures

Evaluation of engagement with measures that are reliable, valid, and robust is essential for designing interactive systems. The notion of engagement is challenging to capture, and it is more challenging for PWD due to the accompanied cognitive, functional, and language impairments.

This study adopted a mixed method for a comprehensive assessment of PWD's engagement. Two types of measures were adopted using different data collections, including: (1) video and audio recordings of all experimental conditions were recorded for video coding analysis using an observational video coding scheme - ELICSE (Perugia et al., 2020), (Perugia et al., 2018); (2) rating data of all sessions of both control and experimental conditions were collected using the scale of OME (Cohen-Mansfield & Dakheel-Ali Maha, 2009), OERS (Lawton et al., 1996), and the EPWDS (Jones et al., 2018). The interaction-triggered user engagement (short-term engagement) was assessed using OME, EPWDS, and video analysis based on ELICSE coding scheme, while the affective states of the participants were measured through OERS.

Table 7.2 Sociodemographic characteristics of the participants.

Characteristics	G1 (n = 7)	G2 (n = 9)	p-value
Age (years)			.33
Mean (SD)	86.6 (4.20)	84.1 (5.18)	
Age range	80 - 92	78 - 92	
Gender, n (%)			.79
Female	5 (71.4)	7 (77.8)	
Male	2 (28.6)	2(22.2)	
Marital status, n (%)			.60
Single/Divorced	1 (14.3)	1 (11.1)	
Married	4 (57,1)	4 (44.4)	
Widowed	2 (28.6)	4 (44.4)	
Type of dementia, n (%)			.72
Alzheimer's Dementia	2 (28.6)	3 (33.3)	
Vascular Dementia	1 (14.3)	2 (22.2)	
Other/Mixed Dementia	4 (57,1)	4 (44.4)	
MMSE score			.48
Mean (SD)	14 (5.3)	11.3(8.3)	
Score range	8 - 22	0 - 23	
Dementia severity, n (%)			.86
Mild	1 (14.3)	1 (11.1)	
Middle	2 (28.6)	3 (33.3)	
Middle to severe	3 (42.9)	2 (22.2)	
Severe	1 (14.3)	3 (33.3)	
Mobility, n (%)	3 (42.9)	3 (33.3)	.72
Use wheelchair	3 (33.3)	3 (33.3)	
Use stroller	2 (22.2)	4 (44.4)	
Use none	2 (22.2)	2 (22.2)	

Note: Abbreviations, G1 - group 1; G2 - group 2.

A trained research assistant who was blinded to the study's objectives completed the video coding analysis. Rating scales OME and OERS were completed through direct observation on-site by a facilitator, while EPWDS was rated by a trained research assistant using videos for indirectly observation-based ratings. The EPWDS was rated based on off-site video recordings due to two reasons: 1) practical time limitation between arranged sessions; and 2) the EPWDS was developed based on a previous video coding tool named VC-IOE (Jones et al., 2015) and was originally evaluated using videos materials, see (Jones et al., 2018).

The ELICSE Coding Scheme for Assessing Engagement of Dementia

The ELICSE coding scheme was developed by Perugia et al. (2018). It aims to measure engagement in PWD through observational behaviors. The coding system was built based on the qualitative analysis of body movements to estimate engagement in activities and social interactions (e.g., direct manipulation using hands when playing puzzles indicates that participants are engaging with the game), and the resulting ethograms were structured based on Laban Movement Analysis (Perugia, 2018). The assessment of the intensity of engagement is gauged by observing the body/facial configurations of the person with dementia during the activity and associating them with an engagement score. The coding scheme is composed of *Behaviors* and *Modifiers*. The *Behaviors* identified in ELICSE measure changes in the direction of attention, and the *Modifiers* define whether such behaviors are associated with affective nuance. The original coding scheme, as in (Perugia et al., 2017b), encompasses three behavioral modalities involving three different body parts respectively: the Head, the Torso and the Arms/Hands.

In order to apply the ELICSE to our specific study, we adapted the original coding scheme considering body portion involvement under the particular context of interaction with *LiveNature*. Three pilot tests were carried out with three random participants to see how residents interacted with the designed interactive system to guide and determine the final coding scheme. Based on the pilot test, we employed two modalities – *Head and Arms/Hands Behaviors* from the original ELICSE coding scheme and removed the *Torso Behaviors*. As preliminary observations indicated, those participants in their later stages of the disease (or in the wheelchair) had few torso movements (i.e., torso position changes, e.g., leaning forward to show more engagement). In addition to the selected behavioral modalities, we used an additional cue – *Conversations* in the final coding scheme. The verbal behaviors are congruent with bodily behaviors, and fit the constructs by demonstrating attention focus through conversational counterparts and affective nuance through the content of verbal expressions. They have the potential to compensate for disorders with facial expression or mobility deterioration, hence providing more comprehensive measures of observable facets of engagement.

The adapted ELICSE coding scheme was constructed by three main components: 1) bodily parts that express behaviors involved in engagement (e.g., *Head Behaviors*, *Arms/Hands Behaviors*, and *Conversations*); 2) a cluster of behaviors in which all former body parts share the same focus to demonstrate their focus of attention (e.g., towards *Facilitator*, *Augmented Reality Display*, *Robotic Sheep*, or *None of the Target*); and 3) modifiers added on former behaviors that express a positive, neutral, or negative affective nuance (e.g., *Positive*, *Neutral*, and *Negative Signs of Affection*). The final coding scheme used in the analysis is presented in Table 7.3. See Table D2 of Appendix D for full details with operational descriptions.

Table 7.3 The adapted ELICSE coding scheme used for scoring video recordings of all experimental sessions.

Behaviors	**Modifiers**
Head (Gaze) Behaviors	**Signs of Affection**
Gaze toward the Facilitator (Gaze_F)	With positive signs of affection (_Pos)
Gaze toward the Augmented Reality Display (Gaze_ARD)	With neutral signs of affection
Gaze toward the Robotic Sheep (Gaze_RS)	With negative signs of affection (_Neg)
None of the target gaze behaviors (Gaze_None)	
Arms/Hands Behaviors	**Quality of Reach Out**
Reach out to the Facilitator (Reach_F)	Warmly reach out (_Pos)
Reach out to the Augmented Reality Display (Reach_ARD)	Neutrally reach out
Reach out to/Manipulate the Robotic Sheep (Reach_RS)	Negatively reach out (_Neg)
None of the target hand gestures (Reach_None)	
Conversations	**Quality of Conversations**
Talk to the Facilitator (Talk_F)	Positive verbal engagement with stimulus or the facilitator (_Pos)
Talk to the Robotic Sheep/Sheep on the Screen (Talk_Sheep)	Neutral verbal engagement
Talk to themselves (Talk_Self)	Negative verbal engagement with stimulus or the facilitator (_Neg)
Not understandable conversations (Talk_None)	
Silence (Talk_Sil)	

Note: Behaviors marked in italic style are assigned with modifiers (i.e., positive, neutral, negative nuance). The “stimulus” here refers to both the augmented reality display and the robotic sheep. Detailed operational descriptions are listed in Appendix D, Table D2.

Observational Rating Scales for Assessing Engagement and Affective States

Three observational rating scales with different emphases in terms of engagement evaluation were employed in this study. As a first, OME was employed for assessing *Duration in seconds*, *Attention*, and *Attitude* towards the stimuli, see Appendix C - OME. As a second, we have adopted OERS. Two of the items - *Pleasure* and *General Alertness* - are used in this study. See Appendix C - OERS. OERS was rated based on the extent of each affect expressed towards both the stimulus and human partners (if any).

In addition, EPWDS, a five-point Likert scale, was also adopted for evaluating user engagement within the long-term care setting, see Appendix C - EPWDS (Jones et al., 2018). Differentiated from OME, which mainly focuses on activity participation (engagement with the stimulus), EPWDS emphasizes the social interaction of PWD as well. The scale could compute an overall score to represent engagement states that could be easily compared across different conditions. This 10-item scale measures five dimensions of engagement: *Affective*, *Visual*, *Verbal*, *Behavioral*, and *Social Engagement*. Each dimension was assessed separately using a positive and a negative sub-scale and interpreted collectively to provide an overall impression of all facets of engagement. Items 2, 4, 6, 8, and 10 are reverse scored items, meaning after scoring is completed, the numerical scoring needs to be reversed to calculate the overall number that measurement engagement. Each item indicates the extent to which the rater agrees or disagrees with the statement ("strongly disagree" = 1, "strongly agree" = 5). The total score ranges from 10-50 if all items across the scale are rated. A higher total score indicates higher positive engagement exhibited.

7.2.4 Procedure

An experimenter and a facilitator were on site to ensure the proper facilitation of study sessions. The experimenter's role was to 1) configure the interactive system design as required by each condition; 2) supervise the study procedures and provide explanations when necessary; 3) manage all the recording devices for proper data collection. The same facilitator facilitated all the study sessions (both experimental and control conditions). The study was arranged during non-planned activity times (i.e., 10:00 - 12:30 and 14:00 - 16:00) to accommodate daily care schedules and control the high behavioral time of the day (e.g., the Sun-downing effect, which describes the challenging behaviors that often appears before dinner time). Individual sessions lasted up to 20 minutes, long enough for explorations and short enough to not be interrupted by nursing care or visitors.

Pre-interaction session: Demographic data were collected by the facilitator before interaction sessions. And all recruited participants were asked to fill in the MMSE with the help of the facilitator, see Appendix B. Before each interaction session started, the facilitator was instructed first to introduce the experiment's intention to participants and spend some time together with the participant to get acquainted. Participants were then invited for a one-on-one interaction session with the consideration of their wishes and mood. Upon participant's agreement, the facilitator guided him/her, walked to where the study took place, and sat in front of the display. In the meantime, the experimenter prepared the setting according to the conditions designed and then introduced and brought the robotic sheep to the participant once he/she arrived (if the condition required the robot). Afterward, the facilitator explained how the system could be interacted with and entertain the participant.

During the interaction session: After the brief introduction, the facilitator switched on the audio recorder and gave the experimenter a sign to imply the session had started. The experimenter then turned on all three cameras to record the session. The facilitator facilitated the interaction with verbal encouragement until participants started to lose interest and focus, intended to leave, or reached the maximum time limitations. The facilitator was instructed to try to be inconspicuous while interacting, let the participants freely explore the system design, and encourage engagement when needed.

Post-interaction session: Once the sessions ended, the facilitator gave an ending sign to the experimenter so that all video/audio recordings were then turned off. The experimenter retrieved the robotic sheep and thanked the participant for their participation. The facilitator then accompanied the participant back to their living/private rooms and came back to complete the OME and OERS.

7.2.5 Ethical Considerations

The research was permitted and conducted in accordance with the requirements of the Eindhoven University of Technology, and written informed consent was obtained from participants or their legal guardians if participants were no longer capable of giving informed consent. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

7.2.6 Data Analysis

The video coding analysis of ELICSE was completed using Noldus Observer XT 14.2 software. IBM SPSS Statistics Version 25 was used for data entry and statistical computations. There was no missing data as all 16 participants finished all experimental sessions. The critical p-value was set at 0.05 (=5% alpha error). For IRR, a second-rater (different from the facilitator or the research assistant who completed the rating of EPWDS and video coding analysis) rated and coded part of the sessions (40%, 13 out of 32 sessions, randomly selected from all experimental sessions). IRR of video coding analysis was calculated using Observer XT (i.e., Reliability Analysis) with Cohen's kappa statistic (Cohen, 1960). When calculating IRR, the Observer XT software considers both the matching of scored behaviors by two coders and the overlap of time. We utilized the "Frequency/sequence" method of comparison and set 3 seconds tolerance for reliability analysis. The IRR result of 13 paired sessions ranged from a minimum Kappa of 0.68 to a maximum Kappa of 0.90 with an average of Kappa 0.82. Moreover, the IRR of rating scales was calculated using Cohen's Kappa by SPSS. According to (Fleiss et al., 2013), a Kappa value between 0.40-0.60 was considered a fair agreement, between 0.60-0.75, a good agreement, and above 0.75 an excellent agreement. Overall, the IRR for all rating items was between good and excellent, ranging from 0.61 to 0.78.

Video Coding Analysis Using ELICSE

Coding Procedures. Initially, video recordings from all three cameras and audio recordings of each session were synchronized to have the same starting and ending point. The synchronization of videos was achieved by editing the video and audio files using Adobe Premiere CC to the same length. A total of 32 video/audio-recorded sessions with a total duration of 5.8 hours were annotated using Observer XT. Three pilot sessions were randomly selected and used to discuss video annotation discrepancies together with the rater (i.e., the trained student assistant). Before scoring the behaviors of a session, the rater was instructed to watch the whole video for a general overview and then code each behavior group (Head Behaviors, Arms/hands Behaviors, and Conversations) separately. Within behavior groups, each cluster of behaviors was scored as mutually exclusive with a continuous sampling technique. The non-verbal behaviors were scored mainly using the video footages from the primary camera - C1 - as they had the clearest view of facial expressions and body movements; while the verbal behaviors (Conversations) were scored using the audio recordings as they provided a higher technical quality. When coding analysis of all sessions was completed, the absolute duration and percentage duration of each scored behavior and modifier were then exported for further data aggregation and pattern examinations.

Data Aggregation. As suggested by the previous work (Perugia et al., 2020), (Perugia et al., 2018), the observable facet of engagement measured through ELICSE is composed of two essential components: *Attention* and *Valence*. The scored Behaviors of ELICSE are associated with the component *Attention* (regardless of attentive or non-attentive expressed), and the scored Modifiers are associated with the component *Valence* (regardless of positive, neutral, or negative valence expressed).

To properly interpret the data collection of video coding analysis, we aggregated relevant scored values to represent the extent to which the user is engaged with the activity. Therefore, the non-verbal behaviors in ELICSE that are relevant to this engagement study (i.e., attention focus directed towards the augmented reality display and robotic sheep) were aggregated into items: Gaze toward *LiveNature* (Gaze_LN) and Reach out to/Manipulate *LiveNature* (Reach_LN). The verbal behaviors during the interaction sessions (i.e., scored items except for Not understandable conversations or Silence) were aggregated into Talk Activity (TalkAct) to represent verbal engagement during a session.

Similarly, the modifiers with the positive nuance of each category that are engagement related (i.e., positive valence directed towards the augmented

Table 7.4 Data Aggregation of scored behaviors and modifiers of ELICSE coding scheme.

Aggregated Items	Data Aggregation Computation
Gaze_LN	Gaze_ARD + Gaze_RS
PosGaze_LN	Gaze_ARD_Pos + Gaz_RS_Pos
Reach_LN	Reach_ARD + Reach_RS
PosReach_LN	Reach_ARD_ Pos + Reach_RS_Pos
TalkAct	Talk_F + Talk_Sheep + Talk_Self
PosTalkAct	Talk_F_Pos + Talk_Sheep_Pos + Talk_Self_Pos
NegTalkAct	Talk_F_Neg + Talk_Sheep_Neg + Talk_Self_Neg

reality display and robotic sheep) were aggregated into Gaze toward *LiveNature* with positive signs of affection (PosGaze_LN), Warmly reach out to/manipulate *LiveNature* (PosReach_LN), and Talk Activity with positive verbal engagement with the stimulus or the facilitator (PosTalkAct) accordingly and the modifier with the negative valence of Quality of conversations (i.e., Negative verbal engagement with the stimulus or the facilitator) was aggregated into Talk Activity with negative verbal engagement with the stimulus or the facilitator (NegTalkAct).

The reason for not including aggregated items of Gaze toward *LiveNature* with negative signs of affection (NegGaze_LN), Negatively reach out to/manipulate *LiveNature* (NegReach_LN) was due to a very low occurrence of such behaviors during the video scoring procedure. For an overview of the data aggregation computation, see Table 7.4. A higher computed value of a certain aggregated item indicates a higher level of engagement or affective states for that specific category.

7.3 Results

7.3.1 Manipulation Check for Baseline Control

To ascertain that the participants allocated to the two groups did not differ in user engagement at baseline, we performed independent sample *t*-tests on all scale items of the OME, OERS, and EPWDS gauged after the control sessions between the two groups. Data collected using three rating scales were summarized using the means and Standard Deviations (SDs), see Table 7.5. The results indicated that there was no significant difference on all rating items except *Attention Highest Level* (Atten_H) t (14) = 2.357, p = .034. Nevertheless, the item Attention Highest Level evaluates participants' highest level of attention during an interaction session. And since *Attention Most of the Time* is not significantly different between the two groups, we considered that the participant allocation would not bias our further statistical analysis regarding the main research

Table 7.5 Independent sample t-tests on rating items from OME, OERS, and EPWDS of control condition to disclose whether there was a significant difference of engagement at baseline between two groups of participants.

Items	Control Condition Mean (SD)		p-value
	G1 (N=7)	G2 (N=9)	
OME			
Atten_M	5.29 (.76)	4.78 (1.09)	.313
Atten_H	6.14 (.90)	5.22 (.67)	**.034**
Atti_M	4.57 (1.13)	4.89 (1.05)	.572
Atti_H	4.86 (1.07)	5.44 (.88)	.248
OERS			
Pleasure	2.29 (1.11)	2.11 (.60)	.693
Alertness	4.14 (9.90)	3.56 (1.01)	.248
EPWDS			
Aff_E	8.43 (2.07)	8.00 (1.58)	.645
Vis_E	7.57 (1.90)	7.11 (1.27)	.570
Ver_E	7.71 (.95)	7.67 (1.87)	.952
Beh_E	6.57 (.79)	6.67 (.87)	.824
Soc_E	6.43 (1.13)	6.22 (.67)	.655
Eng_Sum	36.71 (5.82)	35.67 (4.80)	.699

Note: Significance in bold. Abbreviations, Atten_M - attention most of the time; Atten_H - attention highest level; Atti_M - attitude most of the time; Atti_H - attitude highest level; Aff_E - affective engagement; Vis_E - visual engagement; Ver_E - verbal engagement; Beh_E - behavioral engagement; Soc_E - social engagement; Eng_Sum - overall engagement.

questions. However, we examine further statistical analyses of the item Atten_H with caution.

7.3.2 Effects of System Interactivity and Multimodal Stimuli on Engagement

To answer the main research questions, we performed statistical analyses on all aggregated items of the ELICSE and rating scale items of the OME, OERS, and EPWDS. The Bonferroni corrections were used to avoid alpha inflation. The partial eta squared was used for reporting the effect size due to the limited sample size. Suggested norms for partial eta-squared according to Cohen's guidelines are $\leqq$ 0.01 is considered small, ≈ 0.06 as medium, and $\geqq$ 0.14 as large (Cohen, 2013).

Results of Video Coding Analysis Using ELICSE

The means and SDs of the length of the total duration of a session (Duration in seconds), aggregated items of ELICSE using Absolute Duration, and aggregated items of ELICSE using Percentage Duration (i.e., calculated using absolute duration/length of the total duration of a session) were summarized in Table 7.6. Regarding the collected data using Absolute Duration, we performed a multivariate analysis of variances with repeated measurements and adopted the total duration of a session as a co-variable. The level of system interactivity was used as a between-subject factor, and the multimodal stimuli presented were considered the within-subject factor. The results revealed a significant main effect of multimodal stimuli level on item PosReach_LN (i.e., warmly reach out to the installation *LiveNature* including the augmented reality display and the robotic sheep) F (1,14) = 5.719, p = .031, η^2 = .290, shown in Table 7.6. The above significant result indicates that participants with more sensory modalities engaged during the study showed significantly higher positive behavioral engagement in terms of warmly petting, touching, or playing behaviors with both the robotic sheep and augmented reality display.

For collected data using percentage duration, the mixed factorial analysis of variance (ANOVA) tests showed a significant main effect of multimodal stimuli level on item TalkAct (i.e., the verbal expressions during the session) F (1,14) = 4.720, p = .047, η^2 = .252, meaning the percentage of time that participants were engaged in verbal communications were significantly higher when stimuli with more sensory modalities were presented, see Figure 7.3. We did not find any significant main effect on the level of system interactivity nor interaction effects on items Gaze_LN, PosGaze_LN, Reach_LN, PosReach_LN, TalkAct, PosTalkAct, and NegTalkAct (see Table 7.6).

Results of Observational Rating Scales

We performed the mixed factorial analysis of variance (ANOVA) using the level of system interactivity as a between-subject factor and the level of multimodal stimuli as a within-subject factor on all rating scale items. The results show significant main effects of multimodal stimuli level on Attitude Most of Time (Atti_M) of OME, F(1,14) = 7.574, p = .016, η^2 = .351, Visual Engagement (Vis_E) of EPWDS, F(1,14) = 8.113, p = .013, η^2 = .367, Social Engagement (Soc_E) of EPWDS, F(1,14) = 5.011, p = .042, η^2 = .264, and Overall Engagement (Eng_Sum) of EPWDS, F(1,14) = 5.250, p = .038, η^2 = .273, indicating that the attitude, visual engagement, social engagement and overall engagement of PWD significantly improve when more sensory modalities are provided by the interactive system design. We did not find any main effect on system interactivity or interaction effect. All outputs of the ANOVA analyses with relevant descriptive statistics and critical p-values were presented in Table 7.7.

7.4 Discussion

In this section, we discuss the results with emphasized interesting findings. We then discuss the method use of ELICSE besides the golden standards

Table 7.6 Results of main and interaction effects of levels of system interactivity and multimodal stimuli on all items of ELICSE coding scheme of four experimental conditions.

ELICSE Items	Experimental Conditions Mean (SD)				MS		I		Interaction	
	M1I1 (N=7)	M2I1 (N=7)	M1I2 (N=9)	M2I2 (N=9)	p	η2	p	η2	p	η2
Total Duration	473.00 (83.19)	831.71 (112.01)	731.56 (73.37)	657.56 (98.78)	.177	.126	.628	.017	**.049***	.250
Absolute Duration										
Gaze_LN	243.04 (146.52)	375.86 (208.12)	346.04 (176.94)	325.99 (239.62)	.256	.091	.767	.007	.130	.156
PosGaze_LN	11.96 (22.94)	19.54 (25.76)	29.41 (30.95)	44.67 (87.32)	.506	.032	.257	.091	.794	.005
Reach_LN	234.34 (256.59)	382.09 (311.47)	360.99 (242.73)	361.79 (314.27)	.397	.052	.649	.015	.402	.051
PosReach_LN	26.96 (22.70)	71.48 (59.09)	107.01 (133.49)	135.75 (184.81)	**.031***	.290	.259	.090	.614	.019
TalkAct	334.30 (294.77)	692.13 (408.57)	544.313 (265.39)	539.45 (258.08)	.117	.166	.802	.005	.108	.174
PosTalkAct	69.28 (96.93)	61.94 (100.46)	30.00 (62.34)	62.07 (101.74)	.484	.036	.651	.015	.271	.086
NegTalkAct	34.06 (50.74)	82.03 (72.15)	29.44 (67.31)	42.70 (50.43)	.103	.178	.396	.052	.340	.065
Percentage Duration										
Gaze_LN	54.09 (20.74)	47.27 (17.56)	51.10 (26.41)	48.37 (28.44)	.351	.062	.934	.001	.686	.012
PosGaze_LN	2.70 (3.92)	3.60 (6.52)	4.34 (4.34)	4.89 (7.76)	.693	.011	.547	.026	.927	.001
Reach_LN	44.89 (29.53)	55.39 (33.50)	52.68 (33.22)	48.99 (37.02)	.689	.012	.964	.000	.410	.049
PosReach_LN	9.79 (11.14)	11.56 (13.67)	16.25 (19.96)	17.00 (18.04)	.691	.012	.455	.041	.872	.002
TalkAct	66.60 (31.92)	77.04 (29.76)	71.69 (19.34)	83.64 (19.52)	**.047***	.252	.619	.018	.886	.002
PosTalkAct	20.68 (22.66)	11.67 (24.09)	4.48 (9.01)	6.85 (10.09)	.438	.043	.180	.125	.193	.118
NegTalkAct	6.88 (7.89)	8.37 (6.18)	3.02 (5.95)	7.10 (9.26)	.179	.125	.440	.043	.522	.030

Note: Significance in bold. Significance level *p < .05.
Abbreviations, MS - level of multimodal stimuli; I - level of system interactivity; Interaction - interaction of level of multimodal stimuli and system interactivity.

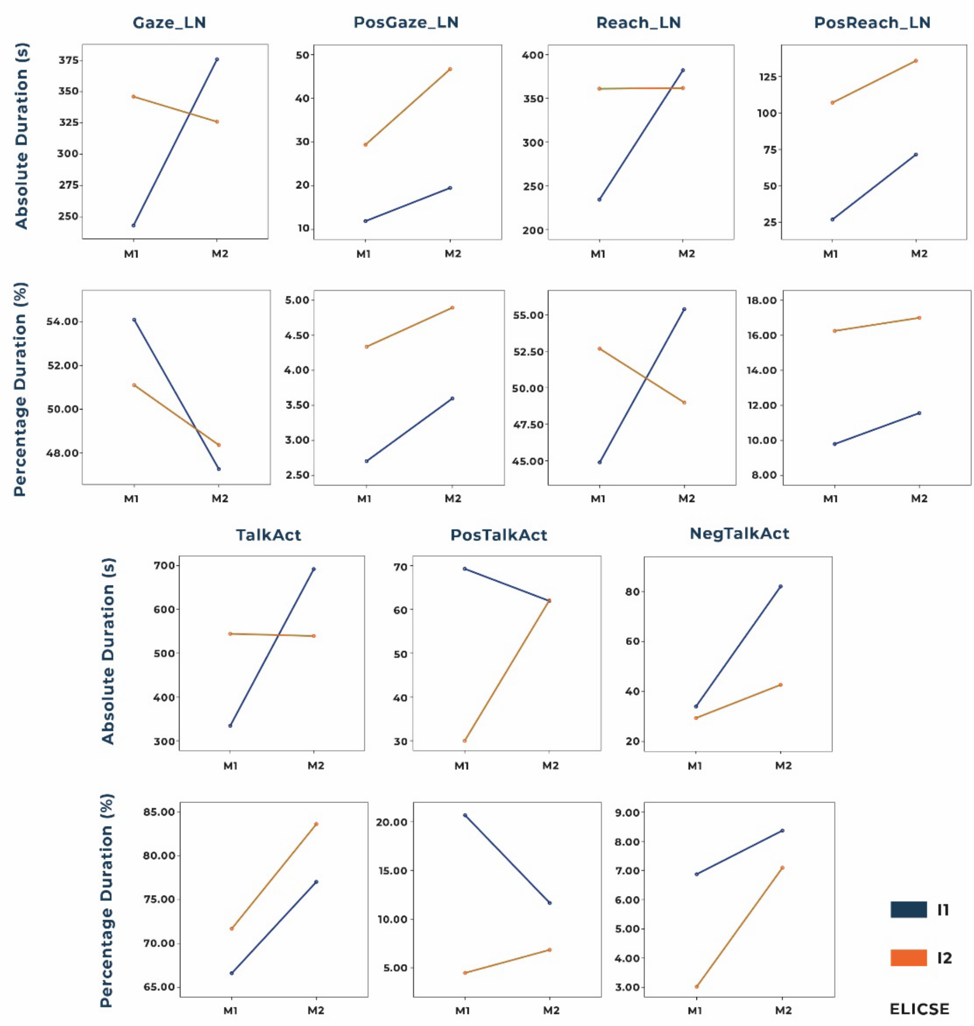


Figure 7.3 Results of aggregated items of ELICSE using Absolute Duration and Percentage Duration. The between-subject variable - levels of system interactivity (I1 and I2) - was shown using two lines in the different color schemes. The within-subject variable - provided multimodal stimuli (M1 and M2) – was shown using two values in the x-axis.

Table 7.7 Results of main and interaction effects of levels of system interactivity and multimodal stimuli on rating scale items of OME, OERS, and EPWDS among experimental conditions.

Scale Items	Experimental Conditions Mean (SD)				MS		I		Interaction	
	M1I1 (N=7)	**M2I1 (N=7)**	**M1I2 (N=9)**	**M2I2 (N=9)**	**p**	**η2**	**p**	**η2**	**p**	**η2**
OME										
Atten_M	5.14 (0.90)	5.86 (0.69)	5.33 (0.87)	5.56 (1.01)	.074	.210	.884	.002	.328	.068
Atten_H	5.86 (1.07)	6.43 (0.54)	6.00 (0.71)	6.22 (0.83)	.201	.114	.911	.001	.564	.024
Atti_M	4.29 (1.38)	4.86 (0.69)	4.22 (0.97)	5.33 (1.23)	**.016***	.351	.662	.014	.392	.053
Atti_H	5.14 (1.57)	5.71 (0.95)	5.22 (1.09)	5.78 (1.09)	.109	.173	.888	.001	.981	.000
OERS										
Pleasure	2.14 (0.69)	2.14 (0.38)	2.22 (0.67)	2.33 (1.00)	.806	.004	.658	.014	.806	.004
Alertness	4.29 (0.76)	4.43 (0.79)	4.11 (0.93)	4.44 (0.73)	.301	.076	.819	.004	.674	.013
EPWDS										
Aff_E	7.71 (1.70)	8.71 (1.38)	7.44 (1.88)	8.44 (1.67)	.063	.226	.071	.011	1.000	.000
Vis_E	8.00 (2.08)	9.00 (1.53)	7.56 (2.35)	8.78 (1.72)	**.013***	.467	.719	.010	.780	.006
Ver_E	7.71 (2.56)	8.00 (2.24)	7.56 (1.74)	8.11 (1.76)	.432	.045	.979	.000	.799	.005
Beh_E	7.86 (2.85)	8.43 (1.51)	7.11 (2.85)	8.67 (1.32)	.072	.213	.802	.005	.383	.055
Soc_E	6.57 (2.15)	7.57 (1.27)	6.56 (1.67)	7.56 (1.81)	**.042***	.264	.984	.000	1.000	.000
Eng_Sum	37.86 (10.30)	41.71 (7.36)	36.22 (9.19)	41.56 (7.83)	**.038***	.273	.822	.004	.718	.010

Note: Significance in bold. Significance level *p < .05.

Abbreviations, MS - level of multimodal stimuli; I - level of system interactivity; Interaction - interaction of level of multimodal stimuli and system interactivity; Atten_M - attention most of the time; Atten_H - attention highest level; Atti_M - attitude most of the time; Atti_H - attitude highest level; Aff_E - affective engagement; Vis_E - visual engagement; Ver_E - verbal engagement; Beh_E - behavioral engagement; Soc_E - social engagement; Eng_Sum - overall engagement.

of observational rating scales. In addition, we summarize implications that contribute to future robotic research and development within dementia care. Limitations and future works are also addressed.

7.4.1 Discussion on Experimental Effects

Contributions of Multimodal Stimuli on Promoting Engagement, Attitude and Communications

In general, the results obtained through the mixed method use of the ELICSE and the rating scales indicate that the level of multimodal stimuli had a significant impact on overall user engagement (according to the result of Eng_Sum of EPWDS), attitude (Atti_M of OME), valence (PosReach_LN of ELICSE), verbal communications (TalkAct of ELICSE), visual engagement (Vis_E of EPWDS), and social engagement (Soc_E of EPWDS), see Table 7.6 and 7.7. Participants demonstrated significantly more positive behavioral engagement and a higher percentage of the duration of verbal expressions when auditory stimuli were presented based on visual-tactile feedback during the study. Besides, the attitude towards the provided activity (during most of the time), the visual engagement, and social engagement were higher when more sensory modalities were involved in the interaction sessions. The above-mentioned findings are in line with previous research stating that everyday sound (i.e., nature soundscape and animal sound in this study) has promising benefits in dementia care as it can stimulate meaningful connections with past memories as well as among interpersonal human interactions (Houben et al., 2020b).

In this specific study setting, adding content-relevant auditory feedback worked as a proactive strategy for facilitating verbal communications and positive affect display even if participants' visual and tangible/tactile sensory modalities were already engaged. As most recent design research that targets PWD with advanced stages tends to emphases on tangible/textile interaction (Huber et al., 2019), (Treadaway et al., 2019b), incorporating sound together with touch explorations could be one promising answer for positive engaging experience design of PWD.

Although we have exhibited significant results of multimodal stimuli level on Atti_M and PosReach_LN, other items that also accessed users' affect (i.e., PosGaze_LN of ELICSE, *Pleasure* of OERS, and Affe_E of EPWDS) did not reveal any statistical significance. To further understand this, we need to know that although many items seem to be conceptually overlapped, each assessment tool has its emphasis. And these are reflected in two aspects: 1) whether the focus of the assessment was on activity-related engagement only or activity and interpersonal social engagement (human-human interaction) as an entity; and 2) whether it was accessed based mainly on one dimension of facial, behavioral and verbal affective expression, or a combined interpretation of all above.

Specifically, according to the manual of OME, this measure was developed to assess user engagement with the provided stimulus/activity. Item Attitude of OME was rated based on the amount of excitement/ expressiveness toward stimulus/activity (e.g., smiling, frowning, energy, excitement in voice), and assessed through a comprehensive interpretation of facial expressions, verbal expressions, and behavioral manipulations in combined. On the other hand, scales of OERS and EPWDS view the interaction with the stimulus/activity and human partner as an entity. Item Pleasure of OERS was rated based on intensity reflected by the duration of pleasure expressions displayed when engaged with both the provided activity and the facilitator. The pleasure expressions were defined by showing signs such as laughing, smiling, singing, kissing, or rapport behaviors with another human. And item Affe_E of EPWDS was rated based on to which extent the rater agreed with two statements: one positive according to (Jones et al., 2018) - “Displays positive affect such as pleasure, contentment, or excitement (e.g., smile, laughing, delight, joy, interest and /or enthusiasm)”; and one negative - “Display negative affect such as apathy, anger, anxiety, fear, or sadness (e.g., disinterest, distressed, restless, repetitive rubbing of limbs or torso, repeated movement, frowning, crying, moaning, and/or yelling)”. Regarding the items of ELICSE, PosGaze_LN focuses on annotating positive facial expressions toward the stimulus, whereas PosReach_LN emphasizes positive affective touch, as to say manipulations of the artifacts in the activity (i.e., the robot and the interactive display) that have a positive affective nuance (e.g., stroke the robot).

The above descriptions could help us understand why we found a significant difference on the item Atti_M but not on PosGaze_LN and Pleasure. The former could be explained by the observation that participants significantly increased overall behavioral engagement towards the activity when the auditory feedback was added. The latter might indicate that this difference was not present when the single modality of facial expressions was taken into account. There are two other possible reasons besides the assumption that there was simply no difference in positive facial expressions between the two levels of multimodal stimuli. First, as PWD are often affected by impaired emotion regulation, some participants might have found it difficult to express their emotions through facial expressions. Further analyses could be performed with participants clustered per emotional disorders. Second, the sample size was too small for discovering statistical significance, under which circumstances more participants need to be recruited in future studies.

In addition, the results of Soc_E and Vis_E from the EPWDS also showed significant main effects of multimodal stimuli. According to the manual (Jones et al., 2018), the item Soc_E evaluates the interpersonal social interaction by measuring whether the participants used the activity provided as a communication channel to interact with others (as we have considered the HRI as part of the activity engagement). Hence, as the participants were more willing to verbally communicate with the facilitator when auditory stimuli were presented, social engagement with the facilitator increased as well. For Vis_E, it differs in that Gaze_LN only focuses on gaze behaviors directed towards the stimulus/activity, while visual engagement of the EPWDS also measures eye contact with the person/s involved. The results could be explained by a consequence of the increased social activity with the facilitator. The discussion further confirmed that sensory enrichment has the potential to promote not only activity-related engagement but also social engagement with human partners within our specific context.

Lack of Significance on Level of System Interactivity and Interaction Effects

The statistical analysis of data collection using ELICSE did not reveal any statistically significant main effects on the level of interactivity or interaction of system interactivity level and level of multimodal stimuli on engagement (except for the total duration of sessions, see Table 7.6). We speculated about two reasons for possible explanations. The **first** reason considers the participants' diverse heterogeneity and the design of experimental procedures. Specifically, how the provided activity should be presented to participants with different cognitive abilities so that they have a better understanding of all the functionalities and interaction possibilities of the system design. Dementia affects each participant differently. Our recruited participants were affected by behavioral disorders varying in severity and type. Participants with more advanced stages of dementia have a higher risk of not recognizing or increased difficulty in recognizing the increased system interactivity design due to narrower attention span and inability to notice the changes in the conditions, especially when only visual feedback were presented on the screen display (i.e., as in condition M1I2). Hence, the logical connection between interacting with the robotic sheep and the responsive feedback from another location - the screen display - could be difficult for participants with a high level of cognitive impairment to comprehend. In the implemented procedure design, we have arranged a brief introduction by the facilitator about how the designed system works pre-interaction session verbally. The intention was to retain the self-exploration, which aims to reinforce the rewarding experience when users successfully discovered the connection between touch input on the robot and feedback from the display themselves. However, in practice, such a connection might not be perceived by every participant, and this highly depends on their condition. Therefore, elaborate demonstrations by the facilitator and necessary guidance during the sessions could be useful for a better understanding of the logic connections, especially for participants with more advanced conditions.

The **second** reason for lack of significance regards the system implementation of the robotic animal design and facilitation of the HRI. The robotic sheep is a PLEO robot with sheep clothes and several touch sensors embedded on the back, rear, head, and chin of the robot. During study sessions, not every touch input on the robot successfully triggered the programmed responses (e.g., when participants were petting the tail or legs). Hence, proper facilitation is crucial in guiding the participants through the designed feedback. Not enough exposure to responsive feedback could also be the reason for the lack of significance. As in this study, the robot was covered in sheep-like fur, and future studies could use textile embedded sensors for better coverage of the surface of the robot to ensure a more sensitive collection of user input. Furthermore, the facilitation of the HRI is also crucial in determining the positive effects. In some cases, we have noticed that certain participants seemed to fail in distinguishing whether the robot was on or off. In other words, unless been constantly addressed and guided by the facilitator on how the robot behaves and reacts, the users are at risk of not knowing the feedback from the robots or even not able to tell whether it is a robot or a real animal. As most traditional therapeutic interventions for PWD are often performed by specialists with professional training, the facilitation of robot use should also consider setting up standards for proper guidance and ethics to have its desired positive impact on dementia users.

Nevertheless, the non-significant results did not necessarily suggest there were no positive effects of increased interactivity of system design on user engagement. The results of ELICSE-based assessment showed a trend of increased positive gaze, and positive reach out behaviors (see Table 7.6), as well as more evident pleasure (see Table 7.7) when the system interactivity was higher. It is well known that the failure to demonstrate statistical significance may also be the result of low statistical power when an important effect actually exists, and the null hypothesis of no effect is in fact false. However, due to the controversy of reporting the post hoc power calculation in literature (see the work of [30] for a complete discussion), we did not perform post hoc power calculations to aid the interpretation of non-significant results but reported a priori power calculation to guide the sample size instead (see section "Method - Participants").

Taken together, this discussion provides more detailed insights on how multimodal stimuli presentations could influence the engagement of PWD under the specific contextual interaction design of this study. In its most direct sense, increased experienced richness at a sensory level influences PWD's engagement by promoting manipulation of the social robot with positive emotions and facilitating communication with the human partner, which further leads to an increased attitude towards the activity and social engagement with the facilitator. In addition, our study showed that designing proper system interactivity requires careful considerations, as there is a need to balance the residual abilities of PWD with the amount of interactive possibilities that the system offers. To accommodate each user's unique conditions and allow users with dementia with different deterioration levels to benefit from the provided activity, it is essential that the activity is appropriately introduced and constantly facilitated throughout the whole session. In conclusion, the findings mentioned above indicate that an increased sensory richness and richer interaction possibilities of an activity design can lead to a more positive attitude towards the activity, and could be used as motivation strategies for initiating and facilitating engagement, maintaining user interests, and facilitating verbal communications of PWD.

7.4.2 Discussion on Engagement Assessment Using ELICSE

Next, we discuss the reasons for presenting the results using both absolute duration and percentage duration (i.e., calculated using absolute duration/ length of the total duration of a session) of the behaviors in the ELICSE, and possible underlining reasons for different results.

The results presented in Table 7.6 showed a significant main effect of multimodal stimuli level on PosReach_LN using absolute duration data collection. However, no significance was found using the percentage duration of the same item. Similarly, the significant main effect of multimodal stimuli level on item TalkAct was only exhibited when using percentage duration. The different results suggest that the two ways of data collection measure engagement differently. The percentage data collection calculates the proportion of a particular behavior/modifier out of the whole session. It has the advantage of even out the influence of a session's total duration by computing a percentage that demonstrates a direct impression on the user's focus distributions. However, in practice, when participants are less interested in the provided activity, they naturally shift their attention towards the facilitator for interpersonal interaction. The interaction with the facilitator would influence the final results using percentage duration. More specifically, participants may gaze towards the facilitator more if they had recollected memories triggered by the interaction and wished to share their experience with the facilitator, consequently reducing the percentage of gaze towards the screen or robotic sheep.

To address the above, we have also exported analyzed data using absolute duration. The duration of time that participant was occupied or involved with a stimulus, suggested by Cohen-Mansfield et al. (2009, 2011), is an essential indicator of user engagement of PWD. Absolute duration data takes the total duration length of an interaction session into consideration, and aims to reflect the extent to which the participant is willingly spending their time with the stimulus regardless of the rapport behaviors with the facilitator. In this sense, the results of bodily behaviors using absolute duration are closer to reflecting the nature of activity-related engagement.

Regarding verbal behaviors - Conversations of ELICSE, they are different in nature from bodily expressions. Most of the verbal expressions occurred between two human partners (i.e., the facilitator and the participant), except self-mumbling or talking to the sheep (both as a robot or as screen content). Hence, we could not separate the facilitator's potential influence when performing data analysis but aggregated it into an item of TalkAct. We then analyzed the percentage of the total verbal expression for a general impression of communications.

7.4.3 Implications for Human-Robot Interaction Research within Dementia Care

Given the trend of global population aging, inflated healthcare costs, and lack of resources in most LTC facilities, there is a large likelihood that older adults with dementia will be accompanied by robots in the future, whether for assisting independent living or fulfilling psychosocial needs. In this section, we present the implications derived from our findings that might be inspiring for HRI within the dementia care field.

Multisensory experience design for HRI. The majority of design research that is conducted with and for PWD is sensory-based in their essence (Thoolen et al., 2020b), (Houben et al., 2020b). Social robots engage PWD in sophisticated multisensory ways to increase activity levels both from physical and social perspectives. On the one hand, recent robotics research is looking for a way to design the HRI experience so that it is more sensory holistic and immersive (Alenljung et al., 2019). On the other hand, studies have started to pay attention to how robot use could help to shape the everyday living experiences for elderly (Frennert & Östlund, 2014). The presented study was conducted based on a specific activity design that employed an augmented reality display to provide contextual information and sensory cues for a more immersive and richer HRI experience. In this way, the system design could benefit users not only from a sensory-stimulating way but also by creating a story narrative and a use context for robot facilitation and acceptance. Although the study has not investigated to which extent adding the artificial "context" on HRI contributes to the significant main effect of multimodal stimuli on enhancing engagement, it could perhaps offer a new perspective on HRI experience design by enabling multimodal feedback from a larger scale setting than the robot itself.

Adaptive system design with multiple interaction possibilities. Our activity design provides multiple interaction possibilities ranging from a simple "outlook experience" at the media content displayed on the screen, to "social robot petting" with HRI, and an "immersive sensory experience" that involves both robot interaction and interactive media content. These adapted levels of interaction allow users to freely explore the system design without the concerns of making mistakes and compose their interaction in the way they are more comfortable with. The multiple interactive possibilities have the potential to adapt to various user conditions regarding various cognitive abilities but personal characteristics (e.g., mood during interaction). For instance, when users are in agitated conditions, the "outlook experience" could provide relaxation and enjoyment. When they are bored and searching for stimulation, the interactive system could provide a social agent that acts as a companion and simulates human-animal therapeutic interaction. Moreover, the interactive system design could also help maintain the user interest and attentiveness, as users can continuously shift their attention between the dynamic media content shown on display and the robot behaviors to remain in flow. In addition, it could also help lower the barrier for physical and cognitive requirements since users in their wheelchairs could also benefit from the low threshold physical interaction of cuddling and petting the robotic sheep.

Crucial role of facilitation during robot interaction. Like most occupational therapies developed for PWD to improve quality of life, interaction with a robot should also value the facilitation of specialists. First, the quality and conditions of facilitation are known to influence users' acceptance, and attitudes towards the robot interaction experience (Heerink et al., 2010). Second, there is a rich body of work that addresses the ethical concerns of social robots' use in dementia care, as it may tend to replace human care and lead to reduced human contact. The facilitation of a human caregiver is crucial as it could help maintain human contact within the HRI experience while lowering the risk of caretaking stress. It requires less focused attention and helps maintain the human-human interaction channel open. The support of a facilitator could also prevent other ethical concerns such as deception (recognizing the robot as a real animal) (van Maris et al., 2020), or infantilization feeling (similar to an adult who plays with a toy). In our research, we view the robot interaction not only as a stimulus for keeping PWD stimulated and improving their mood but also as a meditating artifact for interaction between humans and humans. For designers and developers of robotic research, we would suggest considering making guidelines for human facilitation, and doing so by carefully considering the dynamic relationship among human facilitators, provided stimuli, and users with dementia, and how it would shape the daily living for multi-stakeholders. Also, as recent research starts to involve dementia users in inclusive design processes (Wang et al., 2019), we would suggest including caregivers/facilitators in the initial developing process as well.

7.4.4 Limitations and Future Work

The major limitation of this study lies in the relatively small sample size and uneven participant distribution in the two groups. The small sample size was due to challenges in the recruitment of PWD in the relatively small community of Vitalis, and the uneven group size was due to the participants' withdrawal during the study. The sample size was also a result of considerations influenced by choice of methodologies, which requires a significant amount of effort and investment in time. Given the above practical limitations, partial eta squared effect size values were reported to substantiate the scope of the results. Future work should attempt to replicate the experiment with larger sample size and participants from different locations. Furthermore, due to the small sample size and the low number of participants for each level of dementia severity, we could not perform further statistical analyses focusing on the effects of participants' characteristics on engagement. Future work should consider recruiting a larger number of participants in each level of dementia severity to examine differences caused by the disease's progression. Additionally, since users' facial expressions could also be hindered by emotional disorders, future work should analyze the effect of users' affective disorders (e.g., depression, apathy, anxiety) on their facial expressivity to make the assessment of engagement more sound.

Moreover, there is an uneven sample size between genders (12 female participants and 4 male participants), which potentially gives the impression of gender bias when interpreting the results. In fact, the majority of residents living in Vitalis are women, and so are many other nursing homes worldwide. See reference, for instance (Buchanan et al., 2004). According to the literature, there exists a gender difference among the population of residents with dementia living in nursing homes. The admission rates between the male and female ratio ranged between 1 to 1.4 and 1 to 1.6, according to international studies reported by Luppa et al. (2009). And the gender difference in nursing home placements of PWD is generally explained by the higher life expectancy of women at present, the slightly higher dementia prevalence rates of women than men (10.1% vs. 9.6%) (Freedman et al., 2018), the higher rate of women living alone in older age than man (Luppa et al., 2009), and the tendency of willingly to give care of women than man. Overall, we believe that our sample of this study represents the gender profile of nursing home residents with dementia disease. And this raises the awareness of designing for gender differences, particularly, for older women with dementia in future works.

Other limitations concern the measures and data analysis. First, due to practical consideration, the rating scales were filled out based on varied materials (OME, OERS were rated based on direct observations on-site, while EPWDS were rated based on video recordings) by two different raters. This might have slightly weakened consistency among the three rating scales. However, it did not influence the reliability of results as the use of a single scale was consistent across all experimental sessions. Second, the video coding analysis using the ELICSE adopted both percentage and absolute duration due to the distinct length of each session and mutual dependence between activity-related engagement and interpersonal interaction with the facilitator. Future studies should make clear guidelines of experiment design and procedures to ensure the robustness of ELICSE video coding analysis using percentage data representation. Instructions such as trying to reduce personal conversations that are irrelevant to the study with the participants and trying to be consistent and follow the same study procedure for all participating sessions could be implemented. Lastly, although the mixed method used in this study yielded a reliable assessment of user engagement, future work should consider combining this mixed method with a more qualitative interpretation of participants' behaviors by people who entertain trustful relationships with residents. The meaning of the annotated behaviors would be increased by understanding each participant from a person-centered care point of view (Wallace et al., 2013). Future work could collect participants' lifestyles, personalities, preferences, and past/present interests using tools such as the Self-Identity Questionnaire proposed by Cohen-Mansfield et al. (2000, 2010b) for a better interpretation of the user engagement.

Lastly, as this study invited one participant at a time to better control the experimental conditions, future work should also test how the system adapts to a pair of users and how their activity-related engagement and human-human interaction would be facilitated by such activity. Additionally, the system design presented in this chapter adopted visual-auditory-tactile feedback for multimodal stimuli presentation. Future work could attempt to engage more sensory channels (e.g., aroma-diffuser of grass field for olfactory display) of PWD for a more holistic and realistic sensory experience. Additionally, the robotic sheep design in this study could be further improved by adding heating elements. As suggested by Block et al. (2019), physical warmth helps promote social warmth, the adoption of heating features besides inviting texture and appealing appearance are likely to promote HRI.

7.5 Conclusion

To address the current disengaged and under-stimulated living situation of PWD in LTC facilities, this chapter attempted to explore how to design rich interaction experiences to improve the level of engagement of PWD. The experiment design was built on a prototype design of *LiveNature* that echoes the nostalgic experience of a generation of Dutch elderly and utilized intuitive interfaces that users are already familiar with. The system design suggested a novel approach that combined the interaction with a tangible social robot with an ambient (augmented reality) display.

With social robots being increasingly employed in the complex domain of dementia care, this study investigated the role of multimodal stimuli and system interactivity in improving the richness of the experience. The sensorial level of experienced richness was addressed by the system design's multimodality sensory feedback. And the system interactivity was varied based on whether the HRI was accompanied by contextual cues from the augmented reality display. The engagement of participants was assessed using a mixed assessment method involving the use of video analysis (using the ELICSE) and three observational rating scales (OME, OERS, and EPWDS). Results provide sufficient evidence of the significant contributing role of multimodal stimuli in improving emotional aspects of activity-related engagement and social interaction with a human partner.

The findings could be potentially used as motivation strategies in future design research to promote PWD's positive attitude, communication, and social rapport. It could also contribute to several domains of knowledge, namely: 1) the domain of interaction design for dementia. While most sensory-based designs for PWD mainly focused on stimulating certain senses, for instance, music/sound for reminiscence or textile designs for comforting and relaxation. This research addresses the significant benefits of employing multimodal sensory presentations, including dynamic visual content, auditory stimulation, and tactile explorations; In addition, 2) it contributes to robotic research by offering a novel way of combining sensory cues embedded in environmental settings with the HRI, and addressing the critical role of professional facilitation in user engagement; lastly, 3) it adds insights to dementia engagement study by providing a comprehensive mixed method for engagement assessment.

Part 4
CONCLUSION

Chapter 8 | Implications and Reflections

8.1 Introduction

This chapter endeavors to present implications and reflections gleaned from this research journey to help inform future design and research processes when working with and for PWD. Specifically, we summarize: 1) the design implications regard designing towards a meaningful activity within the LTC context and an enhanced engagement for PWD; 2) the practical implications when conducting design research with PWD; 3) the theoretical implications of design's roles in contributing to the well-being of PWD living in the LTC environment; and 4) the ethical implications that are not only crucial but closely related to design and research activities with and for this user group. Particularly, we raise our ethical concerns in this section, present how we dealt with these issues throughout the research, and propose our recommendations for good ethical practices as well as clear principles and protocols of dementia-related research ethics as a contribution to a dignity-preserving user-centered research environment for PWD. Lastly, we bring forth three commonly discussed dilemmas and demonstrate how they inspired the thinking process of this research.

Although these derived implications or reflections are limited to our research's specific scope and context, this chapter provides insights when working with and for PWD. After reading this chapter, we hope researchers and designers working in the relevant field can transfer these lessons into future practices or inspire open discussions on extended topics based on the following content.

8.2 Implications

8.2.1 Design Implications

First and central to our research goals, we summarized seven design implications targeting the primary research objective of this research - designing interactive systems as meaningful activities for promoting engagement of PWD living in LTC. Part 3 has investigated the contributing role of rich interaction in terms of features like tangibility, interactivity, and multimodality in positively impacting user engagement of PWD. We conclude by providing design implications that contribute to two goals:

- **Fostering Engagement -** Design implications for attracting user attention, motivating interests, initiating behaviors.
- **Sustaining Engagement -** Maintaining behaviors, provoking emotional responses, facilitating conversations, promoting social interactions.

Design Implications for Fostering Engagement of PWD

As discovered in Chapter 3 that one of the major factors preventing engagement is the lack of inner motivation of PWD. Therefore, we propose the following criteria that may help motivate PWD's interests and attract their attention to foster engagement in activities.

Design Implication 1: Provision of Multisensory Experience. The first identified approach, expected to benefit PWD regardless of their cognitive conditions, is the provision of multisensory experience. Throughout our research, we focused on designing interactive systems that offer multisensory experiences as meaningful activities within our specific context of Vitalis. Multisensory environments (also known as sensory rooms or Snoezelen environments) are well-known and widely used in dementia care. They were often built with equipment like bubble tubes, optic fibers, music, aroma diffusers, and vibrating cushions within a dark environment (Collier & Jakob, 2017). Different from the distributed approaches used in such environments, we intend to embed all equipment for stimulating multiple senses in one interactive system design that with concrete, real-life meaning, and elements of reminiscence articles. In this way, we believe that the perceived usability and accessibility can be better supported. Moreover, users are less likely to be intimidated by the unfamiliar "mysterious" environment when they are in the "darkroom", so the risk of confusion by the various equipment they do not know what to do with can be further reduced.

In addition, we consider that the multisensory experience works not only to stimulate PWD or compensate sensory disabilities but also to comfort users and bring relaxation according to their current conditions and needs. Prolonged exposure to large amounts of unhelpful stimulation may be as worse as under-stimulated living. In studies presented in Part 3, we carefully selected what type of sensory stimuli (i.e., nature viewing) for creating an ambient environment and only provide the stimulation when interaction with the system is detected. In this way, we hope to control the potential unhelpful stimuli and optimize the helpful ones.

Design Implication 2: Design with Familiarity and Meaning. The second implication attempts to answer how to initiate the interaction of PWD through aesthetic design. Through the designed form, a sensory stimulus can be provided in a manner that is appropriate and understandable by an individual user of dementia. Thus, we offer our answers using two categories – “Familiarity” and “Meaning”. Specifically, we propose three explicit design criteria to help interpret two implicit categories of “Familiarity” and “Meaning”.

- First, the affordances of the resulting design should help facilitate intuitive interaction using familiar and recognizable properties that are meaningful for the individual user.
- Second, the affordances of the resulting design should capture user interests through reminiscent materials that echo to their long-term memories for personal and emotional connections.
- Third, the affordances of the resulting design should support perceived usability and ease of use through relatable interface and content that responds to their previous life experiences for interaction.

Design Implication 3: Promote Zoomorphic and Life-like Design Features. The third implication is promoting the use of zoomorphic and life-like features when designing for PWD. To motivate the interests of PWD, we referred to the innate psychological needs that human beings tend to pursue experiences that enable relatedness and pleasant emotions (Deci & Ryan, 2000), (Tamir & Ford, 2012). For instance, in this thesis, we have designed movements to mimic animal behaviors using soft textile wrapped mechanics as in the design of *Dynamorph* presented in Chapter 3. We have adopted multimedia content with animal images and sounds as in the design of *Closer to Nature* presented in Chapter 4. Also, we have implemented an animal-like social robot as in the design of *LiveNature* presented in Chapter 6. All the above examples were designed with the intention of evoking users’ emotional responses, bringing forth the feeling of attachment with living beings, and provoking a sense of their nurturing nature. We believe these features could help draw users’ attention and keep them intrigued during the interaction.

Design Implication 4: Incorporate Tangible Interaction and Tactile Explorations. Design implications 2 and 3 address the cognitive and emotional aspects of motivation, while design implication 4 emphasizes motivating behavioral engagement through the use of tangible interaction and tactile exploration. For PWD living in LTC environments, their visual and auditory senses may be easily occupied with stimulations from various sources. However, the touch sensations can hardly be addressed. In addition, purposeful physical movement is known to help maintain health and well-being (Gonçalves et al., 2017). Thus, we incorporate tangible interaction and tactile explorations to promote active participation with intuitive movement and fulfill tactile sensation needs. Specifically, we encourage the use of soft and warm materials/textiles that were suggested to invite touch and make PWD feel safe, assuring, and comfortable (Block & Kuchenbecker, 2019).

Design Implications for Sustaining Engagement of PWD

Imagine a scenario where our users have already been intrigued by an artifact and starts to play with it. What matters that determines when they will lose interest and leave it? For PWD, how to sustain engagement cannot be easily answered due to dramatic personal differences. Here, we offer our insights on this matter as the following.

Design Implication 5: Enable Rewarding Experiences. The fifth implication is implementing a rewarding mechanism to sustain PWD's interests and boost their confidence while interacting. PWD encounters many frustrations when interacting with their surroundings in daily life. The internal reasons for quitting an activity are likely due to avoidance induced by the fear of making mistakes or challenges that strengthen the feeling of confusion. Thus, we offer two aspects that enable rewarding experiences through the system designs:

- The first is through encouraging explorative and playful experiences during an interaction. Unlike activities for PWD that with a clear goal of task completion or have the "right" way to do it (e.g., cognitive games like puzzles), sensory explorative experiences that bring comfort, satisfaction, and pleasure can better reward users, especially those in their more advanced stages.
- Second, we advocate for the involvement of professional facilitation during activity sessions for compensating learning ability through necessary demonstrations and encouragements. Based on our experiences, clear instructions and demonstrations from the facilitator could help reduce PWD's cognitive barriers. Furthermore, appropriate encouragements from a closer relationship caregiver could help foster a sense of confidence, provoke emotional responses, facilitate conversations, and promote social interactions to maintain fluid interaction.

Design Implication 6: Expand Possibilities of Interactions for Users. The sixth implication addresses the adaptivity of interactive systems to various user conditions through the expanded possibilities of interactions. Specifically, we offer strategies that cover three aims. First, to address activity engagement in a spatial environment, we propose combining peripheral and proximal interaction to help maintain user attentiveness (Feng et al., 2019). Second, to cope with different sensory modulations of individuals (i.e., sensation avoiding or sensation-seeking types of users), we offer experiences with varying levels of stimulations to match different sensory preferences for benefiting a wider range of users (Brown et al., 2001). Third, to accommodate users with different cognitive abilities, we adopt adaptive system designs that offer multiple avenues for interaction (see Chapter 6, section "Adaptive System design of *LiveNature"*). Through interaction, the function of the designed artifacts can be extended with the interpretation of users themselves ("Interpretive Flexibility") (Šabanović et al., 2013).

Design Implication 7: Support Social and Ethical Value of Design. Social and ethical values (such as dignity) are two vital factors that influence and determine user engagement of PWD. Thus, our last implication explains how we could empower the above two values through design. The social value is addressed by designing artifacts and amenities that create opportunities for residents living in LTC and multi-stakeholders to interact more easily in designed activities during daily living. The ethical value is addressed by design considerations that help retain self and social identity, support determination process and independent use, boost esteem and confidence, and enable connection to close relationships. For instance, both designs of *Closer to Nature* and *LiveNature* were situated in a public shared hallway within the Vitalis care home. Such location creates a space that enables unrestricted access and supports independent use of PWD. Moreover, it leaves residents free choices to be socially engaged or stay alone.

8.2.2 Practical Implications

Conducting research with "extra-ordinary" users like PWD can have "extra-ordinary" challenges. In this section, we conclude our knowledge learned throughout our practices to alert future researchers in thinking ahead of the potential challenges and assisting in designing and conducting more robust experiments.

Participant Recruitment of Experimental Studies

Participant recruitment of PWD with the required quantity and variety as in experiment design can be very challenging. Despite practical reasons, for instance, the potential participants that are difficult to approach; the related ethical approval procedures that are complex and strict; and the assessments of cognitive and other abilities, which are both labor-intensive and time-consuming. There are also challenges due to the diverse heterogeneity of participants that could potentially influence the experimental findings. Take the study by Perugia (2017a) for an example. It disclosed the significant differences of PWD with and without motivational disorders (i.e., apathy and depression) on affective states during free interaction with the Pleo robot. Thus, researchers need to carefully consider the inclusion and exclusion criteria in combination with practical situations to ensure that the experimental study is well-controlled and rigorous. In the following, we summarize three concerns with recommendations and examples from this thesis to contribute to participant recruitment of future experimental studies with PWD.

The first concern regards the inclusion and exclusion criteria of participants. On the one hand, conducting an experiment on a recruited group of PWD means viewing the selected sample as a community with similar qualities shared. On the other hand, it has been acknowledged that individual differences can potentially influence the findings and further compromise the robustness of the research. Thus, setting inclusion and exclusion criteria wisely, collecting sufficient demographic information of participants, and performing pre-experiment assessments are the keys to successful experiment design.

In our case, we have conducted cognitive tests before the actual experiments using a well-developed tool – the MMSE (see Appendix B). The MMSE test involves answering questions verbally, writing required sentences down, drawing pictures, and folding papers by PWD. This procedure can help the researchers gather not only valuable insights into cognitive abilities but also impressions of their language expression, hearing, eyesight, writing abilities, and physical ability to interact. All this information can potentially be used to support setting inclusion and exclusion criteria and avoid inabilities that may have an acute impact on the engagement of participants. For instance, if the designed activity enables physical interaction, participants' physical ability to interact with an artifact should be assessed ahead. Similarly, their visual and auditory ability can influence how they respond to audio-visual content enabled by design. In addition to the above, other factors should be considered ahead, including participants' dementia severity, gender, and their medication uses (if the evaluative studies mainly rely on facial expressions and certain sedated medication could suppress emotional expressions).

The second challenge regarding participant recruitment is determining

the sample size with limited resources in practice. We conclude two noteworthy aspects for sample size determination and avoiding running underpowered studies with unclear results.

The first aspect regards the experiment design – the utility of within-participant design. The repeated measure experimental design usually requires few participants with each participant exposed to several independent variables. Since it is of utmost importance to take individual differences into account when working with PWD, it allows the researchers to determine the effect of the independent variable/s on dependent variable/s by controlling other possible causes for the change in the dependent variable (Steingrimsdottir & Arntzen, 2015). Steingrimsdottir et al. (2015) advocate the use of within-participant research design when working with older adults with neurocognitive disorders, in particular, when the intervention is intended to observe behaviors changes. Use our case as an example (i.e., the experiment design presented in Chapter 7). Given the difficulty of participant recruitment due to the limited residents living in our collaborative location, we performed a two-by-two mixed factorial design with one within-subject variable and one between-subject variable. In this way, we could reduce the required sample size compared to full factorial design without compromising the validity of the results.

The second aspect is the sample size estimation prior to the experiment. We suggest using statistical tools to calculate the required minimum sample size and ensure sufficient participants are recruited to achieve sufficient test power. To use the same study as an example (i.e., the experiment design presented in Chapter 7), we performed a priori statistical power analysis using the GPower software for the sample size estimation of our within-between interaction comparison. Based on the results, we then recruited more participants than calculation results to ensure the sample size was adequate for the main objective of this study.

The third challenge concerns the high participant dropout rate during the experiment. Given ethical considerations, researchers conducting experiments with PWD usually consult each time a participant was invited for the sessions to ensure the voluntary nature of the participation. Although informed consent has already been obtained, the researcher should prepare for multiple situations that participants imply or express refusal of their participation on the day when experimental sessions were planned. For instance, their personal conditions may not fit for any activities anymore, the medication use makes them sleepy, or simply not in the mood. In such cases, refusal can lead to dropout sessions, disturb the initial experiment arrangement, which further causes missing data and loss of test power of statistical analysis. Take one experimental study reported in Chapter 5 as an example. We experienced a high number of dropout sessions that eventually caused a modification of data analysis (i.e., statistical analysis of the repeated measure was changed into between-subject analysis) and a sacrificed power. We then reflected on this issue and took improvement strategies in the subsequent experimental study, which turned out useful. Our lessons learned are as follows:

- Be aware and prepare ahead that when conducting studies with PWD, you may experience dropout sessions due to various situations, from as small as mood swings to as severe as hospitalization or even death.
- Based on our experiences, two things may help researchers reduce the chance of rejection of participation. First, consult the caregivers who are familiar with your target participants for their professional opinions on their status, current mood, and appropriate ways to communicate; Second, get familiar with participants' daily activity schedule, care services, and avoid the high behavioral time of the day.
- Last, allow certain flexibility with your experimental time schedule to cope with a large dropout rate.

Participatory Co-Design with PWD and Facilitators

The primary challenge of designing for PWD, as addressed in Chapter 2, **is the "inability to put ourselves in the shoes of users"** (Pullin & Newell, 2007)**.** Design research has long dealt with this challenge through better involvement of PWD and their living context in the design process. And the design research has already started to embrace a person-centered approach and ensure the voice of real target users is heard. On the basis of the above, we advocated the involvement of potential facilitators of designed activities besides PWD within such a process as co-creators. Our experiences showed that most design-mediated activities within LTC still need facilitation from others in practice (e.g., caregivers). And the quality of such activities is highly dependent on the quality of facilitation. People who facilitate interventions can have different needs, expectations, and perceived usefulness than PWD. Therefore, by involving the facilitators in the design process, our solutions can serve better as a medium for supporting, even guiding the facilitation, enhancing engagement, and promoting the relationship bonding between facilitators and users.

The second challenge concerns the knowledge transfer within multidisciplinary fields that contribute to dementia engagement and well-being. During this research journey, we found that there is little consistent language for designers, psychologists, and clinical practitioners who all work in dementia-related research fields to transfer their knowledge. Each area works independently with well-developed approaches and tools that have great potential to benefit significantly from each other. As design research comes later in this field with all kinds of assistive technologies and interactive systems, we encourage designers to spend time in care homes with residents, caregivers, families, and managers to understand the underlying dynamics of dementia care. And operate as social researchers to be able to transfer knowledge from ethnographic studies to practical design interventions. In addition, we also encourage to implement and explore the designed outcomes in real-life environments for acquiring feedback from target users, their caregivers, and people familiar with PWD to interpret their behaviors and communications better.

Measurement Use for Assessing Design's Effectiveness

In this thesis, a mixed method with combined qualitative and quantitative data collection was adopted with different research emphasizes. The qualitative data collection aims to gather person-centered feedback, document preliminary evidence of design solutions' positive impact, and prove the proposed solutions are meaningful within the context. Meanwhile, the quantitative data collection through experimental research aims to investigate how PWD's engagement in activities is influenced by the features of a system design. Taken together, we attempt to provide a comprehensive understanding of user engagement that not only values this group of users as a community but also embraces the individual uniqueness of PWD.

The implications are two-fold:

First, we offer implications of measurement use regarding the observational rating scales. In this thesis, we have employed five observational rating scales, including OERS for affective states assessment; OME and EPWDS for assessment of general engagement of PWD; the PEAR–Apathy Subscale and CMAI for apathy and agitation assessment accordingly. The selected measures are either widely used within dementia research (e.g., OME, OERS, CMAI) or represent the up-to-date engagement/behavior assessment (e.g., EPWDS, the PEAR–Apathy Subscale). Detailed reasons for adoption and instructions of the use of these scales can be found in previous chapters.

We list three recommendations regards how these scales can be combined in practical use as complementary strategies to fit different contexts of interaction. These recommendations are reliable, executable (as they are behavioral observational based), timely efficient, suitable for different design purposes, and can be used on relatively small-scale experiment design regardless of cognitive impairment levels of PWD.

1. For a general evaluation of user engagement between the designed artifacts/systems and PWD, we recommend the combined use of scales - OME and OERS. The use of scale OME can provide a general impression regards user’s engagement duration, attention, and attitude towards the stimuli. As it cannot distinguish positive or negative emotions further with intensity level, we suggest using OERS in addition to complement the evaluation of affective states by addressing the intensity of five emotions (i.e., *Pleasure*, *Anger*, *Anxiety/ Fear*, *Sadness*, and *General Alertness*).
2. When social interactions are relevant and to be investigated by researchers, we recommend the combined use of scales - EPWDS and OERS. The EPWDS measures five aspects of engagement. Besides Affective, Visual, Behavioral aspects of engagement, it also offers separate assessments for Social and Verbal engagement, which are valuable parameters for activities that involve social interaction. Moreover, the scale could compute an overall score to represent overall engagement states that could be easily compared across different conditions. Like the OME, the assessment of Affective Engagement of EPWDS could not offer an assessment regarding the intensity of emotions. Thus, we suggest supporting the affective measurement using the OERS as well.
3. The above assessment tools are used to measure the engagement of PWD during the interaction with provided stimuli. In line with engagement evaluation, if researchers are also interested in monitoring behavior changes pre-and post-experiment sessions, we recommend the use of rating scale/inventory (e.g., the PEAR–Apathy Subscale, CMAI) that assesses two most noticeable challenging behaviors that are closely relevant to dementia care - apathy or agitation. The PEAR–Apathy Subscale is a valuable scale that assesses the extent to which the participants are intrinsically motivated to behave despite being positively or negatively engaged. The CMAI is an inventory with listed agitated behaviors to assess the frequency of manifestations of those behaviors among PWD during a pre-defined period. What is worth noticing is that using averaged results of a group of participants for comparison can be influenced by their performance at a baseline level. Thus, we would suggest using these in future studies to trace behavior changes that are individually based.

Second, we present implications regards quantitative observations through video coding analysis. We have explored two video coding schemes – the VC-IOE (further developed into the scale EPWDS) in Chapter 3 and the ELICSE coding scheme in Chapters 5 and 7. Here, we focus on implications derived from experience with the ELICSE. Compared to observational rating scales that can be rated onsite directly and efficiently, methods through video coding analysis can be time-consuming. Therefore, the question raised is: What are the time cost tradeoffs for assessing participants' engagement using the video coding scheme ELICSE?

- First, the nature of video coding analysis through coding schemes allows second-by-second observations of participants' behaviors and quantification of each behavior with frequency and duration documented objectively and robustly. In addition, unlike post-experiment measures that require raters to recall previous experiences, coding analysis is rated by taking the ongoing process of the interaction into account, which reduces the risk of human error and wrong impressions.
- The second reason concerns the adaptivity nature of the video coding scheme – ELICSE. Specifically, ELICSE allows modification to be made according to the specific context of the interaction, the role of the observed participant, and the type of activities to ensure the final coding scheme is meaningful within the specific context. ELICSE was developed based on a theoretical understanding of the engagement of PWD. It identifies engagement-related behaviors under a particular context of interaction and helps the researcher associate a meaning (i.e., Attention or Valence) to each specific behavior s/he observes. These meaningful associations further allow data aggregation of observed variables into latent variables and conduct statistical analysis according to specific research goals.
- Third and last, data analysis using ELICSE allows separation of activity-related engagement from social interaction related engagement. Thus, it enables investigation of effects of independent variables on dependent variables, meaning ELICSE can be used to investigate engagement with the stimuli or social engagement with an agent/human separately according to research questions. For instance, we aim to investigate how the user engagement with the provided activity could be influenced by different system configurations applied in designed experimental conditions, regardless of their social interaction with the facilitator. Data aggregations of the ELICSE can be performed according to their attention focus on the activity provided only. Vice versa.

8.2.3 Ethical Implications

PWD has challenges in making logical decisions and expressing agreement or even disagreement, which makes research and care practices complex and ethically challenging. Conducting research and care practices with PWD requires special attention to ethical concerns regards determination, decision making, understanding of the research procedure properly, and their rights to withdraw. Furthermore, proper ethical protocols should be set up clearly for obtaining informed consent, privacy protection of data collection, storage, and access; ensuring safety, control, and autonomy; and maintaining human dignity during the experiments.

The following content aims to pinpoint ethical concerns when conducting research with PWD, specify our expectations of good ethical practices, propose principles and protocols of dementia-related research ethics, and envision value-sensitive designs in future works.

Obtaining Informed Consent and Data Privacy Protection

The introduction of designed activities to conduct user testing with PWD in a care setting requires informed consent by those affected. Prior to the experimental studies, ethical approvals both from the research institute and the place where the study takes place should be obtained. Informed consent contains information, including, but not limited to: the persons and institutions in charge of the investigation and their contact, the intention of the research, the procedures, duration, risks, and potential benefits of the study sessions, the confidentiality issues (e.g., which data will be collected and how they will be stored, accessed, and the potential use of the output of data analysis to protect data privacy), and most importantly, their voluntary participation during the whole experiment. So the potential participants can fully understand the statement of consent to ensure no misgiving about participation.

Ensure that PWD understand the communication and their rights to withdraw. Given the cognitive impairment associated with dementia, particular explanations are needed to ensure participants are engaged in communication with sufficient information. Communication techniques, such as short, easy, understandable conversations, or questions with simple answers like yes or no, could be employed to encourage expressions and support understanding and decision making. In addition, before and during the experiment sessions, participants could be reminded again to be aware that participation is entirely voluntary, and they are free to withdraw at any time without their care activities being affected.

Moreover, a priori assessment of participants' cognitive impairment and ability to give consent could also be conducted to support the consent given. There are cases that participants are no longer capable of giving consent anymore, and obtaining informed consent in such circumstances is highly ethically related. It can be controversial whether their legal representatives (e.g., family members) should sign the consent on behalf of the participants.

In our cases, we conducted meetings before the experiment sessions started to present all relevant information regarding the experiment and research, to sign informed consent, and to introduce residents' rights to refuse to participate at any time. We obtained written consent from participants or their legal guardians in cases: if participants cannot write and sign but verbally give consent with their legal guardians present and agree, the principal investigator was not sure if the participants fully understand the statement of informed consent, they could not clearly express their willingness, and their legal representatives agreed and considered beneficial to participate in.

Maintain the confidentiality of data collection. We propose our understanding of good research ethics that considers three aspects - data collection, data storage and access, and potential use and presentation of collected data.

- Data collection: Experiment design, activity provisions, and measures should be carefully considered and implemented to avoid unnecessary or intrusive data collection on PWD as much as possible.
- Data storage and access: We conclude two protocols: 1) Researchers should ensure data is stored safely on secure computers and servers and with limited personal access to the collected data; 2) When performing data organization, all collected information including demographic data and experiment data should be anonymously sorted and treated confidentially.
- Use and presentation of data: The collected data will be only used for purposes as agreed in informed consent (e.g., academic purpose only). The result of data analysis should be presented in academic publications or presentations with confidentially as well.

Ensure Users' Safety and Dignity During Experiment

The second primary ethical concern when conducting research with PWD is protecting users' safety and dignity during the whole experiment phase.

To ensure the safety of participants, researchers should fully consider the potential harm, safety hazard, risk of fall, fatigue, etc., that could happen during the study. Interaction involving physical actions will naturally raise safety concerns. Thus, close observations should be in place all the time. Additionally, conducting risk assessments before the actual experiment (such as a trial study to estimate potential risk, and get sufficient information regarding participants' mobility) could also support the management of safety risks.

The journey of dementia research and design should always start and end with supporting dignity. **To address the ethical concern of how to better maintain users' dignity during the study sessions**, we propose knowledge learned as the following:

- To avoid personal interaction with a stranger that may cause discomfort for PWD, researchers or facilitators involved in the experiment should get acquainted with participants before the experiment sessions start. A proper introduction of themselves and spending some time with participants are recommended to get familiar with participants.
- When communicating with PWD, act and ask politely. Always treat PWD like adults as they are. Researchers could use communication skills strategically (e.g., the phrasing of sentences, enthusiastic voice, and appropriate touch) to support relationship building. Moreover, researchers should give sufficient encouragement and ask promptly for users in more advanced stages of dementia to support their decision-making and expression of preference.
- Before each experiment session starts, researchers could consult caregivers or those who are close to the participants for their current mood and conditions to ensure a good status for participation.
- The last point regards the proper facilitation of study sessions. The quality of facilitation can determine the success of an experiment and is highly ethically relevant. Unclear instruction may further confuse participants and potentially negatively impact their well-being. Thus, facilitators should give clear instructions and avoid confusion of participants intentionally. In addition, researchers should avoid the use of measures or designs that are invasive, stigmatize dignity, or cause any discomfort unless necessary.

Lastly, we address the issue of potential deception and perception that may negatively affect users' dignity during activity engagement. Participants engaged in certain designed activities can be perceived as dehumanizing one's dignity by others. Take the social robot interaction of

PWD as an example. On the one hand, PWD are at risk of recognizing the robot animal as a real one, which is considered a deception issue. On the other hand, it can be emotionally challenging in the perception of family members, seeing their loved ones interacting with a “toy” compared to their previous self without dementia. Such impressions can cause negative impacts on users’ dignity due to the “infantilization” features of a social robot. However, it is precisely the “infantilization” features, such as dolly eyes and furry textures, that contribute to user engagement and are desirable for promoting acceptability. In other cases, wearing a help alarm with a big red button located in the center or an ankle bracelet that monitors and tracks PWD should be avoided when designing for this venerable group of users regardless of any functional excuses.

Consider Withdrawal Protocol to Address Potential Attachment and Dependency Issues

Withdrawing interventions after regular participation can also raise ethical concerns. Here we list two potential situations. First, PWD may grow reliance on interventions due to their assistive nature. Thus, the sudden withdrawal may deskill users and compromise their autonomy in making decisions and executing daily tasks. In another situation, users may get emotionally attached to the provided agent (e.g., a robotic companion). Therefore, the abrupt withdrawal can be harmful emotionally. In order to cope with the potential negative impact due to the withdrawal of interventions, a phased withdrawal protocol should be considered and carefully implemented. We propose to gradually lower the frequency of the exposure to designed interventions and leave sufficient time for users to adapt to new situations instead of abrupt withdrawal.

The Nature of Care is Human Care

At last, we re-address an ethical concern that has been significantly discussed in the literature - that the use of technologies, especially social robots, may have a reductive understanding of the nature of care for PWD. The nature of care is human care is a deep ethical value that society assigns to genuine human caring relationships for both recipients and the providers of care. And any relationship we grow and have with technologies that tend to replace human relationships can raise profound ethical concerns.

To reduce such concerns, we propose our principles when designing for PWD:

- We aim to design interactive systems that facilitate enjoyment between PWD and relevant stakeholders (e.g., caregivers or loved ones) instead of replacing human care with the occupation of merely the design itself. Design for PWD should not sever as a replacement for human care but as a tool for facilitating interpersonal interactions and bridging real human contact.

- In our studies, we seek to ensure that a facilitator is always present during interaction to observe closely, manage potential risks, and ensure reflective and ethical use.

8.2.4 Theoretical Implications

This section offers the theoretical implications using a triangle-shaped framework that concludes the design's triple roles in contributing to dementia well-being within the specific context of LTC. See Figure 8.1.

We conceptualize this triangle-shaped framework based on the model of compassionate design, which was proposed by Treadaway and colleagues (2019b). The notion of compassionate design emphasizes the positive emotional experience with a particular focus on designing for positive affect in advanced dementia. It was defined as "*design that stimulates the senses, that is highly personalized and helps to foster connections between people*". Corresponding to its definition, the model of compassionate design is a pyramid with three vital components taking three corners. These essential components are: *Sensory*, *Connecting*, and *Personalized*. Additionally, as the model was built based on positive design methodology as described in (Desmet & Pohlmeyer, 2013), it put *Love* at the center of the design process to maintain dignity, personhood, and well-being of the persons living with dementia. Extended on the two vital components – *Sensory* and *Connecting* of the model of compassionate design, we added an environmental attribute to the framework considering the influence of the dynamic context of LTC on PWD.

The conceptual framework proposes three central roles of design (R1-R3) in contributing to a meaningful and engaging activity for PWD within LTC environments, which are:

- **R1:** *Design for PWD living in LTC as a solution for providing meaningful multisensory engagement.*
- **R2:** *Design for PWD living in LTC as a bridge for connecting PWD with multi-stakeholders.*
- **R3:** *Design for PWD living in LTC as a means for shaping the physical and psychosocial environment.*

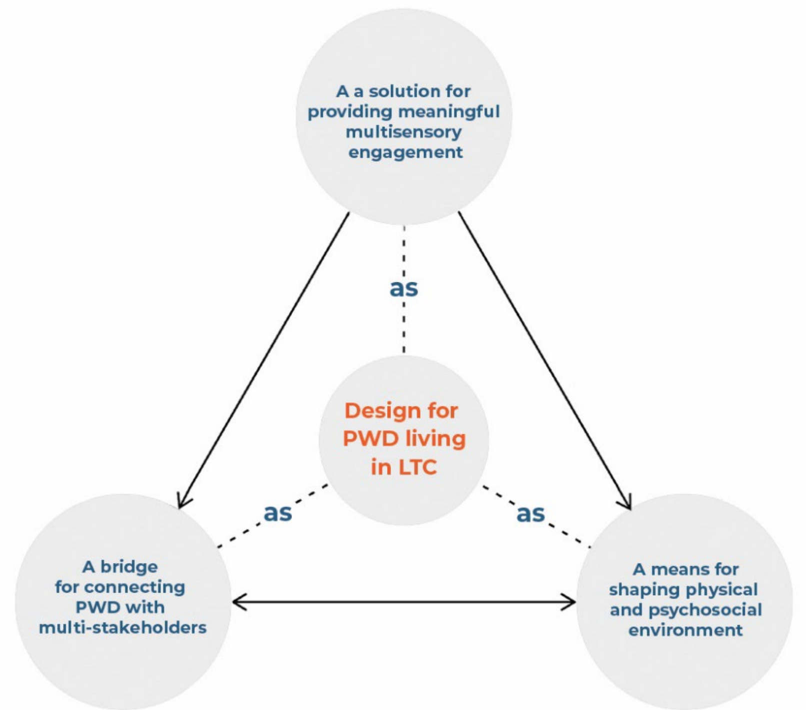


Figure 8.1 Conceptual framework of design's triple roles in contributing to enhancement of engagement and quality of life for PWD living in the LTC environment.

Three roles emphasize different functions of design to meet the psychosocial needs for PWD living in LTC environments, which are:

- Providing sensory experiences that are meaningful for individuals. Such experiences could be enabled through personalized experiences related to individual upbringing. They could compensate and serve sensory needs through stimulating or relaxing stimuli and support higher psychological needs such as curiosity, independence, and dignity.

- Promoting social inclusion that is meaningful for a small-scale community of users. Social interaction can boost individual engagement and directly influence the well-being of residents. Moreover, it can also help build meaningful social connections with care staff, consequently influencing the dynamic and quality of care activities that benefit both the caregivers and receivers.

- Reshaping the context of living to influence the well-being of its inhabitants positively. Both physical and psychosocial environments that PWD lives in were reported extensively in the literature to directly influence the inhabitants' well-being (Vogt et al., 2012).

Designs that involve physical environment as a part of design through transferring a living environment into enriching sensory experiences, such as (Anderiesen, 2017); or creates a smart environment in which devices and agents work collectively towards the meaningful goal for PWD, such as (Thoolen et al., 2020b); are likely to serve as a meaningful activity for PWD living in LTC.

8.3 Reflections

In this section, we list and describe reflections raised from three dilemmas when designing for PWD and further discuss how these dilemmas inspired the thinking process of this research.

8.3.1 Designing for a Community or Tailored to Individual?

Tom Kitwood's life research in social psychology focused on personhood theory related to PWD and the uniqueness of each individual's experience with the disease (Kitwood & Bredin, 1992). In modern dementia care, Kitwood's well-known person-centered care approach – putting the PWD as a person in the middle of the care process – has been long adopted as a gold standard in many dementia care institutions (Dewing, 2008). Following this philosophy, design applications that provide customized stimulations based on PWD's profile (e.g., ability, background, and personality) appear to be successful in achieving positive effects; examples see (Gowans et al., 2004), (Trahan et al., 2014), and (Thoolen et al., 2020b). However, such customization can be challenging due to the constant change of individuals' needs, moods, and interests. As the famous saying in dementia care goes, "*what works today may not work tomorrow, and what works now may not work later*." And it takes a skilled professional to sense the changes as well. In addition, personalized stimulation often means participation in an individual activity, which may increase the risk of social isolation. Research suggests that social interaction among peers, or between PWD and caregivers or family can have a boosting effect on user engagement and well-being (Chang et al., 2013). In institutionalized settings, group activities are also optimal choices due to limited care resources.

The dilemma is: *On the one hand, customized or personalized stimulations and activities designed based on their cognitive functions or past experiences are effective approaches with proven significant positive effects. On the other hand, practitioners who work in dementia care wish for an ideal universal solution in practice that can socially engage PWD and other stakeholders and let them benefit from a single activity all at* *once.*

There always seems a debate in dementia research that the customization and the “universal” solution cannot co-exist. Our research presented in Part 3 was inspired by this dilemma and adopted a shared nostalgia experience, that echoes to a generation of Dutch elderly living in Eindhoven, the Netherlands, as design materials for a “tailored” design for a small community of users with dementia (i.e., residents from the Vitalis). Furthermore, we incorporated system adaptivity in our designs by offering multiple avenues for interaction to adapt to different user abilities. Therefore, in accordance with the above, we offer two design knowledge based on lessons learned along with the research:

- Design for PWD living in the LTC context could utilize shared interests, backgrounds, and times of PWD to enable “tailored” experiences. Experiences that relate to a generation of users that take them on a nostalgia trip can be good resources for future design applications. Unlike reminiscence experiences which are personally associated, experiences that embrace a more extensive community possess the possibilities to open new experiences while withholding quality of familiarity.
- The system design for PWD facing a community of users may also consider incorporating adaptive system design to cope individuality of a community of users for meeting various needs. In specific, instead of having one “right” way to interact with the system, the design could offer diverse experiences with leveled flexible interaction possibilities. Additionally, instead of achieving task-oriented goals, the design could encourage explorative experiences that afforded user choice in the ways of user-initiated interactions.

8.3.2 Professional Facilitation or Self-engagement?

As addressed in ethical implications, “the nature of care is human care.” Interpersonal interaction and human empathy are essential for the high-quality care of PWD. And the proper facilitation of a human caregiver in activity is crucial to ensure that the process is both ethical and effective. In the meantime, PWD also needs activities to be self-engaged in to occupy time and alleviate boredom like we usually do. This could be explained by reasons, for instance, personality (one may prefer to stay alone), limited resources in care (unrealistic to have a caregiver for accompanying all day long), or other concerns like support one’s autonomy (since self-engagement can support PWD’s autonomy, give them a sense of control, and boost a feeling of still capable of doing things by themselves).

Here, the dilemma is: *Human care for PWD is both a necessity in reality and where society's value lies. However, in practice, self-engagement can also benefit PWD successfully. Then our question raised is: is human facilitation a necessity when designing for PWD, especially within the LTC context?*

Our answer regards this issue experienced a change throughout the journey of research. In the earlier phase, as in Part 2, with clear reported feedback in mind that the care provision experiences can be very challenging and stressful, we aimed to develop designed activities that PWD can be self-engaged in and require little effort from care staff. With reflection on the role of interactive table design – *Dynamorph* - in facilitating the meaningful engagement for PWD in the LTC environment, our design started with an intention to help ease caregivers' workload and reduce care burdens by occupying the residents during non-planned activity times. The user study findings suggested that the positive impacts of the design also came from the desire to share their experiences and receive comfort, attention, and confirmation from the facilitator, which plays a crucial role that differs from engagement with their peers. Consequently, our objective experienced a shift from self-occupation focused to creating designs that help to guide the facilitation. In addition, most available designs targeting advanced stages of dementia focus on experiences of "reminiscence," "sensation," and "relaxation" (Anderiesen et al., 2015). Our findings through later studies, presented in Part 3, revealed that users with dementia could benefit more from such layback experiences with necessary encouragement from a professional facilitator.

To address whether human facilitation is a necessity when designing for PWD in LTC, we propose the following. First, designing for PWD living in the LTC context should always leave opportunities for social involvement of others (whether a family member/s, a caregiver/s, or a peer resident/s). And this is because receiving sufficient attention, confirmation of reality, and building the personal connection between caregivers and PWD are influential factors that determine the positive effect of a session. Meanwhile, future designs for PWD living in an LTC context should consider finding a balance between activities that mainly rely on professional facilitation and activities that facilitate self-engagement only. Moreover, design should also allow freedom for PWD to choose whether socially engaged or stay alone.

8.3.3 Reminiscence or Something New?

Reminiscence is a significant topic and a useful approach within dementia-related research. This could be easily understood as dementia is closely associated with memory loss. Without the ability to access short-term memories and recall recent events, PWD largely relies on their longer-term memories and benefits from reminiscence activities to feel in control of life. Reliving past happy memories has well-documented positive effects. For instance, emotional enjoyment, increased verbal communications, promoting and expressing self-identity (Huber et al., 2019), (Klein & Uhlig, 2016). Thus, many available design applications for PWD attempt to access remote memories through reminiscence for therapeutic effects (Lazar et al., 2014). However, the process of understanding reminiscent materials may also risk a sense of loss induced by a comparison of past life and current ones. And to flourish in life, we also need experiences that are stimulating and new.

There seems to exist a trend of design for PWD that mainly focuses on coping with memory defects and indulging PWD in past experiences. In contrast, neglecting the encouragement of experiences that are explorative, playful, and open-ended. Studies even suggest that the "exploration" experience - one of the 22 playful experiences proposed by Korhonen et al. (2009) – is the only one that is not suitable for any stage of PWD. This was explained using neuropathology evidence that the exploration experiences are related to areas in the brain, like the hippocampus and prefrontal brain areas, where is likely already compromised for PWD (Anderiesen et al., 2015).

The dilemma is: *For PWD, especially the persons in their advanced stages of dementia, whether the designed activity should focus on re-creating reminiscence in its most realistic way or encouraging experiences that are explorative, even surprising through something stimulating and new?*

Our research presented in previous chapters provided positive evidence that PWD can also benefit from properly designed explorations enabled by design-empowered interventions. For instance, when engaged with the installation *LiveNature*, participants who successfully figured out how the system works and how the feedback of robotic sheep could be triggered expressed facial and verbal enjoyment.

Therefore, inspired by our research, we advocate that the researchers and designers should reconsider the role that "reminiscence" plays in design for PWD. In particular, we believe that the reminiscence approach could be a successful motivation strategy for provoking active engagement, creating familiarity which may improve accessibility and useability, promoting emotional well-being, supporting autonomy, and facilitating recollection of personal narratives to enhance self-identity rather than an ultimate goal of the designed activity. We aim not only to allow the users to remember the past and live in those happy memories but open up broader opportunities for new experiences. The adoption of reminiscence objects in our research provided tools to facilitate communications, enable new experiences of sharing, and social bonding with others. This might help us understand how to design and offer new types of interactive systems for promoting well-being in dementia, rather than simply indulging them in old memories.

Chapter 9 | Conclusions

9.1 Answers to Research Objectives and Questions

This research is mainly motivated by the current inactive and disengaged living style of PWD admitted to LTC facilities. The prolonged lack of engagement in sensory, physical, and social activities can lead to accelerated disease development and improved risks of depression, thus threatening physical and psychosocial well-being. Engagement in meaningful activities is suggested by literature as the key to improving quality of life and can offer opportunities to live well with dementia after diagnosis. For decades, psychiatrists and psychologists developed multiple approaches for increasing engagement and reducing behaviors perceived as challenging in practical dementia care. However, the resources required to implement many of the traditional approaches far exceed that are available in most LTC facilities, which leads to limited use or no use in practice. Interactive technologies of HCI withhold great potential in promoting active engagement and addressing unmet psychosocial well-being of PWD in LTC. Therefore, it has become an emerging field and started to gain mainstream attention from researchers working with PWD.

The main objective of this thesis is: *Design interactive systems with rich interaction as meaningful activities for PWD living in LTC facilities towards enhanced engagement, which then consequently improves their quality of life as well as subjective well-being during daily living.*

The main objective is two-folded:

- On the one hand, this research explores how to ensure the provided interactive systems designs as meaningful activities for PWD within the specific context of LTC environments.
- On the other hand, this research endeavors to investigate how to design interactive systems towards an increased level of engagement of PWD.

9.1.1 Approaching the First Research Objective

In response to the first research objective, we combined desktop literature research work (presented in **Chapter 2**) with empirical field explorations (presented in **Chapter 3**). The former aims to acquire insights from existing research and clarify "engaging PWD in meaningful activities";

the latter aims to gain sensitivity of our target user group, dynamic care context, and related multi-stakeholders within their real-living environment.

Findings throughout Literature Research

RQ1: *How to design interactive systems as meaningful activities for PWD within the specific context of LTC environments?*

To understand why PWD are disengaged and under-stimulated in the first place, we identified three groups of challenges that researchers can influence to promote the current unsatisfied situation - the individual, contextual, and stimuli factors. Strategies were proposed accordingly: 1) To accommodate challenges from the individual perspective, we need motivation strategies suitable for personal profiles (abilities and interests) to motivate participation and engagement. 2) To accommodate challenges from the contextual perspective, we need a deeper understanding of the dynamic care context to offer meaningful solutions for PWD and multi-stakeholders. 3) Last and most importantly, to accommodate the stimuli perspective, innovative solutions addressing psychosocial needs are in need for engaging PWD in experiences that are enjoyable, fun, and engaging.

RQ1.a: *What is the status of meaningful activities for engaging PWD in the existing literature?*

To find effective approaches for benefiting PWD as the ground truth, we carried out literature research and provided a state-of-the-art of the developed “meaningful activities” from multidisciplinary research. Two categories of activities for PWD were reviewed – the traditional activities (i.e., non-pharmacological interventions) and technology-empowered ones. We learned that although non-pharmacological interventions have great potential in managing behaviors and provide the meaningful pursuit of life with dementia, they are limited in practical use due to barriers including: 1) the passive role of PWD as recipients of such interventions; 2) high dependency of the facilitation quality from professionals, including the ability to combine the use of multiple strategies and tailor them to individual needs; 3) limited effectiveness for community-based users and users in their advanced stages; 4) limited effectiveness in addressing the higher level of needs – the psychosocial needs of PWD. Thus, it calls for technology solutions to address these limitations.

To further zoom our focus regarding the use of interactive technologies, we provide an overview of HCI development for PWD. We identified a research gap in which small proportions of technologies were developed for psychosocial needs and users of more advanced stages of dementia. The psychosocial needs are identified as the most unmet in the LTC context, and the majority of residents in LTC are composed of moderate to severe stages of dementia. Thus, a thorough literature search was further performed on technology-empowered psychosocial activities for PWD. We included studies regardless of PWD's living environment in Chapter 2 due to the limited quality studies. As a result, four primary areas of design were summarized and enlisted. We gave each category an evaluation in terms of the focus of most research efforts and a potential research trend.

The first area – Sensory-based Designs is where most studies allocate. Within this area, majority efforts of sensuous engagement for PWD are through auditory and tactile modalities. In line with the pursuit for an immersive experience in HCI nowadays, sensory-based designs for PWD aim to enable multimodal sensory experiences rather than engagement in certain senses. The second area - Design for Reminiscence, Communication, and Connection is another major focus where most technology applications are digital applications and tablet/cellphone-based. Employing tangible interfaces and social/conversational agents is one emerging trend in this design area. The third is Augmented Environment Designs which transform the daily living environment into enriching sensory experiences. Most current designs curate passive sensory experiences with limited possibilities of self-initiated interactions. And experience allows playful interaction possibilities are arising with the development of sensing-based technologies. The last area - Other Designs (ICT technologies, exergaming, and VR) presents challenges for PWD with more severe conditions. Therefore, future studies are still needed for feasibility tests.

In addition, to evaluate the effectiveness of designed activities, we reviewed how the effects of meaningful activities were measured. We noticed that, for traditional activities, most evaluations were based on the occurrence of BPSD and a few on engagement assessment. Meanwhile, with more understanding towards PWD's engagement and its measurement, we adopted engagement assessment as the primary indicator; and concluded our definition and construct of engagement based on previous engagement research of PWD. On the other hand, for designs within the field of HCI, most evaluations were qualitative empirical studies. Thus, we propose the combined multidisciplinary approaches and collect both qualitative and quantitative data during different phases of our iterative design process to offer individually based findings and evidence that can be generalized.

Findings throughout Empirical Explorations in Context

RQ1.b: *Which qualities interactive systems possess could potentially contribute to a meaningful activity design for PWD and multi-stakeholders living in the LTC context?*

To provide meaningful designs within the specific context of LTC, we conducted context explorations in a real-living environment at one location of our close collaborator - the Vitalis. The empirical explorations are two-fold. On the one hand, three sub-studies were conducted to gain sensitivity of our target user group and dynamic dementia care context to better understand practical challenges and current coping strategies. The results concluded eight inhibiting factors of challenges and barriers encountered from both client-based perspectives and staff's point of view, and nine enabling factors subtracted from reported coping strategies. Besides practical limitations such as inadequate personnel and overloaded work, we learned that staff needs effective tools for managing challenging behaviors and promoting social interactions with their clients. And for PWD, in line with literature views, lack of interests and motivation, limited social interactions, and limited access to outdoor spaces are the leading cause for disengagement and inactivity in such facilities.

On the other hand, to zoom the design opportunities of the provision of meaningful activities for PWD in LTC, we generated four design concepts and empirically tested them with residents and caregivers in Vitalis. We learned from the implications derived from contextual inquiries using three quick prototypes:

- **i1.** When designing psychosocial activities, the challenges of the provided activity should match individual abilities and preferences to generate positive impacts on users. Thus, we identified that sensory engagement could be a pathway to engage a community of users with dementia with various personal conditions.
- **i2.** For design to have expected positive emotional responses, designers should carefully consider the reminiscent material use to avoid potential negative influences such as further confusion or extreme emotions.
- **i3.** Interaction design for PWD should consider its connection with real-life experiences. Thus, we learned that interaction should be able to refer to their previous living experience to promote intuitive interaction.

Based on lessons learned, we developed the fourth prototype to explore the design of sensory experience and social interaction for PWD in a small-scale living community. As the outcome, an interactive table *Dynamorph* was designed to engage four residents around a table in sensational touch explorations and collective play experiences with limited facilitation effort from staff/caregivers. The evaluation findings further detailed the abovementioned design implications (i.e., i1-i3) for psychosocial activity design for PWD in LTC, that are:

- Extended on i1, we found that design that provides sensory engagement and encourages explorative and playful experiences without the concerns of making mistakes could be a promising direction for designing for a community of users living in the LTC context.
- Extended on i2, the use of sensory stimuli also risks over-stimulating users and leads to raised negative emotions and agitated behaviors. Thus, researchers and designers need further considerations on the amounts and types of sensory stimuli a person experiences to address under-stimulated living and avoid over-stimulating users.
- Extended on i3, we identified three features regarding interaction design for PWD that might help motivate interests, invite to touch, and lower the cognitive ability barriers - Aliveness, Familiarity, and Concreteness. They could be adopted in future designs for fostering and sustaining the engagement of PWD.
- Besides the above, our design also offers insights regards design for social inclusion. We conclude that the affordance of design should provide possibilities for social connections; and proposed that design could be employed in a more public space to support independent use and social inclusion of multi-stakeholders.

As a conclusion to the first research objective, we propose our idea of the potential suitable activity design for PWD within the LTC context:

A psychosocial activity design that: provides multisensory engagement to comfort or stimulate residents; encourages explorative and playful experiences without the concerns of making mistakes; with rich interaction possibilities that are intuitive, familiar, and can use previous living experiences as references; with affordance that supports independent use, allows easy access, and enables social inclusion of multi-stakeholders within an LTC context.

9.1.2 Approaching the Second Research Objective

Built on the above, we continue the exploration of the second research question - *how to design interactive systems towards increased* *engagement for PWD*. We found our answers through a combined design phase (**Chapters 4 and 6**) and research phase (**Chapters 5 and 7**) based on two design iterations, the *Closer to Nature* and the *LiveNature*. Investigations were conducted to achieve the second research objective and to obtain conclusive evidence on the role of rich interaction (**Chapter 5**) and two related features - multimodality and system interactivity (**Chapter 7**) on the engagement of PWD.

Findings throughout the Design Iteration Closer to Nature

Based on the lessons learned in Chapters 2 and 3, in Chapter 4, we implemented a public interactive installation, *Closer to Nature* at Vitalis, for providing multisensory experiences with rich interaction. The installation aims to connect residents living indoors with outdoor due to their limited contact with real nature. Corresponding to the proposed qualities of meaningful activity design, we embedded a large-scale public display on a wall of Vitalis for virtual farm viewing. The virtual content displayed was augmented with a tangible interface using a reminiscent old-fashioned water pump for a simulated animal watering experience. The former experience aims to offer PWD soothing and relaxation through immersive passive multisensory experience, and the latter enables playful interaction for fun and stimulating experiences. The design concept was based on shared nostalgia experiences (e.g., farm visiting and animal nurturing) familiar to a generation of elderly Dutch people, especially our target users who have grown up in the Eindhoven, the Netherlands. In addition, this public installation supports independent use and social inclusion of multi-stakeholders through allowing free access to the public installation. A preliminary user study was conducted with 21 participants (15 residents, 4 family members, and 2 caregivers) using qualitative interviews. The findings demonstrated preliminary positive evidence of improved mood, bonding with nature and family members, and a recollection of youth memories for benefiting residents in the LTC setting.

RQ2.a: *To what extent can interactive systems with rich tangible interaction enhance engagement and reduce challenging behaviors of PWD living in an LTC environment?*

We conducted an experimental study with 15 residents (i.e., participants) to investigate the effect of adding tangible augmentation to the screen-based installation on improving interaction-triggered engagement and reducing participants' apathy and agitation. A repeated measurement design with two settings as experimental conditions: with and without tangible augmentation of the installation *Closer to Nature* as the representation of with and without rich interaction, and one control condition – manipulative tactile stimuli interaction was performed. A mixed method of video coding analysis (using ELICSE coding scheme) and observational rating scales (OME, OERS, PEAR Apathy-subscale, and CMAI) was used for quantitively assessing user engagement and challenging behaviors (i.e., apathy and agitation) comprehensively.

The statistical findings suggest a significant positive impact of adding tangible, therefore rich, interaction on enhancing user engagement in terms of Attention aspect and enabling recollection of memories through verbal communications. The findings also indicate a promising trend in promoting positive user emotions and reducing apathetic behaviors, however not statistically significant. To further interpret the significant positive impact on the Attention aspect of the engagement, we offered fair explanations by purposing three potential contributing features of interactive system design - tangibility, multimodality, and interactivity. The latter two were further investigated in chapters 6 and 7 to answer to what extent these features could influence user engagement of PWD.

As a result, we conclude that PWD's user engagement in terms of its Attention aspect could be enhanced by rich interaction of interactive system design in our specific study setting enabled by the design of *Closer to Nature*.

Findings throughout the Design Iteration LiveNature

An iteration of the design *Closer to Nature*, the *LiveNature* has been designed and implemented to 1) address design recommendations raised in Chapters 4 and 5, and 2) promote effects on the user's emotional aspect of engagement. This design suggested a novel approach by combining an augmented reality display mounted on the wall and an interactive robotic sheep for two reasons: 1) the tangible augmentation of *Closer to Nature* proved could enhance the Attention aspect of engagement. Thus, we further emphasized the tangible interaction design to enlarge behavioral richness. 2) the animal-like social robot was suggested by literature can evoke positive emotional responses and motivate communications of PWD during the interaction. To gather preliminary feedback from multi-stakeholders, we performed a qualitative user study to compare the interaction experience of *Closer to Nature* with *LiveNature* through interviewing 20 participants (9 residents, 5 family members, 2 caregivers, and 4 volunteers). The findings indicate that the *LiveNature* could help PWD living in Vitalis enact embodied behaviors through multiple possibilities for interaction, perceive and express emotions in a tailored context, restore attentiveness and communication, and establish relationships by encouraging communication.

RQ2.b: *To what extent can the features of rich interaction in terms of the system interactivity and the multimodal stimuli influence the engagement of PWD living in an LTC environment?*

We conducted an experimental study with 16 residents to explore the effects of rich interaction in terms of system interactivity and multimodal stimuli on user engagement. The sensorial level of experienced richness was addressed by the multimodality sensory feedback of system design. And the system interactivity was varied based on whether the HRI was accompanied by contextual cues from the augmented reality display. The study followed a two-by-two mixed factorial design with one within-subject variable - multimodal stimuli – and one between-subject variable - system interactivity. The engagement of participants was assessed using a mixed assessment method involving the use of video coding analysis (using the ELICSE) and three observational rating scales (OME, OERS, and EPWDS).

Results disclose that when additional auditory modality was included besides the visual-tactile stimuli, participants had significantly higher scores on Attitude, more positive behavioral engagement during activity, and a higher percentage of communications displayed. The multimodal stimuli also promoted social interaction between participants and the facilitator.

As a result, we conclude that the findings provide sufficient evidence regarding the significant role of multimodal stimuli in promoting the emotional aspects of activity-related engagement of participants. These could be potentially used as a motivation strategy in future research to improve emotional aspects of engagement and social interaction with the human partner.

To conclude our answers to RQ2:

Designing interactive systems for PWD that enable rich experiences behaviorally through adding tangible augmentation might be one contributor for enhanced Attention aspect of engagement; and rich interaction in terms of the sensorial level of experienced richness through multimodal stimuli might be one contributor for a successful enhanced Valence aspect of engagement.

9.2 Limitations and Future Work

The presented research has several limitations. Besides limitation concerns the small sample size, which has already been discussed in the Limitation sections of Chapters 5 and 7. All the studies presented in this thesis were conducted in collaboration with one particular location as a representation of the LTC context. This choice of a **single geographic location to unfold our research practices** was limited by practical constraints - a lack of resources to implement the designed interactive system. Therefore, the generalization of research findings still needs further studies for validation. We look forward to future replications of the studies in other locations of LTC to examine whether the same effects hold.

The second limitation regards **the potential influences of dementia severity, gender, and other personal characteristics on user engagement**, which has not yet been further investigated. There are two explanations for this. The first one concerns the practical difficulty in participant recruitment. We could not perform further statistical analysis and conclude valid findings regards demographics due to insufficient sample size. Thus, future studies should consider recruiting a sufficient sample for each level of dementia severities, genders, or other characteristics for a deeper understanding of how user engagement can be shaped by designs as well as personal attributes. Second, there exist differences in LTC home placements on gender and dementia severity in general. People with more advanced stages tend to be admitted compared to mild stages, and female residents composed a larger proportion of residents compared to male residents (Luppa et al., 2009) and (Freedman et al., 2018). Our sample recruited in multiple studies reflected the same trend in line with the literature. Thus, future work could gather more evidence for guiding gender-specific designs to raise awareness in designing for gender differences, particularly for older women with dementia.

The third limitation regards the methodologies for measuring the engagement of PWD. Recent studies also suggest data collection of physiological signals (e.g., electrodermal activity) can also be used to assess PWD's engagement (Perugia et al., 2017c). In the presented thesis, engagement assessment is mainly based on combined subjective measures – qualitative interviews, and behavioral measures – observations of verbal and non-verbal behaviors. Therefore, future studies could consider **adopting physiological data collection in addition to subjective and behavioral measures for engagement assessment**.

Another limitation considers the **customization and personalization of designed activities for individuals within a small-scale community**.

Although we have attempted to strike a balance between design for a community and for an individual, personalized approaches and solutions that related to personal experiences, characters, and interests were known can significantly benefit individual users. Specifically, user feedback from Chapters 4 and 6 indicated that people who grew up on a farm and had pets responded more positively than those without. In the thesis, we offered experiences that were expected to benefit the majority of participants instead of tailoring according to personal profiles. Future designs should keep exploring how to address individual personhood with personalized features within a small-scale community setting.

Fifth, the evaluative research studies reported in this thesis are based on observations of short-term sessions around 10-20 minutes. **How the repeated short engagement of each session would contribute to a longer-term behavior change of PWD still needs further investigations.** We did not test the endurability of effects enabled by our interactive systems design using valid long-term evaluations with PWD due to feasibility issues and a lack of valid measures for assessments. First, qualitative studies such as interviews are not feasible options for advanced stages of users. Moreover, since the care staff is composed of mixed regular staff and flex workers, interviewing caregivers with different levels of familiarity with the residents is not a rigorous approach. Second, studies have suggested that mood status and behavioral changes (e.g., agitation) could be potentially used as indicators for a longer-term effectiveness evaluation (Kolanowski et al., 2011). However, multiple factors can influence mood states, including but not limited to medication use, family visiting, personal hygiene, or sleep conditions in practice. To ensure that the study design is well-controlled for long-term evaluations can be very challenging. In addition, our assessment measures are primarily observational based. Thus, the data collection of PWD's behaviors for a longer-term period through video recording can raise ethical and privacy issues. Meanwhile, data analysis can be overwhelmingly time-consuming for researchers as well. Future work implementing intelligent systems for real-time behavior recognition and interpretations might help with the above issues.

Last, we look beyond what has been presented so far, and discuss from what to provide as a meaningful activity for PWD living in the LTC environment to how to design rich interaction for rich experiences. Thus, we propose further investigations of the **social and interpersonal dynamics when multiple stakeholders** (i.e., residents, family members, caregivers, or volunteers) **or agents are involved in the interaction**. In current research, we conducted experimental studies (reported in

Chapters 5 and 7) limited to interaction between a single user and system with a facilitator accompanied for investigating engagement with the provided stimuli. The choice was intentional given that PWD can be easily distracted by others during an interaction, potentially influencing the stimuli-related engagement. The complex interaction dynamics when multiple users are involved may also risk agitation induced by too many stimulations. Nevertheless, the intention of the activity design aims also to provide opportunities for social inclusion of multi-stakeholders within the dynamic care context. Therefore, following the design insights, further studies could be conducted to investigate the dynamics of interaction among multiple roles of stakeholders; and how system features could impact social engagement in addition to stimuli-related engagement when multiple stakeholders/agents are engaged for generating value-sensitive designs.

9.3 Research Contributions

This research contains a series of explorations, multiple iterated designs, and two experimental studies dedicated to designing for PWD living in LTC with a better wish of living well with the disease after formal diagnosis. It investigated the nature of rich interaction within a specific context of LTC. It provided insights to support future researchers in designing interactive systems that could positively influence user engagement of PWD.

This thesis makes the following contributions that could be interesting for several domains of knowledge:

- It contributes to field practitioners (i.e., caregivers) by introducing a pool of existing approaches and technological solutions that could effectively benefit clients' well-being as well as their daily care activities.
- It provides dementia-related design research, context-specific knowledge and insights on what might contribute to the "meaningfulness" for PWD in activity design. It gives examples of designing meaningful activities by promoting intuitive interaction, tangible interaction, and sensory enrichment experiences.
- It contributes to HCI research in general by extending the enhanced engagement study to the user group of PWD, demonstrating the role of rich interaction in contributing to enhanced engagement, and clarifying influential features of rich interaction through investigating system interactivity and multimodal stimuli on engagement of PWD.
- It offers designers a series of design implications, reflections,

principles, and protocols to help inform future design and research processes when working with and for PWD.

- It also enlightens social robot designers to incorporate contextual cues as part of the robot interaction experience to maximize the robot’s positive therapeutic effects on cognitively impaired users such as PWD.
- It contributes to the dementia engagement research by exploring the methodologies used for assessing the engagement of PWD and reflecting on the pros and cons of each measure.

Last but most importantly, it contributes to living well with dementia for those suffering the disease themselves.

APPENDICES

Appendix A

Table A1. Five identified categories of existing non-pharmacological interventions with descriptions and reported effectiveness in literature.

Category	Intervention	Description	Reported Effectiveness
Cognitive/Behavioral Oriented Interventions	Reality Orientation	Remaindering of facts about time, environment, and themselves to cope with memory loss and disorientation in time and spaces (Douglas et al., 2004).	Beneficial to clarify confusions about time, space, and reality; reduce challenging behaviors. Adverse effects were reported in some cases, including frustration, anxiety, depression, and a lowering of self-esteem (Douglas et al., 2004).
	Validation Therapy	Encouraging and validating expression of feelings through communicating with PWD by empathizing with feelings and meaning behind verbal/non-verbal behaviors (Douglas et al., 2004).	Managing behavior problems. Increased mood, psychological states, and reduced depression (Finnema et al., 2000), (Douglas et al., 2004).
	Reminiscence Therapy	Relive past experiences, especially that are positive and personally significant, through digital, non-digital cues, or discussion with another person or a group. Commonly using non-digital cues such as old newspapers, family photos, and familiar reminiscent items (Woods et al., 2009).	Benefit on mood, reduce depression, enhance self-esteem, social connectedness, create a sense of meaning in life, and support BPSD. Increased agitation was reported in some cases (Takeda et al., 2012).
	Simulated Presence Therapy	A variation of reminiscence therapy using audiotapes made by family containing scripted "telephone conversations" about cherished memories from earlier life (Zetteler, 2008).	Able to tap remote memory, improve behavioral symptoms, and enhance the quality of life. Some studies suggested ease of agitation, some with increased agitation (O'Neil et al., 2011).
	Cognitive Stimulation	Stimulating and training remaining cognitive functions (Spector et al., 2003).	Improved cognitive ability post-intervention, improved function, memory, unclear long-term effects (Douglas et al., 2004)
	Behavioral Therapy	Strategies aimed at suppressing or eliminating challenging behaviors, including staff training on behaviors	Manage BPSD. Suggested by the literature of better effects with tailored interventions to individual cases (O'Neil et al.,

		management, coping strategies, moderating personal reactions, identifying and encouraging pleasant activities (Gitlin et al., 2009).	2011).
	Differential Reinforcement	Differential reinforcement of other behavior involves delivering items with known or suspected reinforcing properties contingent on the omission of a target behavior (Vogl & Rapp, 2011).	Decrease in noise-making, wandering, disruptive behaviors, self-injurious behaviors, inappropriate vocalizations (Cohen-Mansfield, 2001), (Vogl & Rapp, 2011).
	Cognitive–Behavioral Therapy	A person-centered therapy for understanding individual's distressing experiences (Kwon et al., 2017).	Reduce depression and anxiety (Yamaguchi et al., 2010).
Sensory Interventions (Enhancement/ Relaxation)	Music Therapy	Engagement in music-related activities, such as playing instruments, sing-along, and listening to music (Strøm et al., 2016).	Relieve stress and boredom, stimulate reminiscence, encourage physical movement, facilitate social interactions, ease abnormal vocalization and agitation (Cohen-Mansfield, 2001), prevent wandering (Martín et al., 2013), formulate aspirations (Creech et al., 2014), improve attention and concentration (Bugos et al., 2007).
	Art therapy	Art creations and self-expression through drawing, painting, and other art-related activities (Chancellor et al., 2014).	Improve self-esteem, social interaction, and provide meaningful stimulation (Marshall & Hutchinson, 2001).
	Complementary Therapies	A number of different approaches for relaxing and healing purposes, including aromatherapy, massage, reflexology, reiki, acupuncture. Among which, aromatherapy is the fastest growing one, which uses fragrant oils (e.g., lavender and Melissa) for a sensory experience through inhalation, bathing, massage, and application in the cream (O'Neil et al., 2011).	Suggested can ease agitation, restlessness, anxiety, depression and with excellent compliance and tolerability. However, with limited rigorous evidence (O'Neil et al., 2011).
	Sound Therapy (White Noise Therapy)	The use of environment sound, white noise, or modified white noise. White noise is a sound that has a frequency distributed continuously and uniformly over the wide range of the 20–20,000 Hz, and this is applied in the form of natural sound such as waves, rain, and wind, and environmental sound such as car exhaust sound (Son & Kwag, 2020).	Induce relaxation and sleep and thereby decrease nocturnal restlessness (Cohen-Mansfield, 2001). Reduced psychological anxiety and agitation, and improved focus on tasks and activities (L. W. Lin et al., 2018), (Son & Kwag, 2020).
	Multisensory Stimulation Therapy (Snoezelen	Multisensory stimulation (Snoezelen) room, a designated space that aims to offer sensory enriched experiences and activities - either for stimulation or helping to relax to enhance feelings of comfort and wellbeing. It addresses the	Positive in reducing agitation and improving mood. However, no consistent evidence demonstrates a durable effect on BPSD (Sposito et al., 2017).

	Therapy)	senses of vision, touch, hearing, smell, taste, and movement with limited or no need for higher cognitive processing (Collier & Jakob, 2017).	
Social Interventions (Real/Stimulated)	Animal-Assisted Therapy	Including the existence of animal/s (e.g., fish aquarium), animal petting, and animal interactions with domestic animals and/or farm animals (Filan & Llewellyn-Jones, 2006), (Hassink et al., 2017).	Increased positive emotions, mood, and communications; decreased passivity and agitation; motivation in engagement; control of BPSD; increased nutritional intake (Hassink et al., 2017), (Lai et al., 2019).
	One-on-One Interaction	One-on-one social contact, such as family visit, volunteer visit, staff contact, or one-on-one professional therapy (e.g., humor therapy) (Cohen-Mansfield, 2013).	Increased positive emotions, building interpersonal relationships, improved connectedness, facilitating family bonding; decrease in verbal agitation (Cohen-Mansfield, 2013).
	Staff and Group Contact	Group social contact, such as group games or structured activities within a group of participants (Cohen-Mansfield, 2013).	Increased social connectedness, alleviated boredom, and improved mood; provided social roles.
	Simulated Animal/Human Interaction	- Simulated human interaction, such as the use of family photos, audio recordings, and videos of family members; or presence of dolls (Strøm et al., 2016); - Simulated animal interaction, such as the utilization of social robots or animal videos (Mordoch et al., 2013), (Serpell et al., 2017).	Providing company, enjoyment, and relaxation; decreasing problem behaviors; and improving social interactions (Cohen-Mansfield, 2001), (Strøm et al., 2016).
Environmental Interventions	Bright-Light Therapy	Provide bright light (2500Lx) within the living environment or during a specific time duration (e.g., dinner time or in the morning) (Ayalon et al., 2006).	Improve fluctuations in diurnal rhythms, improving restlessness and with particular benefit for sleep disturbances (Cohen-Mansfield, 2001).
	Reduced-Stimulation Unit	Reduce stimulation from the environment, such as using camouflaged doors; small tables for eating; small-group activities; neutral colors on pictures and walls; no televisions, radios, or telephones (except one for emergencies); a consistent daily routine; and an educational program for staff and visitors concerning the use of touch, eye contact, slow and soft speech (Cleary et al., 1988).	Declined agitation and use of restraints, reduced challenging behaviors (Cohen-Mansfield, 2001).
	Wandering Areas	Wandering areas provides a specific place for reducing safety hazard and make wandering behaviors manageable (Siders et al., 2004).	Reduced agitation, restless, anxiety (Robinson et al., 2006).
	Enhanced Environment	- With access to a natural outdoor environment like outdoor gardens (Chalfont, 2005), (Poon et al., 2016);	- Enhanced outdoor environment (simulated or real) shows an increase in mood and a decrease in

		- Simulated outdoor environment, such as using pictures, videos, or soundscapes of outdoor environment for simulated outdoor experiences (Eggert et al., 2015); - Simulated home environment, such as using pictures of familiar homes, home decorations, the smell of home, familiar everyday sounds for simulated home experiences (Cohen-Mansfield, 2001).	agitated and aggressive behaviors (Eggert et al., 2015). - Enhanced home environment shows less trespassing, exit-seeking, and other agitated behaviors (Cohen-Mansfield, 2001).
Structured Activities & Customized Activities	Group-Structured Activities	Structured activities that were organized in groups, such as group games and reading roundtable (Cohen-Mansfield, 2018), (Anderiesen et al., 2014).	Improved engagement, affect, mood, and social interaction (Skrajner & Camp, 2007); diminished boredom and loneliness; provided adequate quality of life; prevented behavioral problems (Cohen-Mansfield, 2018).
	Individual-Structured Activities	- Manipulative games, such as puzzles, blocks, tetherball, texture blankets (Jakob & Collier, 2017b); - Work-like tasks, such as folding towels, arranging flowers, sorting envelops, sewing, and knitting (Tak et al., 2015); - Physical activities, such as outdoor walks, dance, and sports (Scherder et al., 2010).	- Individual manipulative games and/or work-like activity shows enhanced engagement, manageable agitated behaviors, improved self-identity (Tak et al., 2015). - Physical activity shows improved affective states (Kinnafick & Thøgersen-Ntoumani, 2014), increased sleep duration and decreased nighttime awakenings (Cohen-Mansfield, 2001), improved social dynamics (Ren et al., 2019), reduced agitation, stress, and increased cognitive functions (Scherder et al., 2010).
	Individualized/Personalized/Customized Activities	Activities that were customized into individual needs, personalities, and preferences (A. M. Kolanowski et al., 2001), (Gitlin et al., 2009), (Leone et al., 2012).	Reduced passivity, apathy, motivated engagement in activities, increased positive affect, and significantly improved behavior problems (Leone et al., 2012), (Sánchez et al., 2016).

Appendix B

Mini-Mental State Examination - MMSE

The Dutch version

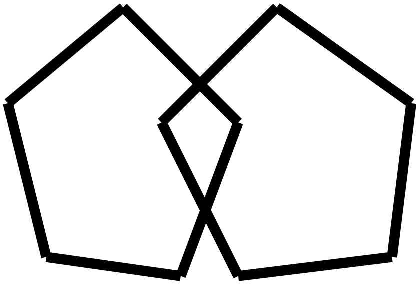
Front page:

Naam patiënt: __________Datum invullen: __________Naam invuller: __________
Ik ga u nu enkele vragen stellen en geef u enkele problemen om op te lossen. Wilt u alstublieft uw best doen om zo goed mogelijke antwoorden te geven.

	Noteer antwoord	**Score:**
1.	a. Welk jaar is het? b. Welk seizoen is het? c. Welke maand van het jaar is het? d. Wat is de datum vandaag? e. Welke dag van de week is het?	(0-5) ________
2.	a. In welke provincie zijn we nu? b. In welke plaats zijn we nu? c. In welk ziekenhuis (instelling) zijn we nu? d. Wat is de naam van deze afdeling? e. Op welke verdieping zijn we nu?	(0-5) ________
3.	Ik noem nu drie voorwerpen. Wilt u die herhalen nadat ik ze alle drie gezegd heb? Onthoud ze want ik vraag u over enkele minuten ze opnieuw te noemen. (Noem “appel, sleutel, tafel”, neem 1 seconde per woord) (1 punt voor elk goed antwoord, herhaal maximaal 5 keer tot de patiënt de drie woorden weet)	(0-3) ________
4.	Wilt u van de 100 zeven aftrekken en van wat overblijft weer zeven aftrekken en zo doorgaan tot ik stop zeg? (Herhaal eventueel 3 maal als de persoon stopt, herhaal dezelfde instructie, geef maximaal 1 minuut de tijd) Noteer hier het antwoord. of Wilt u het woord “worst” achterstevoren spellen? Noteer hier het antwoord.	(0-5) ________
5.	Noemt u nogmaals de drie voorwerpen van zojuist. (Eén punt voor elk goed antwoord).	(0-3) ________
6.	Wat is dit? En wat is dat? (Wijs een pen en een horloge aan. Eén punt voor elk goed antwoord).	(0-2) ________
7.	Wilt u de volgende zin herhalen: “Nu eens dit en dan weer dat“. (Eén punt als de complete zin goed is)	(0-1) ________
8.	Wilt u deze woorden lezen en dan doen wat er staat’? (papier met daarop in grote letters: “Sluit uw ogen”)	(0-1) ________
9.	Wilt u dit papiertje pakken met uw rechterhand, het dubbelvouwen en het op uw schoot leggen? (Eén punt voor iedere goede handeling).	(0-3) ________
10.	Wilt u voor mij een volledige zin opschrijven op dit stuk papier? (Eén punt wanneer de zin een onderwerp en een gezegde heft en betekenis heeft).	(0-1) ________
11.	Wilt u deze figuur natekenen? (Figuur achterop dit papier. Eén punt als figuur geheel correct is nagetekend. Er moet een vierhoek te zien zijn tussen de twee vijfhoeken)	(0-1) ________
	TOTALE TEST SCORE: (0-30) ________	

Back page:

Sluit uw ogen



Appendix C

Observational Measurement of Engagement – OME

Date _________ Resident's name ___________________ ID# ____ Condition _____Time _____

Attention to stimulus during engagement	**Attitude to stimulus during engagement**
7 very attentive	7 very positive
6 attentive	6 positive
5 somewhat attentive	5 somewhat positive
4 not attentive	4 neutral
3 somewhat disruptive	3 somewhat negative
2 disruptive	2 negative
1 very disruptive	1 very negative
Use scale above to rate:	**Use scale above to rate:**
Most of the time ___	**Most of the time ___**
Highest level ___	**Highest level ____**

Duration of engagement (until not interested) ____:____ minutes and seconds (mm:ss)

Attention. Amount of attention resident is paying to stimulus during the engagement (manipulating/holding/content of talking about object is all attention). Following staff instructions without any change in affect is still attention. Attention can be Physical, (i.e., stroking cat even if looking away), or Visual, (i.e., staring at dog while it moves even if not interacting with it). Mark number that best represents what participant is doing most of the time, and separately mark what best represents the highest level of attention (such that if the resident is very attentive for a little while and somewhat attentive most of the time- mark a 2 for "most of the time" and a 4 for "highest level").

Attitude. Amount of excitement/expressiveness toward stimulus (smiling, frowning, energy, excitement in voice). If resident is involved (manipulating stimulus) but has no visible affect then still mark "somewhat positive" for both "most of time" and "highest level"; if resident is not interested at all or looking at object but never actively participates (not holding or manipulating) then mark "neutral".

Duration of engagement. Fill in the length of the observation in minutes and seconds. Engagement is involvement with stimulus regardless of appropriateness of behaviors.

Observed Emotion Rating Scale - OERS

Date__________ Resident's name _______________________ ID# _____ Condition _____Time _____

Please, rate the extent of each affective state during the activity. Some possible signs of each emotion are listed. If you see no sign of a particular feeling, rate "Never".

			7	**1**	**2**	**3**	**4**	**5**
		Signs	**Not in view**	**Never**	**Less than 16 sec.**	**16-59 sec.**	**1-5 min.**	**More than 5 min.**
Pleasure		Laughing; smiling; kissing; stroking or gently touching other; reaching out warmly to other; responding to music (only counts as pleasure if in combination with another sign)						
Anger		Physical aggression; yelling; cursing; berating; shaking fist; drawing eyebrows together; clenching teeth; pursing lips; narrowing eyes; making distancing gestures.						
Anxiety/Fear		Shrieking; repetitive calling out; restlessness; wincing/grimacing; repeated or agitated movements; line between eyebrows; lines across forehead; hand wringing; tremor; leg jiggling; rapid breathing; eyes wide; tight facial muscles.						
Sadness		Crying; frowning; eyes drooping; moaning; sighing; head in hands; eyes/ head turned down and face expressionless (only counts as sadness if paired with another sign).						
General Alertness		Participating in a task; maintaining eye-contact; eyes following object or person; looking around room; responding by moving or saying something; turning body or moving towards person or object.						

Person-Environment Apathy Rating Apathy Subscale – PEAR-Apathy Subscale

Date _________ Resident's name ___________________ ID# ____ Condition _____Time _____

Apathy Subscale				
	1	**2**	**3**	**4**
Facial Expression	Extreme expression	Moderate expression	Mild expression	Minimal expression
Eye Contact	Sustained eye contact with specific target	Random eye contact with unspecific target	Eyes open but blank	Eyes closed
Physical Engagement	Enthusiastic engagement	Basic engagement	Slight engagement	Minimal engagement
Purposeful Activity	Self-initiated purposeful activity	Purposeful activity with prompt	Activity without observable purpose	Minimal activity
Verbal Tone	Lound volume and/or extreme intonation	Moderate intonation and/or volume	Flat intonation and/or soft volume	Silent, no observable verbal communication
Verbal Expression	Self-initiated OR greatly expressive	Expanded but passive OR moderately expressive	Brief and passive OR not expressive	No verbal expression

Facial expression. It assesses facial expressions that express positive or negative moods. Extreme expression is a constant or excessive expression, such as laughing or weeping aloud. In contrast, in minimal expression, there are no observable moods or expressions, such as no furrowing of the forehead or eyebrows and no smile or frown.

Eye contact. It assesses the degree of attention, curiosity, and interest in other people and surroundings.

Physical engagement. It assesses the extent to which the individual physically engages in activities or interacts with others. Enthusiastic engagement refers to constantly and energetically engaging in any activity or interaction with intimate physical contact or thoughtful physical actions. Minimal engagement refers to no physical engagement in any activity.
Purposeful activity. It assesses the extent to which the individual takes initiative or carries out activities with purpose.

Verbal tone. It assesses individuals' volume or intonation to reflect their affect.
Verbal expression. It assesses self-initiation of communication and expressiveness of the verbal content.

Cohen-Mansfield Agitation Inventory – CMAI

Date _________ Resident's name ___________________ ID# ____ Condition _____Time _____

Instructions: For each of the behaviors below, check the rating that indicates the average frequency of occurrence over the session duration.
1 - never 2 - less than once within the session 3 - once or twice within the session 4 - several times within the session 5 - several times within 3 minutes.

Physical/Aggressive	**Descriptions**	**1**	**2**	**3**	**4**	**5**
Hitting (including self)	Physical abuse, striking others, pinching others, banging self/furniture.					
Kicking	Striking forcefully with feet at people or objects.					
Grabbing onto people	Snatching, seizing roughly, taking firmly, or yanking.					
Pushing	Forcefully thrusting, shoving, moving putting pressure against another.					
Throwing things	Hurling objects, violently tossing objects up in air, tipping off surfaces, flinging, dumping food.					
Biting	Chomping, gnashing, gnawing, either other people or self.					
Scratching	Clawing, scraping with fingernails either other people or self.					
Spitting	Spitting onto floor, other people etc. Does not including uncontrollable salivating, or spitting into tissues etc.					
Hurting self or others	Burning self or other, cutting self or other, touching self or other with harmful objects, etc.					
Tearing things or destroying property	Shredding, ripping, breaking, stomping on something.					
Making physical sexual advances	Touching a person or self in an inappropriate sexual way, exposing genitals, unwanted fondling or kissing, etc.					
Physical/Non-Aggressive	**Descriptions**	**1**	**2**	**3**	**4**	**5**
Pacing and aimless wandering	Constantly walking back and forth, including wandering when done in a wheelchair. Does not include normal purposeful walking.					

Inappropriate dress of disrobing	Putting on too many clothes, putting clothing in a strange manner, taking off clothing in public, or when it is inappropriate.					
Trying to get to a different place	Inappropriately entering or leaving a place, such as trying to get off the building, sneaking out of room, trying to get into locked areas, trespassing within unit, or other resident's room or closet.					
Intentional Falling	Purposefully falling onto floor, include from wheelchair, chair, or bed.					
Eating/drinking inappropriate substance	Putting into mouth and trying to swallow items that are inappropriate.					
Handling things inappropriately	Picking up things that don't belong to them, rummaging through drawers, moving furniture, playing with food, fecal smearing.					
Hiding things	Putting objects out of sight, under or behind something.					
Hording things	Putting many or inappropriate object in purse, pockets, or drawers, keeping too many of an item. Does not include regular collection.					
Performing repetitive mannerisms	Stereotypic movement, such as patting, tapping, rocking self, fiddling with thing, twiddling with something, rubbing self or object, picking imaginary things out of air or off floor, manipulation of nearby objects in a repetitious manner, etc. Does not include repetitious words or vocalizations.					
General restlessness	Fidgeting, always moving around in seat, getting up and sitting down, inability to sit still.					
Verbal/Aggressive	**Descriptions**	**1**	**2**	**3**	**4**	**5**
Screaming	Shouting, piercing howl, making loud shrills.					
Making verbal sexual advances	Sexual propositions, sexual innuendo, or "dirty" talk					
Cursing or verbal aggression	Only when using words, wearing, use of obscenity, profanity, unkind speech or criticism, verbal anger, verbal combativeness. Does not include unintelligible noises (rated under screaming or strange noises).					
Verbal/Non-Aggressive	**Descriptions**	**1**	**2**	**3**	**4**	**5**
Repetitive sentences or questions	Repeating the same sentence or question one right after the other, addressed to a particular person or to on one (complaining, even if oriented and possibly warranted is rated under the complaining section)					

Strange noises	Including weird laughter or crying, weeping, moaning, grinding teeth, does not include intelligible words.					
Complaining	Whining, complaining about self, somatic complaints, personal gripes or complaining about physical environment or other people.					
Negativism	Bad attitude, doesn’t like anything, nothing is right, does not include overt verbal anger, such as what can be rated as verbal aggression.					
Constant unwarranted request for attention or help	Verbal or nonverbal unreasonable nagging, pleading, demanding (indicate also for oriented people).					

Engagement of a Person with Dementia Scale - EPWDS

Details of Observation Period and Psychosocial Activity

Start & End Time of Observation Period: ______Total Duration of Observation Period: _______
Type of Psychosocial Activity: _______Group or Individual Psychosocial Activity: ______
Location of Psychosocial Activity: _______

Appropriateness of the Environment:

Please indicate the extent to which you agree or disagree to the following statement: The overall environment (e.g., lighting, noise level, and presence of other) is appropriate for the target psychosocial activity to induce positive engagement in persons with dementia.

1	**2**	**3**	**4**	**5**
◻	◻	◻	◻	◻
Strongly disagree				**Strongly agree**

	Affective Engagement Please indicate the extent to which you agree or disagree to the following statement: the person with dementia.		
1	Displays positive affect such as pleasure, contentment, or excitement (e.g., smile, laughing, delight, joy, interest and /or enthusiasm).	**1** ◻ **2** ◻ **3** ◻ **4** ◻ **5** ◻ **Strongly disagree** … **Strongly agree**	**N/A** ◻
2	Display negative affect such as apathy, anger, anxiety, fear, or sadness (e.g., disinterest, distressed, restless, repetitive rubbing of limbs or torso, repeated movement, frowning, crying, moaning, and/or yelling).	**1** ◻ **2** ◻ **3** ◻ **4** ◻ **5** ◻ **Strongly disagree** … **Strongly agree**	
	Visual Engagement Please indicate the extent to which you agree or disagree to the following statement: the person with dementia.		
3	Maintains eye contact with the activity, materials used, or the person/s involved.	**1** ◻ **2** ◻ **3** ◻ **4** ◻ **5** ◻ **Strongly disagree** … **Strongly agree**	**N/A** ◻
4	Appears inattentive, has an unfocused stare, or turns head/eyes away from the activity, materials used, or the person/s involved.	**1** ◻ **2** ◻ **3** ◻ **4** ◻ **5** ◻ **Strongly disagree** … **Strongly agree**	

<table>
<tr><td></td><td colspan="2">Verbal Engagement
Please indicate the extent to which you agree or disagree to the following statement: the person with dementia.</td><td rowspan="3">N/A
☐</td></tr>
<tr><td>5</td><td>Initiates, participates, or maintains verbal conversation, sound, or gestures (e.g., nodding) in response to the activity, or the materials used, or the person/s involved.</td><td>1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Strongly disagree … Strongly agree</td></tr>
<tr><td>6</td><td>Refuses to participate in the activity or in a conversation related to the activity by verbalizing e.g., “no”, “stop”, etc. OR verbalizes negative comment, complaint, and sound (e.g., groaning, or cursing, or swearing) in response to the activity, or the materials used, or the person/s involved.</td><td>1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Strongly disagree … Strongly agree</td></tr>
<tr><td></td><td colspan="2">Behavioral Engagement
Please indicate the extent to which you agree or disagree to the following statement: the person with dementia.</td><td rowspan="3">N/A
☐</td></tr>
<tr><td>7</td><td>Responds to an activity by approaching, reaching out, touching, holding, or handing the activity, or the materials used, or the person/s involved.</td><td>1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Strongly disagree … Strongly agree</td></tr>
<tr><td>8</td><td>Responds to an activity by avoiding, shoving away, pulling back from, hitting, or mishandling the activity, or the materials used, or the person/s involved.</td><td>1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Strongly disagree … Strongly agree</td></tr>
<tr><td></td><td colspan="2">Social Engagement
Please indicate the extent to which you agree or disagree to the following statement: the person with dementia.</td><td rowspan="3">N/A
☐</td></tr>
<tr><td>9</td><td>Use the activity or the material/s to encourage others to interact, or as a communication channel to interact and talk with others (e.g., staff and other residents).</td><td>1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Strongly disagree … Strongly agree</td></tr>
<tr><td>10</td><td>In response to the activity, is distracting or disrupting others (e.g., staff/facilitator and other residents).</td><td>1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Strongly disagree … Strongly agree</td></tr>
</table>

Appendix D

Adapted ELICSE Coding Scheme with Operational Descriptions Applied in Chapter 5

Table D1. The final ELICSE coding scheme with detailed operational descriptions for video coding analysis of the study presented in Chapter 5.

Behaviors	**Modifiers**
Head (Gaze) Behaviors	*Signs of Affection*
Gaze toward the Facilitator (Gaze_F) The participant directs the head and eyes (or only eyes) towards the facilitator. This behavior is scored when the eyes of the participant are directed toward one of the body parts of the facilitator even without the head rotation. ***Gaze toward the Installation/Stimulus (Gaze_IS)*** The participant directs the head and eyes (or only eyes) towards the installation (including the interactive pump positioned at the left of the installation), or the presented stimulus in the control condition. Note: Given considerations that the interactive pump is outside the field of view of the main camera, we therefore used the video footages recorded by camera 2 for coding analysis. ***None of the target gaze behaviors*** In case none of the above-described behaviors are present, the coder should score this behavior. **Nonvisible gaze behaviors** In case the observed participant is not positioned in view of any camera views, the coder should score this behavior.	- **With positive signs of affection (_Pos)** With facial expressions or gestures that display positive affect: smile (participant open mouth, raised eyebrows, eyes bulging); laugh (widened and raised sides of the mouth, widened and flattened eyes, protruded cheeks, associated sound); surprise (participant open mouth, raised eyebrows, eyes bulging); sticks his/her tongue out; send/give kisses. - **With negative signs of affection (_Neg)** With facial expressions or gestures that display negative affect: angry (aggression, yelling, cursing, drawing eyebrows together, clenching teeth, pursing lips, narrowing eyes); anxiety and fear (shrieking, repetitive calling out, line between eyebrows, lines across forehead, tight facial muscles); sadness (crying, frowning, eyes drooped, moaning, sighing, eyes/head turned down); disgust, frowning, boredom (yawn), pain. - **Without signs of affection** Without facial expressions or gestures that display positive or negative affect. In case none of the above signs appear, the coder should score “Without signs of affection”.
Arms/Hands Behaviors	*Quality of reach out*
Reach out to the Facilitator (Reach_F) Actions are included regardless of physical contact or movements of approach to the facilitator, either direct or mediated by the presented installation/stimulus. Specifically, the participant touches or indicates the the facilitator, pointing at facilitator with either hands, palms, or fingers, and manipulates the stimulus when held by the facilitator (when during the control condition).	- **Warmly reach out (_Pos)** <u>When directed towards the facilitator:</u> The participant handshakes, pats on shoulders, or hugs the facilitator. <u>When directed towards the installation:</u> The participant strokes the wood or metal textures; feels the running water; reaches, touches, or pet the animals showing on the screen; illustrates the shapes of animals with fingers in the air.

Reach out to the Installation/Stimulus (Reach_IS) Actions are included regardless of physical contact or movements of approach to the installation (including the interactive pump positioned at the left of the installation), or the presented stimulus in the control condition. Specifically, pumping, touching, pointing at, or other ways of interacting with the installation/stimulus with body parts of participants. ***None of the target hand behaviors*** In case none of the above-described behaviors are present, the coder should score this behavior. **Nonvisible hand behaviors** In case the observed participant is not positioned in view of any camera views, the coder should score this behavior.	<u>When directed towards the stimulus:</u> The participant strokes, pats, hugs, or gently squeezes the provided stimulus. - **Negatively reach out (_Neg)** <u>When directed towards the facilitator:</u> The participant hits, pushes, or rejects the facilitator behaviorally. <u>When directed towards the installation:</u> The participant rejects the interaction; waves to drive the animal away, hits or knocks the animals showing on the screen, hits the water bin. <u>When directed towards the stimulus:</u> The participant hits, strongly squeezes, or throws away the provided stimulus. - **Neutrally reach out** In case none of the above signs appear, the coder should score "Neutrally reach out".
Torso (Approaching/Lean in) behaviors)	Without Modifier
Lean in the Facilitator (Lean_F) Actions are included where the observed participant moves the body or rotates the torso in the direction of the facilitator by approaching the point where he is positioned. **Approaching/Lean in the Installation/Stimulus (Appro/Lean_IS)** Actions are included where the observed participant moves his/her position from the original standing point to near reach the bottom line shown in the main camera view by approaching the point where the installation is positioned. Note: In order to lean in the installation, the body of the participant often shows a tilted angle. When approaching/leaning in the stimulus, the participant tilts the torso toward the stimulus or holds the stimulus close to the torso. **None of the target torso behaviors** In case none of the above-described behaviors are present, the coder should score this behavior. **Nonvisible torso behaviors** In case the observed participant is not positioned in view of any camera views, the coder should score this behavior.	**NA**

Conversations	*Quality of talk*
Talk about the Facilitator (Talk_F) Conversational topics include apprising, introducing, sharing self-stories with the facilitator. Note: During a conversation, the coder does not need to score the short stop between conversations, unless the participant stopped talking for a longer while (+ 10 s). ***Talk about the Installation/Stimulus (Talk_IS)*** Conversational topics that include describing or discussing features that related to installation/stimulus (color, texture, image, etc.); describes or discusses experiences that related to pumping, animal feeding, watering, or nurturing; describes or discusses the built-in systems of the installation; describes or discusses the interacting experiences. ***None of the target conversations*** In case none of the above-described topics are covered, the coder should score this behavior. **Silence** In case the participant is silent, the coder should score this behavior. **Not understandable conversations** In case the participant's speech is not understandable or unable to hear clearly, the coders should score this behavior.	- **Descriptive conversations (_Des)** The participant describes what he or she sees, experiences, feels, etc., without any recollection of memories. - **Associated conversations (_Asso)** The participant expresses topics that are associated with past memories, such as past occupations, pets, farming experiences, family members.

Note: Behaviors marked in italic style are assigned with modifiers.

Adapted ELICSE Coding Scheme with Operational Descriptions Applied in Chapter 7

Table D2. The final ELICSE coding scheme with detailed operational descriptions for video coding analysis of the study presented in Chapter 7.

Behaviors	Modifiers
Head (Gaze) Behaviors	*Signs of Affection*
Gaze toward the Facilitator (Gaze_F) The participant directs the head and eyes (or only eyes) towards the facilitator. This behavior is scored when the eyes of the participant are directed toward one of the body parts of the facilitator even without the head rotation. ***Gaze toward the Augmented Reality Display (Gaze_ARD)*** The participant directs the head and eyes (or only eyes) towards the augmented reality display, including all its components. ***Gaze toward the Robotic Sheep (Gaze_RS)*** The participant directs the head and eyes (or only eyes) towards the robotic sheep. Note: when the robotic sheep is held by the facilitator, the coder should score this behavior as "Gaze toward the Facilitator". ***None of the target gaze behaviors (Gaze_None)*** In case none of the above-described behaviors are present, the coder should score this behavior.	- **With positive signs of affection (_Pos)** With facial expressions or gestures that display positive affect: smile (participant open mouth, raised eyebrows, eyes bulging); laugh (widened and raised sides of the mouth, widened and flattened eyes, protruded cheeks, associated sound); surprise (participant open mouth, raised eyebrows, eyes bulging); sticks his/her tongue out; send/give kisses; blows on the surface of the robotic sheep; approaches his face to the surface of the robot and rubs it with the nose (nuzzle). - **With negative signs of affection (_Neg)** With facial expressions or gestures that display negative affect: angry (aggression, yelling, cursing, drawing eyebrows together, clenching teeth, pursing lips, narrowing eyes); anxiety and fear (shrieking, repetitive calling out, line between eyebrows, lines across forehead, tight facial muscles); sadness (crying, frowning, eyes drooped, moaning, sighing, eyes/head turned down); disgust, frowning, boredom (yawn), pain. - **Without signs of affection** Without facial expressions or gestures that display positive or negative affect. In case none of the above signs appear, the coder should score "Without signs of affection".
Arms/Hands Behaviors	*Quality of reach out*
Reach out to the Facilitator (Reach_F) Actions are included regardless of physical contact or movements of approach to the facilitator, either direct or mediated by the presented installation/stimulus. Specifically, the participant touches or indicates the facilitator, points at the facilitator with either hands, palms, or fingers. Note: this behavior is also scored when the participant passes the interactive robotic sheep to the facilitator; when the participant takes the interactive robotic sheep handed	- **Warmly reach out (_Pos)** <u>When directed towards the facilitator:</u> The participant handshakes, pats on shoulders, takes the hands, or hugs the facilitator. <u>When directed towards the augmented reality display:</u> The participant strokes the wood or metal textures; feels the running water; reaches, touches, or pet the animals showing on the screen; illustrates the shapes of animals with fingers in the air.

out by the facilitator; when the participant touches, takes, interacts, or indicates the interactive robotic sheep while this is held by the facilitator. ***Reach out to the Augmented Reality Display (Reach_ARD)*** Actions are included regardless of physical contact or movements of approach to the augmented reality display, including all its components. Specifically, the participant pumps, touches, points at, or other ways of interaction with the augmented reality display with body parts of participants. ***Reach out to/Manipulate the Robotic Sheep (Reach_RS)*** Actions are included regardless of physical contact or movements of approach to the robotic sheep. Specifically, the participant points at, touches, holds, strokes, pats, manipulates, checks, flips, interacts, or indicates the robotic sheep. **None of the target hand gestures (Reach_None)** In case none of the above-described behaviors are present, the coder should score this behavior.	When directed towards the robotic sheep: The observed participant waves, hugs, cradles, stokes, pats, or gently squeezes any body part of the interactive robotic sheep; takes the chin of the robot; tries to adjust its legs comfortably on the walker; turns its position towards the screen. - **Negatively reach out (_Neg)** When directed towards the facilitator: The participant hits, pushes, or rejects the facilitator behaviorally. When directed towards the augmented reality display: The participant rejects the interaction; waves to drive the herd away, hits or knocks the animals showing on the screen, hits the water bin. When directed towards the robotic sheep: The participant rejects, hits, strongly squeezes, pulls or presses on the robot with a strong force, throws away the robot, or intentionally lets the robot fall. - **Neutrally reach out** In case none of the above signs appear, the coder should score "Neutrally reach out".
Conversations	*Quality of conversations*
Talk to the Facilitator (Talk_F) The participant directs the conversations towards the facilitator regardless of topics and shows initiative of forming a conversation with the facilitator regardless turn his/her head towards the facilitator or not. Note: During a conversation, the coder does not need to score the short stop between conversations, unless the participant stopped talking for a longer while (+ 10 s). In the case of more than one actor joining in the conversation, which includes the facilitator, score "Talk to Facilitator". ***Talk to the Robotic Sheep/Sheep on the Screen (Talk_Sheep)*** The participant directs the conversations towards the robotic sheep, or the sheep shown on the screen display regardless of topics. Note: Usually with eyes engaged with the robotic sheep or sheep shown on the screen display. If the eyes are not engaged with the robotic sheep or the edge is blurred between a talk with sheep or to themselves, score as "Talk to themselves". ***Talk to themselves (Talk_Self)*** Conversations with no obvious directed targets but self-mumbling.	- **Positive verbal engagement with stimulus or the facilitator (_Pos)** The participant appreciates, praises, makes jokes, expresses happiness, fun, playful experiences, purposeful maintaining conversations, verbally responding to the stimulus. - **Negative verbal engagement with stimulus or the facilitator (_Neg)** The participant verbalizes the desire to leave, refuses to participate in the activity, makes repetitive generalized somatic complaints, cursing or swearing. - **Neutral verbal engagement** In case none of the above signs appear, the coder should score "Neutral verbal engagement".

Not understandable conversations (Talk_None)
In case the participant's speech is not understandable or unable to hear clearly, the coders should score this behavior.

Silence (Talk_Sil)
In case the participant is silent, the coder should score this behavior.

Note: Behaviors marked in italic style are assigned with modifiers (i.e., positive, neutral, negative nuance).

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CURRICULUM VITAE

Biography

Yuan Feng was born on the 08th of August 1990, in Xi'an, Shaanxi Province, China. She received both her BEng and MSc degrees in industrial design from Northwestern Polytechnical University (NPU) in 2012 and 2015 respectively. During her masters at the faculty of Industrial Design, she went to Oslo School of Architecture and Design in Norway for half a year of exchange study. Since then, her designs and research are motivated by promoting senior health and well-being regards both physical and psychosocial aspects.

After the master graduation, she started her PhD research in Industrial Design department at Eindhoven University of Technology (TU/e). This PhD project was carried out under the supervision of dr. Emilia Barakova, dr. Jun Hu, and Prof. dr. Matthias Rauterberg. The thesis is the result of her PhD research on the topic of "Rich Interaction for People with Dementia - Designing Interactive Systems with Rich Interaction for Enhancing Engagement of People with Dementia Living in Long-term Care Facilities". Her current recent research interests include multimodal interaction, human-robot interaction, and design for health and well-being of elderly users in particular people with dementia.

Publications

Journal Articles

Feng, Y., Perugia, G., Yu, S., Barakova, E., Hu, J., and Rauterberg, M., 2022. Context-Enhanced Human-Robot Interaction: Exploring the Role of System Interactivity and Multimodal Stimuli on the Engagement of People of Dementia. International Journal of Social Robotics, 14(3), 807-826.

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Designing Interactive Systems with Rich Interaction
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