Dementia Eyes: Co-Design and Evaluation of a Dementia Education Augmented Reality Experience for Medical Workers

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ABSTRACT

Dementia describes a syndrome of cognitive degeneration, and Behavioural and Psychological Symptoms of Dementia (BPSD) is the non-cognitive symptom. BPSD can be improved by care services. To aid better care service, we explore the potential of using Augmented Reality (AR) to support dementia education for medical workers in three steps: (1) We explore medical workers' perspective on dementia care lived experience and XR, (2) we co-design an educational experience containing an AR-based application and a 5-min activity with medical workers, (3) we evaluate the effectiveness of the system through a mixed method study. Our result shows that the AR experience successfully touches participants, and motivates them to reflect on the provision of care service. On this basis, we discuss the elements and challenges of designing XR-enabled dementia education for users unfamiliar with novel technology, and the potential of using XR in clinical education.

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CCS CONCEPTS

• **Human-centered-computing → Human computer interaction (HCI)**; *Augmented Reality*.

KEYWORDS

dementia, education, augmented reality, experience-centred design

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1 INTRODUCTION

With over 50 million patients worldwide and an estimated increase of 10 million per year, dementia has become a world health crisis of physical, social and economic impacts[1]. Most types of dementia are neurodegenerative [35], yet the non-cognitive symptoms - Behavioural and Psychological Symptoms of Dementia (BPSD), is prevalent in people with dementia (PwD) regardless of the subcategory [88]. BPSD can be alleviated by care services [111, 114], but caring for PwD is not easy. Current dementia care worldwide faces challenges including heavy financial cost [30] and the related time consumption [45], limited access to specialists [39], and the

[1] https://www.who.int/news-room/fact-sheets/detail/dementia

lack of a dementia care protocol [30]. Therefore, more investment into dementia care is being called for [93, 114]. Quality of education is pivotal in dementia care because the quality of care service depends primarily on the caregiver's skill and knowledge about dementia care [105]; while alternatively, insufficiency in practical experience and professional knowledge can result in aggravated BPSD [113]. There are several attempts to mitigate the educational gap in dementia [2, 3], yet dementia education faces obstacles. For example, temporary staffing of caregivers [39], medical worker's physical and mental well-being [24], and the efficacy of applying theoretical knowledge to practical settings [103].

Technology offers a new opportunity because it is more enjoyable, has less geological restriction, and promotes creativity likewise interactivity [1, 85]. The mainstream formats of technology-enabled dementia education include online courses [13, 47], interactive discussion [67], and hybrid methods [23, 43]. Convenience and flexibility are the key benefits of using technology in dementia education [75], while more technology-enabled approaches and their benefits are still to be explored. The potential of using XR to assist dementia education has been investigated in the past few years, such as task-orientated nurse role-play VR game for student nurse [31], VR dementia simulator focused on PwD daily scenarios [53], as well as using AR tracking technology and dolls as virtual PwD for dementia care training [46]. Nevertheless, little is known about the design process of using Extended Reality (XR) technology in dementia-related education. To mitigate these gaps, we raise these research questions:

RQ1: What are the design considerations for XR-enabled dementia education?

RQ2: How do medical workers perceive XR-enabled dementia education?

RQ3: How effective is a simulation of dementia stakeholders' lived experience in impacting its user, and what is its potential in dementia care?

To answer these questions, we frame our work in three phases. In Phase I, we conduct a series of workshops to inquire about medical workers' lived experience in dementia care, and understanding of XR technology through thematic analysis [18]. In Phase II, we carry out our first Experience Prototype [20] functioning in Augmented Reality (AR) and VR. We use Unity engine to create the digital contents that represents the general visual and audio changes of Alzheimer's type of Dementia (AD). For the AR experience, the digital content is rendered in real-time using iPhone 12 Pro camera and microphone; the hardware is a combination of the iPhone, a head-mounted display (HMD) and a pair of Apple EarPods with Lightning Connector; a scenario was designed in which the user is asked to perform tasks wearing the prototype. For the VR experience, we design and record a scenario using a RICOH THETA 360° camera and layer the digital contents; the hardware choice is a Meta Quest 2 HMD. We recruit the participants from Phase I to try both experiences in a pilot test. Based on the results, we elicit the educational elements of the VR experience and merge them into the AR experience. We underline that users can pair their experience towards the session to PwD's behaviours they see in hospital, which drives them to reflect on their provision of the care service. In Phase III, we do a mixed method study with 16 medical workers. We carry out before and after questionnaires to evaluate empathy and emotional response, and a semi-structured interview afterwards. Throughout the study, we receive insights about the potential of using the AR prototype for dementia-friendly environment improvement.

To summarise, our work makes the following contributions: (1) We co-design a dementia education AR experience with dementia care stakeholders, (2) we gain empirical insights about the potential of using an XR-enabled system in clinical dementia education, (3) we analyse the relationship between novel experience and self-reflection in the setting of dementia education.

2 RELATED WORK

2.1 Dementia and BPSD

Dementia is a broad spectrum of progressive cognitive disorders. With one new case every 3 seconds [4], it is estimated that in 2019 there were 57.4 million PwD worldwide, which will increase to 152.8 million by 2050 [77]. There are various categories of dementia: most commonly Alzheimer's disease, vascular dementia, and Lewy Bodies disease; BPSD is prevalent in the dementia population in spite of the subcategory [28]. BPSD is often grouped into affective symptoms (e.g. depression and anxiety), hyperactivity (e.g. agitation and aggression) and psychosis (e.g. delusions and hallucinations). It is as clinically important as cognitive symptoms since it is strongly correlated with the degree of functional and cognitive impairment [21]. BPSD has become one of the major reasons for emergency room visits [78] and institutionalisation [22], and efforts on treatment have been explored. There are many approaches to treat BPSD, including non-pharmacological interventions [80], pharmacological treatments [71], and effective care services [66, 106].

2.2 Dementia Care, Education, and Caregiver's Wellbeing

Global public health institutes are striving for better dementia care services [2, 3, 5]. Nonetheless, barriers to dementia care still presents – economic inequality [62], belated diagnosis [86], and the accelerated demand for a dementia-oriented care system distinguished from the other caring home [108]. To construct a dementia-oriented care system, expert knowledge and skills are crucial, yet little is known about the current dementia education system that is supposed to lead to proficiency [19]. Robinson et al. [87] surveyed 443 care staff and family members of PwD on their level of dementia knowledge and found significant knowledge deficits in both formal caregivers and informal caregivers or family. A systematic review of nurses' knowledge towards dementia care [32] pointed out that besides knowledge, nurses have insufficient communication skills, management strategies, and confidence in providing care service to PwD.

On the other hand, caregivers suffer likewise from patients' BPSD [64]. Schmidt et al. [96] ran a self-report questionnaire with 731 registered nurses on BPSD-related distress and discovered that BPSD is a significant stressor with clear impact on nurses' health and work ability. Sakka et al. [90] tackled the family-to-work conflict between employed family caregivers and PwD with BPSD, and found that BPSD is associated with family-to-work conflict for employed family caregivers. Chen et al. [24] investigated formal caregivers' day-to-day challenges through a qualitative interview study and found that formal caregivers struggle in the physical, emotional and social aspects while their needs are invisible even to their social connections. Hence, we should not forget that medical workers' opinions and well-being are vital for quality dementia care.

2.3 Technology to Support Dementia

The technology community is offering new solutions to ease the burden on PwD along with the people around them. For PwD, applying technology in cognitive training has become a primary focus [44, 59]. Secondarily, daily assistive tools like companion-type robots [11] and physical sensors to predict falling [97] have been explored. For the convenience of both PwD and caregivers, researchers also investigated the feasibility of remote activity monitoring [74] and daily task reminders for both patients [38] and caregivers [36]. For dementia education purposes, there are endeavours into the use of online learning modules with audio, video, and interactive real-time text entry [47] or video vignettes [50, 84]. Another close technique is hybrid-style dementia workshop using digital material and classrooms [23, 43]. However, a recent review paper on applied technology in dementia care [73] points out that social views about acceptability of new technology, as well as the insufficient inclusion of end-user in early design and development process are the key issues in the field of dementia technology.

At the same time, Experience-Centered Design (ECD) has been adopted in a number of researches in the field of Human-Computer Interaction (HCI) [10, 15, 109]. Narrowing down to dementia-related works, previous works explored the possibility of co-designing with PwD on different aspects: empathy [65], playfulness [17], sound-based activities [48], art expression [58] and communication [110] to improve patients' quality of life. However, caregivers' and medical workers' needs have long been an additional factor rather than the main subject of study in dementia in HCI. Stowell et al. [104] examined the possibility of using exergames to encourage physical activities and social connectedness of caregivers and family members of PwD. Their result shows that the role inside the hospital has a huge impact on design considerations for the exergame, in addition to their access to physical activities and social connectedness. Waycott et al. [115] looked into medical staff's perspective on installing VR for care home residents. They concluded that there is a need for new care ethics framework, not to mention the perspectives of those who will hold responsibility for operation of the technology.

XR simulation has potential in medical education since the field of medical and nursing training has been using simulation systems for decades [8, 98]. Amongst the categories, VR has become a popular choice because of the proven positive effect of immersion and presence – its core characteristics – on learning outcomes [51]. In dementia education specifically, the use of VR simulation has been explored in several practices. Wijima et al. [116] used a 360° movie to simulate daily situations PwD faces. They examined informal caregivers' empathy towards the simulation and received positive results about the quality of the relationship between caregivers and PwD. Adefila et al. [7] designed a VR environment where medical students perform tasks through an avatar of PwD, and found its compassion effect on students towards patients. Kidd et al. [56] developed a VR program allowing undergraduate students to experience nurse duties such as complete patient assessment, symptoms identification and communication tasks. The program was shown to be educationally effective. Alternatively, AR – with its real-world focus – is commonly used to convey the educational experience by enhancing reality. Hiramatsu et al. [46] fabricated a dementia care training system with AR and full-body wearable sensors for caregiver trainees, allowing users to interact with a soft doll as a virtual PwD. Jones et al. [52] examined the feasibility of an 3D brain visualisation learning AR app on medical students' knowledge improvement of dementia mechanism. Hamilton et al. [42] and Wolf et al. [117] designed caregiver-orientated PwD-support AR systems that displays real-time visuals and texts, which aims to support certain PwD training and support tasks. Previous works have shown that XR simulation is promising in the field of dementia education. Nonetheless, most of the design methods and decisions for these prototypes remain unknown. Based on the need for reinforced dementia education and more profound understanding of medical workers' perspectives, we aim to incorporate medical workers' lived experiences into an XR-enabled dementia education.

3 PHASE I: EXPLORING MEDICAL WORKER'S PERSPECTIVES ON DEMENTIA CARE AND XR TECHNOLOGY

We followed an exploratory research approach to invite a group of former medical workers to a series of 3 activities to share their lived experience with PwD, and perspectives on implementing XR in dementia education. This phase serves two purposes. First, we want to elicit design components for our prototype described in Phase II (see section 4) from dementia stakeholders' lived experience. Second, we want to understand medical workers' perspective on implementation of XR in dementia education. Through this phase, we tried to answer **RQ1**.

3.1 Methods

To explore the technical feasibility, design consideration, and dementia education elements to be included in XR, we conducted design workshops comprise of three activities:

Activity 1: A semi-structured interview guided by the first author. We chose this approach as an initial step for 2 reasons: first, we leveraged it as an icebreaker activity for participants to exchange opinions with researchers; second, we wanted to elicit the dementia care challenges they face. The goal of this activity was to gather insights of the lived experience of dementia-related medical workers, how they view the care services, and how they imagine XR can be used in the system.

Activity 2: An XR device experience session, during which we introduced XR-enabled devices in 3 formats: iPhone with HMD, Meta Quest 2, and Varjo XR-3; and asked participants to experience all three in VR (virtual) and AR (real-world) mode. We highlighted the difficulty in installation inside the hospital and the price point for each. The goal of this activity was to help participants to familiarise with XR.

Activity 3: A design workshop and storyboarding activity, in which we invited participants to describe 2 scenarios of medical

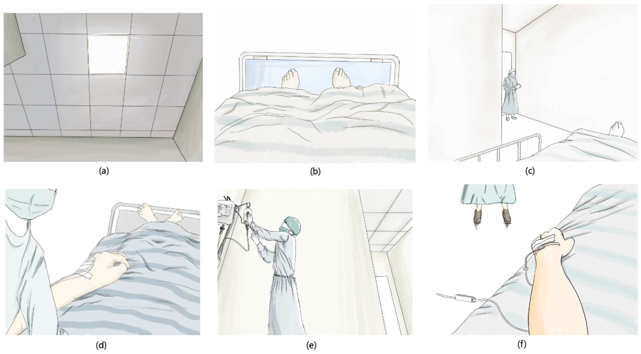

Figure 1: Sketches of PwD's FPV Scenario Design and Described by Participants in Acitivity 1: (a) PwD opens eyes and sees the light; (b) PwD realises they are on a bed in a hospital; (c) PwD watches as a medical worker enters the room; (d) the medical worker gets very close to the PwD, the PwD also sees there is IV drip on their arm; (e) PwD can see the medical worker is doing something with the IV; (f) PwD stares at the IV drip as the medical worker leaves.

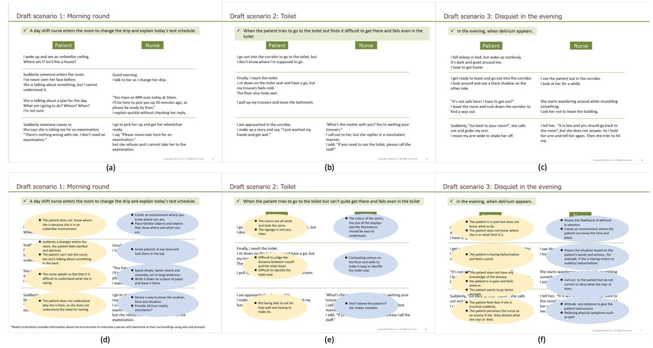

Figure 2: Examples of Scenarios of Patient-Medical Worker Interaction Designed and Described by Participants In Activity 3: (a) Draft scenario 1: A morning check for PwD; (b) Draft scenario 2: A problematic toileting behaviour of PwD; (c) Draft Scenario 2: An evening wandering-around experience of PwD; (d) Mental Activity For Both Patient and PwD in Draft Scenario 1; (e) Mental Activity For Both Patient and PwD in Draft Scenario 2; (f) Mental Activity For Both Patient and PwD in Draft Scenario 3.

worker-PwD interaction based on their lived experience: a good one that PwD satisfies with medical worker's assistance, and a bad one which their BPSD is triggered by medical worker's behaviour. The goal of this activity was to collect design elements for the prototype.

3.2 Participants and Procedure

We recruited five participants via online contact with a medical professional organisation through a snowball sampling method, between October 5, 2020, and January 13, 2021. Table 1 shows the demographic information. Participants' average age was 40.6 years old (M=40.6), while 2 of them were male and 3 were female. Participants were registered nurse (1), registered physiotherapists (2), disaster medical operation staff in acute care hospital (1), medical operation staff in elderly home (1); and the formal/clinical experience in healthcare sector was between 5 and 10 years. Participants resided in Japan, but one grew up in China, another gained higher education degree and clinical experience in the UK.

All activities were originally planned offline, yet due to institutional Covid-19 safety measure concerns, *Activity 1* and *Activity 3* were carried out online because both activities involved long conversation (above 15 minutes). *Activity 2* required physical interaction with the devices and was thus conducted offline. We proceeded with the activity series chronologically between February 1, 2021 and June 9, 2021, of which each lasted about one hour. Participants joined *Activity 1* individually, *Activity 2* in random pair, *Activity 3* all together for participants' time convenience. English was the primary language used to conduct all activities and Japanese was the secondary source of information.

Participants gave informed consent to this IRB-approved research before the activity series started through digital method, and were asked to give consent on paper at the beginning of the first offline session.

3.3 Data Analysis and Methodology

We followed the 6-step approach of thematic analysis described by Maguire and Delahunt [69] to process the data generated from the four activities and disclosed relevant digital raw material to elaborate the statements. Initially, 43 codes were identified under 9 themes. The data was later reviewed and refined to 24 codes under 3 main themes.

3.4 Results

Here, we present the three main themes crafted from the activities: *Lived Experience in Dementia Care*, *Dementia Education*, and *"What if We Use XR?"*.

3.4.1 Lived Experience in Dementia Care. This theme discusses the knowledge medical workers gain from clinical experience with PwD. It highlights how challenging dealing with PwD could be even for veterans.

Participants emphasised that skilled communication was a powerful tool for treating BPSD. For example, when we asked "what is the one thing you learn from dealing with PwD", one participant highlighted that *"Communication. I was from cancer center, there was not much information about dementia, so I also doubted, but it really works."* (P3). Another participant commented *"Keep in mind basic human communication, you need to refrain from using technical terms.[...] When you are going to touch the patient's body, you need to explain each item beforehand."* (P2). One participant further elaborated that *"Usually they have eye and ear problems too because they are old, that is why you need to stand in front of them first, and then talk."* (P1). It is agreed by all participants that communication with PwD requires certain techniques.

Participants also reported common PwD behaviours they encountered such as *wanting to go home* (P2, P4, P5), *saying they can see black hole on the floor* (P4, P5), *leave the bed with Intravenous*

ID	*Age*	*Gender*	*Educational and Medical Experience*
P1	48	F	BSc Degree in Nursing, registered nurse (qualified in 1996), 7 years of clinical experience in university hospitals.
P2	49	M	MSc Degree in Physiotherapy, registered physiotherapist (qualified in 2005), 9 years of clinical experience.
P3	40	M	MSc Degree in Rehabilitation, registered physiotherapist (qualified in 2005), 5 years of clinical experience.
P4	33	F	MA Degree in Social Welfare, 6 years experience in medical operation management, specialised in operational improvement of elderly care services and dementia-friendly environment design.
P5	33	F	BA Degree in Policy Management, 10 years experience in medical operation management, specialised in medical cooperation and disaster medicine in highly acute care hospitals.

Table 1: Participants' Demographic Information

(IV) infusion set on or pull out the IV (P3). To deal with these situations, one participant learned to *"fix the IV set somewhere the patient cannot see, e.g. from upper arm to head, and hide it under the clothes ."* (P3). Many observed problematic behaviours are classified as BPSD, yet clinically BPSD is frequently confused with delirium – a disorder of consciousness [14], as participants noted: *"Can you imagine what happens? The patient's executive function is impaired, but the staff misdiagnoses it as a consciousness problem and gives them medicine."* (P3); *"[as long as the patient is saying something you don't understand, you will say this is delirium and give him medicine] is not right, we should understand that PwD also do those things"* (P5). Misdiagnosis of BPSD can lead to overtreatment, and eventually more burden on medical workers.

To correct this problem, more understanding of PwD and their symptoms is crucial. One participant mentioned to *"Think about whether it is necessary to use IV each time, try to match the patient's pace."* (P1). There was also a broad agreement to *understand the patient from the interaction with the patient* (P1, P2, P4). One participant detailed: *"other reasons might also have a huge impact on patients' behaviours, like huge change within the day, recent habits, lifestyle outside hospital etc."* (P3). Therefore, it is important for medical workers to stand in the shoes of PwD: *"Suddenly being told by unknown people 'let's go somewhere' and taken is scary for PwD, and then more medical staff gather together, and the PwD becomes more nervous, and BPSD is triggered, we have to give them sedatives"* (P4). Dementia has diverse causes and myriad manifestations, and we still have a long way to go to understand it.

3.4.2 Dementia Education. This theme centres around the clinical dementia education participants had experienced. This includes their perspectives on what is lacking and what can be improved.

We first inquired about the current clinical education formats, and one participant identified the standard checklist [94] used in the hospital. Because *medical staff are busy, it is difficult to gather them together to have lectures* (P2, P4), the checklist can be used flexibly while allowing reinforcement for knowledge, and is thus powerful. This further indicates that an education process that is flexible and *can be embedded into on-duty medical workers' daily work* (P4) is considered efficient.

Regarding dementia education, 3 topics were repeatedly brought up: communication, delirium, and prevention. The necessity to raise awareness about communication was highlighted: *"Communication is the first thing, choose the language suitable for the cognitive function level, always introduce yourself first."* (P3). Furthermore, one participant pointed out that performing the task slowly and steadily is required, because *"if you say 'I will take off your diaper' and touch their body immediately, it can cause BPSD."* (P2). Communication is a useful prevention technique, and there are more prevention techniques medical workers should know. One participant suggested *"preventing from the small unnoticeable things, i.e. dehydration, constipation, whether there is body pain, [...] sharing about current treatment details, treatment plans, [...] practice reality orientation, help them to regain orientation through daily interaction."* (P3). Many of these mentioned symptoms do not only happen to PwD, but also patients with delirium; therefore, there was a common urge for education on the difference between delirium and dementia (P1, P2, P3, P4). One participant elaborated: *"I really hope they can teach how to treat not just delirium but dementia. Because sometimes you see the symptoms, you think it is delirium, so you want to use antideliriants, but it is actually dementia. There are reasons behind the behaviours of PwD, and they can sometimes be controlled without medication."* (P3).

Our participants shared reflections about daily interaction with PwD, and self-reflection was another point we identified. One participant strengthened: *"It is important to let them ask themselves: 'can I read the blood data correctly', 'did I assess their physical status careful enough', always think about what you are doing, understand why the PwD is doing what they are doing"* (P5). Therefore, we hypothesise that *a short but touching experience* (P4) could be educational for medical workers. This further highlights the potential of dementia education that elicits self-reflection, in which self-reflection aids performance [29], can thereby motivate medical workers to improve care service.

3.4.3 What if We Use XR?. This theme describes medical workers' perspectives on using XR for education. It includes participants' device preferences, situations to be simulated, and feasible components that we extracted from the activities.

Before being introduced to actual contents, we observed instances that participants prioritised practicability over functionality in terms of device preferences (P1, P3, P4). We highlight that ease of use is a key point directing participants' technical preferences. One participant was discouraged by the setup process and cables of Varjo XR-3 headset: *"having cables around is troublesome, and it is impossible to walk around the hospital, [...], new nurses themselves might belong to the ageing society, so they might be reluctant when you ask them to operate on a huge device with heavy cables around"* (P4). Concurrently, Meta Quest 2 was appreciated for the ease of use (P1, P2, P3), and iPhone with HMD was an *unexpected* (P1, P5) combination. Difficulty level of installation inside software was also considered by participants: *"if there are too many steps that ask them to operate inside the program, even if it is not actually hard to operate, some people might think it is too hard"* (P2).

Early exposure to the devices also granted participants access to an overlook of the capability of XR in the dementia education setting. However, we noticed instances of inclination to comment on the potential content creation under the collective concept "XR"; as participants insisted communication simulation should be included in the experience regardless of the technology's ultimate format (P1, P3, P4, P5): *"it would be nice if we can observe and interact with PwD during education"* (P1), and *Having them try out the good and bad experiences should be striking* (P4). Furthermore, simulation of PwD should be considered because medical workers are also *curious about the perspective of PwD with cognitive impairment* (P1, P3, P5). One participant proposed that *"if we have 2 VR working together with both patient and nurse's view, it should be effective"* (P3). Our data suggests that a dementia education-focused simulation should include medical worker-PwD daily interaction, communication, PwD behaviour together with BPSD triggers, and allows practice from both parties.

Here, we identified the components feasibile to simulate in a first-person point of view (FPV) based on participants' paraphrase ofwD's description, as well as the PwD behaviours that they repeatedly mentioned. The individual elements that we pinned down are: misperceived black hole – *"in the elderly home, we usually stick a piece of white paper on the TV when it is not in use because PwD said it looks like a black whole and it is scary"* (P4) and *"they said floor looks like a hole"* (P5); misperceived water puddle – *"sometimes they think light reflection is a water puddle"* (P2); distorted color contrast – *"they cannot distinguish between two adjacent areas i.e. wall or floor"* (P2) and *"sometimes they think high contrast between two adjacent areas is a step"* (P2); misperceived dark corner – *"they think there is somebody hiding there and feel anxious"* (P2); impaired hearing – *"when we talked to them, they could not understand where does the sound come from"* (P1).

4 PHASE II: CO-DESIGNING AN EXPERIENCE PROTOTYPE

Our second phase contributed to the design process of an Experience Prototype based on the findings in Phase I. We created the initial prototypes, then reunited the participants from Phase I to experience the prototypes through a pilot test in a lab setting. Based on the new feedback and reactions from the same stakeholders, we revised the prototype. The goal of this phase was to address **RQ1** and **RQ2**.

4.1 XR as an Experience Prototype

Designing technical systems for inexperienced end users can be challenging because the system might not accommodate to its end user's best interest, which leads to speculation and refrain from using it [20, 73]. Therefore, the concept of experience prototyping has been adopted in the HCI field [37, 107, 109]. Experience prototyping is a prototyping approach emphasising the exploration and interaction with low-fi prototypes to facilitate any design ideas that can contribute to the final product. We opted for this approach for two reasons. First, XR is a novel technology that can be hard to understand or imagine about the final product for certain end users. Second, our work contributes to an area of professional education that pursues authenticity of the expression, which requires in-depth communications with experts in the area.

4.2 Prototype Design

This session describes the design and decisions for the initial prototypes. Our design process prioritised three factors: user preference, sensory authenticity, and PwD interaction scenario development. Our first simulations focus on daily life of PwD that participants observed and are curious about based on results in section 3.4.3. The result is comprised of a VR prototype and an AR prototype, both from the perspective of a PwD.

4.2.1 User Preference. In Phase I, participants did not have preferences between AR and VR. Aiming to deepen their understanding of the diverse approaches and feasibility of XR, we created a VR prototype and an AR prototype. Following the findings in section 3.4.3, we decided the goal for the technical implementation of the initial prototypes to be the realisation of the sensory changes of PwD. Since the decision resulted in prototypes prioritising the visual and auditory components, only the selected HMD and the corresponding auditory system were used at this stage.

For implementation in VR, we used a RICOH THETA Z1 51GB 360° camera to record the simulated scenario crafted from the FPV, then applied the elements described in section 4.2.2 in post-production, and exported to the Meta Quest 2. Our choice of hardware depended on the device's wireless nature and the provision of high-resolution videos simultaneously.

For implementation in AR, we applied the same elements described in 4.2.2 to a Unity-based iPhone application and completed the hardware setup with an iPhone-based HMD. We rearranged the environment to match the designed scenario. We chose different hardware for the following 3 reasons: (1) it is the hardware all participants in Phase I were most familiar with and whose performance in XR they were curious about; (2) the lighter weight (189 grams) is less than half of that of the Meta Quest 2 (503 grams), providing more convenience and safety while user performs physical tasks of extensive movements, i.e. sitting down; (3) the ease of use allows participants to have control over the novel experience.

4.2.2 Sensory Authenticity. We further investigated the components that were identified as technically possible to simulate in section 3.4.1 and regrouped them by the corresponding pathological reasons. While dementia is known for the cognitive impairment, clinical research has shown that PwD experience sensory changes in their visual [91, 99] and hearing system [63]. For example, distinguished from individuals with mild cognitive impairment or "normal aging", unique retinal changes have been found in individuals with AD [41, 68, 92]; and therefore visual changes are being used in detecting early-stage AD [9]. Based on these clinical findings, we underscore that we simulated PwD experience through reproducing general sensory changes of people with AD.

Delayed Pupillary Light Response. Pupillary light response is due to the pupil's dilation and constriction in response to light changes. Pathologically, AD neurodegeneration has a negative effect on the speed of the response [25]. This phenomenon can be

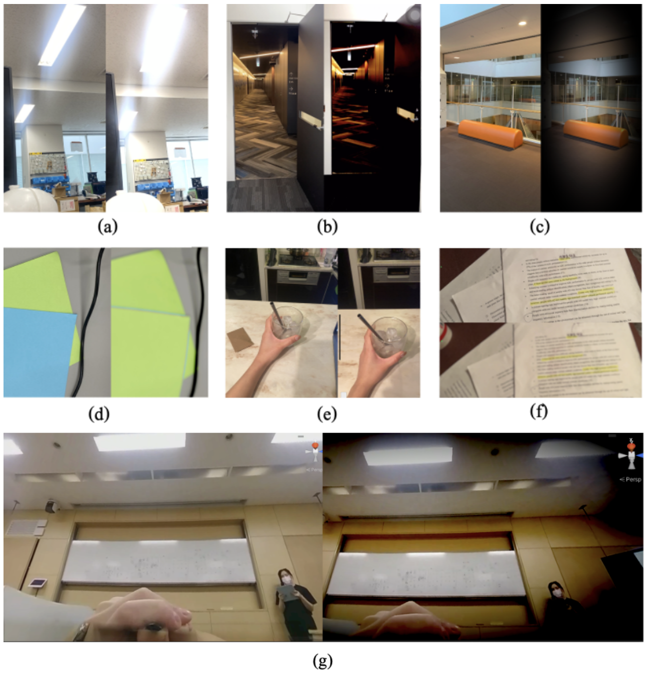

Figure 3: (a)(b): Delayed Pupillary Light Response in AR; (c) Visual Field Defects in AR; (d) Decreased Color Sensitivity in AR; (e) Impaired Depth Perception in AR; (f) Decreased Visual Acuity in AR; (g) VR Scenario Development in Unity with visual effects (a)-(f).

interpreted visually as the incapability of the pupil's adaptations to light changes. When a PwD moves from a comparatively dark location to a brighter space, their pupils fail to shrink without delay, causing overwhelming amount of light input into their eyes. Vice versa, a sudden switch from bright to dark environment causes the surroundings to look extremely dark because the pupils fail to open in time. This is illustrated in Figure 3. (a) and (b) which shows glaring lights and dark corridors. To simulate the human eye's sensitivity to light, we adjusted the gamma correction. In graphics, gamma encoding can achieve maximized utilization of the use of bits by simulating the non-linear characteristics of human eyes when perceiving light and color [83].

Vision Field Defects. Vision field defects are a common issue that accompanies aging. It has been proved by Patino et al. [82] that "both central and peripheral vision loss were independently associated with increased risk for falls and falls with injury in a dose-response manner", thus we decided that vision field defects are a value-added phenomenon for the simulation experience. Peripheral vision refers to the field of vision outside our central viewpoint, which accounts for the majority of the field of vision, and the loss of it was realised in this experience as shown in Figure 3. (c). We implemented this with vignetting, which is a reduction of brightness or saturation from the periphery of the image.

Decreased Color Sensitivity. Decrease in color sensitivity is another frequently observed problem in the aging society owing to the yellowing of the lens. This is different from red-green color blindness – a common type of congenital color deficiency – in that for the aging population, only selective colors on the yellow-blue scale are hard to distinguish. Cronin-Golomb et al. [27] discovered evidence of diminished sensitivity of blue and green among people with AD. This is illustrated in Figure 3. (d) where blue paper looks green. We used the combination of color grading curves to achieve a mixed effect of green and blue, as well as red and pink.

Impaired Depth Perception. Depth perception represents the visual ability to identify distance with objects and three-dimensional perception. This disorder that occurs to the visuo-spatial function of the brain is caused by focal cortical lesions that involve the parietal and temporal lobes, which is associated with decreased glucose metabolism in the posterior cerebral cortex – a major reason for cognitive declination [72]. Due to the disorder, the brain of advanced PwD might process information received through one eye, even though visually they can still see from both. This is shown in Figure 3. (e) where the vision is perceived to be much closer. To achieve this effect, we leverage the lack of stereoscopic cameras for the iPhone. The XR plugin splits the image from a single camera with a small amount of zoom and crops just enough to accommodate an image for each eye. This results in the overall vision appearing closer than it actually is.

Decreased Visual Acuity. Visual acuity refers to the ability to identify shapes and details of objects visually, where its declination leads to myopia and/or presbyopia. Gittings and Fozard [40] found that regardless of pathology, visual acuity decreases with age because flexibility of the lens decreases. Since majority of the neurodegenerative PwD belongs to the aging population, a decreased visual acuity effect was added to the experience. We visualised this in Figure 3. (f) where words on paper appear blurrier. We used the depth-of-field feature, which simulates the focus properties of a camera lens, to achieve change in acuity.

Selective Hearing Disorder. Selective hearing disorder refers to the inability to distinguish the direction and distance of the sound resource. Clinical research has shown that selective hearing disorder is prevalent in people with AD [81]. For PwD, clinically it is represented by the difficulty to focus on the person talking in front of them because the background noise is equally loud. We created this hearing phenomenon using the iPhone's microphone to collect 3D spatial sound and process the volume to the same value in real-time.

4.2.3 PwD interaction scenario development. Drawing from our findings in Phase I, we crafted one scenario for each prototype. We decided on two distinct scenarios to avoid the potential emotional desensitisation due to repeated exposure to the same stimulus [26]. Both scenarios aimed to *provoke self-reflection on dementia care challenges through the realised PwD sensory change simulations* and to *foster understanding of the XR technologies.*

Scenario for VR The scenario we describe here is crafted from draft scenario 1 described in Phase I (see Figure 2. Draft Scenario 1 and supplementary material). We opted for this scenario that requires only above-the-shoulder movements because it allows users to have an overlook of the immersive nature of VR technology with low risk of motion sickness. The scenario includes 3 actions all aiming to convey the experience of regular morning checkup for institutionalised PwD. Here, the virtual dementia care experience is portrayed through a situation where the nurse attempts to interact with the PwD in fast pace and uses standard terminologies to communicate:

Action 1: Eyes open. The storyline starts from when the FPV opens eyes. The FPV looks around and finds the lighting to be unexpectedly bright. The FPV realises that they are in bed and sees an IV drip attaching to the arm.

Action 2: Observing nurse coming in. The door suddenly opens. The FPV sees a nurse walking towards the bed. The nurse stops next to the bed and checks on an IV drip hanging above the FPV.

Action 3: Listening to the medical staff talking. The FPV sees the nurse starting to talk. The nurse describes the FPV's current physical condition.

Scenario for AR The scenario we describe here is crafted from draft scenario 2 described in Phase I (see Figure 2. Draft Scenario 2 and supplementary material). We opted for this scenario that requires users to perform tasks on real-world objects to introduce the real-world add-on effect of AR technology. The 4 actions present a PwD's daily necessary interaction with a nurse who provides standard verbal and mobility assistance:

Action 1: Sitting on a Chair. The storyline starts from when the FPV stands in an empty aisle inside the hospital. The FPV looks around the environment and sees a chair. The PFV sits on the chair by themselves.

Action 2: Opening the Door. The FPV then stands up with the help of a nurse. The nurse holds the FPV's arm to assist with walking. The FPV walks to a wall with a door and finds the doorknob to open it.

Action 3: Mock Using of the toilet. The FPV walks to the toilet with the help of the nurse. The FPV is asked by the nurse to turn on the light. The FPV looks for the toilet seat with the help of the nurse and sits on it. The FPV flushes the toilet.

Action 4: Identifying an Object on the Table. The FPV walks outside the toilet, goes back to the main room. The FPV is guided to a table with the help of the nurse. The FPV identifies the objects on the table.

4.3 Pilot Study: Evaluation from Stakeholders

To evaluate our rapid AR and VR prototypes, we invited the five medical workers from the previous session in an exploratory study that examines their perspective towards the simulated experience. Phase I in combination with the pilot test from Phase II forms a longitudinal study on medical workers' perspectives and preferences on XR-enabled dementia education under repeated exposure to XR. We opted for this approach because longitudinal study has the advantage of providing information on within-individual changes, continuity and prediction [33].

4.3.1 Methods. We recruited participants to evaluate the AR and VR prototypes that we developed. We conducted a focus group discussion afterwards to inquire into their perspectives on: (1) impression of the sensory elements and the simulated scenario, (2) relationship between the simulated experience and lived experience in dementia care, (3) perception on the difference between the AR and VR experience. We asked questions like *"How was the experience of PwD-nurse communication from the PwD side?","What do you think about the tasks you just performed?"*and *"How do you think this kind of experience can be integrated into clinical settings?"*.

4.3.2 Participants and Procedures. We recruited the 5 participants from Phase I (see section 3.2 and Table 1. for demography information) to a lab setting to run the pilot study. We followed the group-based approach commonly used in nursing education to involve all participants in the study simultaneously. In nursing education, group-based approach is widely used for its advantages of generating critical thinking and preparing students for the collaborative work environment in healthcare [79].

The pilot study took about three hours in total, in which the participants gave informed consent in print before it took place. The study was divided into three successive parts: experiencing the AR prototype one by one in random order, experiencing the VR prototype one by one in random order, and a group discussion at the end. Part one and two were conducted in Japanese to make the virtual experiences close to the participants' lived experience. Part three was primarily conducted in English, while Japanese was the second source. The AR experience lasted approximately 3 minutes for each, the VR experience lasted approximately 2.5 minutes for each, and the discussion lasted approximately 30 minutes in total. During the procedure, participants were free to communicate with each other. Because participants' observation of the HMD user's behaviour, likewise the interpersonal discussion were considered as elements for XR-enabled dementia education. The IRB-approved research complied with the facility's Covid-19 regulations.

4.4 Results

Here, we present two themes crafted from the discussion findings, which focus on the *"Aha!" Moment About Lived Experience in Dementia Care* and the *Factors that Affect Implementation of XR-Enabled Experience in Clinical Dementia Education.*

4.4.1 "Aha!" Moment About Lived Experience in Dementia Care. This theme narrates how the simulated experiences affected users and arose self-reflections on their provision of care service.

In general, participants expressed complex attitudes towards the experience, suggesting it was *"scary"* (P1, P4, P5), *"impressive"* (P3), and *"educational"* (P4). Participants pointed out that, sensory changes of both experiences reflected memories about dementia care lived experience, and so they could relate PwD's words to the simulated experience: *"It looked really really dark, the TV monitor was all black. PwD always said TV is scary so we actually attach white papers on the screen while they are not in use."* (P2). P1 was wearing a pair of black trousers and black shoes, after being asked to walk on the dark carpet, they detailed: *"It looked like a black hole, and it looked like I'm falling into it, I cannot see my lower body at all. PwD says that they can see black hole."* (P1). For the hearing part, one participant mentioned *"It was too loud, I could not identify who is talking from which direction [...] some patients are like that."* (P1).

Regarding the AR experience, observing other participants performing tasks in HMD was effective in recalling memories of lived experiences in dementia care. One participant specified: *"I've seen this kind of behaviour a lot, that when PwD sits on the chair they eventually land on only one side of the bottom"* (P1). Furthermore, it arose a mixed feelings of fear and curiosity about trying the AR experience. Because from the outsider's point, it looked *scary* (P1, P5) but also *interesting* (P3, P4). We noticed that, when the first user (P2) was trying the AR prototype, multiple participants asked: *"what can you see?"* (P1, P4, P5).

Regarding the VR experience, we captured instances in which negative emotions were derived from the virtual nurse's communication skills, driving participants to resonate with PwD. Participants commented *"This is the kind of word I say everyday, but it sounds so cold here."* (P5), and *"Saying it is one thing, hearing it is another [...] I wonder if my patients feel the same."* (P3). Participants acknowledged the nurse's communication skills to be realistic and professional: *"it was very close, the IV checking and changing part. We usually need to check on them in the morning, check their health condition and brief the schedule like that."* (P1).

Our data also suggested experiencing the simulations, in addition to observing and discussing, induced reflections on participants' provision of care service. For instance, during the discussion one participant pointed out: *"if they really experience this on a daily basis, it is a terrible feeling, the care provision has to be changed"* (P1). Regarding the care service improvement needed, one participant further elaborated: *"[...] that is why we should definitely not rush when we carry them with their hands, it felt really unsafe"* (P2). We also discovered instances of connecting simulated sensory changes to BPSD triggers: *"If you think about it, they have cognitive problems while they see and hear like this. They cannot understand what they see, that's why things became scary to them, that must be a horrible feeling."* (P5).

4.4.2 Factors that Affect Implementation of XR-Enabled Experience in Clinical Dementia Education. This theme reports participants' opinions on the feasibility of implementing such XR-enabled experience in clinical settings. It highlights the factors that can contribute to the harmony between XR-enabled education program and clinical environments, along with responses to the disparity between the two prototypes from the perspective of its end users.

We noticed consistency in participants' appreciation for the condensed nature of both experiences. Participants commented:*"It's a good thing that it is short, it is hard to squeeze anything longer than this into their already busy schedule"* (P4) and *"this is efficient and effective"* (P1). Participants also valued the ease of use feature of both experiences. For instance, one participant underlined: *"It is very easy to understand, you just put it on and off [...] I like that there are no extra cables, so you don't need to worry about tripping over things."* (P4).

While embracing the experience brought by our low-fi prototypes, participants also formed their opinions on the difference between the two, in which we found an inclination to discuss the AR experience. Participants agreed that while the VR prototype was *easier to use* (P2), the AR experience allowed the participants to see the same environment in a completely different way: *"you want something to shock their cold, rocky heart from working with so many patients for so long in the same place, and this is it"* (P4). One participant further strengthened: *"The AR one was already too impactful, I was overwhelmed by it."* (P1). Participants spontaneously proposed new application scenarios for the AR prototype, focusing on its potential to better the facility environment PwD live in:*"people can do lots of things with it, you can just give them the device and ask them to walk and explore, even without any tasks it can already achieve things*" (P2), *"we can also ask them to walk into the hospital cafeteria"* (P4), *"just walking with it on inside the hospital, we can see the world we see everyday become something so different"* (P3). When being inquired about the VR experience specifically, we also observed the tendency to compare the AR experience with. In general, participants acknowledged that *the VR prototype stood out in representing the medical worker-PwD communication* (P1, P4), but *the AR prototype provided a more thorough educational experience* (P3) and *shown more possibilities* (P2, P3, P4).

We also seized minor disharmony that impede the conveyance of dementia education experience, which centred around sensory authenticity of the prototypes. Participants expressed mixed feeling towards the audio element for the AR experience but not for the VR experience, because the audio effect *made it hard for participants to listen to the instruction* (P5, P5). We also found disparity in participants' comprehension of the decreased colour sensitivity as some spotted *orange* (P2) or *purple* (P3), instead of green that we intended. Finally, we would like to declare that in our data there is no evidence that any participants was discouraged in spite of the sense of discomfort.

4.5 Prototype Revision

Findings from the pilot study suggest the complexity of lived dementia experience-based education, which is the goal of sufficient knowledge input while not placing a burden on medical workers' already heavy work schedule. This suggests the need to design experiences that can promptly attract medical workers' attention in their everyday clinical setting and evoke reflection on existing dementia care challenges. More specifically, our data discloses the strong preference for experience that is sensory-wise realistic, and impactful in bringing sensory changes to an everyday setting, by which making comparison to the pre-experience standpoint can affect reflection. This suggests the simulation of lived experience in dementia care needs to convey the experience that fuse the educational elements, such as the communication skills and group discussion, with user-centred experience elements, such as format and content preference, and actual field implementation approaches.

4.5.1 VR and AR. We halted the development for the VR prototype because: (1) participants' comparatively limited feedback on the improvement and future direction of the VR prototype, (2) the conveyance of communication experience, which is the primary deliverables of the VR experience reported by participants, was partially achieved by the AR prototype, while the latter stood out owing to the unique potential of contributing to understanding PwD's perspective flexibly, (3) the purpose of fabricating two initial prototypes was to build familiarity of XR-enabled technology for the dementia stakeholders, which had been fulfilled in the pilot study based on the findings.

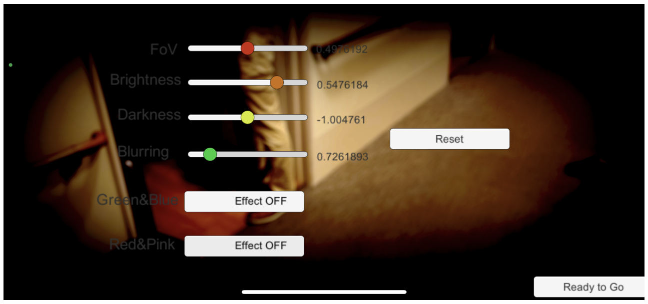

Figure 4: UI Interface of the AR Application

Regarding the AR prototype, we revised the sensory elements, along with the scenario with more input to convey communication skills as a substitute for the VR experience. Furthermore, we added a UI (see figure 4) with separate sliders for each element, which allows real-time adjustments of the prototype.

4.5.2 Sensory Elements. Based on findings in section 4.2.2, we removed the color contrast sensitivity effect and hearing effect. For the color contrast sensitivity, because many on-duty medical workers themselves belong to the aging population, the individual difference of the perceived color was large. To avoid the unnecessary confusion that might be caused by individual differences, we removed the element. As for the hearing effect, we had two reasons. (1) To eliminate the latency in real-time data transfer and processing, we selected wired earphones. However, wire is a potential inconvenience for upper body tasks. (2) The unintended communication obstacle that participants reported.

4.5.3 Scenario. The new scenario we describe in this session includes three activities all aims to enlighten *"Aha!" Moment About Lived Experience in Dementia Care.*

Activity 1: Black Mat. The FPV walks with the help of a helper inside an empty hospital room. The FPV is stopped when they step on a piece of black mat.

Activity 2: Checking the Pinboard on the Wall. The helper asks the FPV to look at the pinboard on the wall in front of them. A hospital cafeteria menu is pinned on the board, and the FPV is asked to identify the menu.

Activity 3: Sitting on A Chair. The FPV sits on the chair with the help of the helper.

5 PHASE III: EVALUATING EFFECTIVENESS OF THE AR EXPERIENCE

To further evaluate the effectiveness of our revised AR experience, we involved end-use medical workers in a conclusive study using a mix-method approach including both quantitative and qualitative analysis. The primary purpose of this phase is to answer **RQ3**.

5.1 Methods

The positive effect of simulation in enhancing understanding of the aging society has been explored. Jutten et.al [54] suggested that VR simulation is effective in eliciting empathy for PwD. Lee and Teh [60] found that immersive aging suits added to the ability to understand the physical limitations and visual issues of aging. We designed the study to investigate any such effects for a lived experience-based AR experience. We followed a within-participant design approach to measure the participants' subjective assessment data at baseline (before starting the experiment), and after using Before and After questionnaires. At the end of the study, we conducted a semi-structured interview to inquire about the authenticity, effectiveness, and implementation possibility of the simulation.

5.1.1 Questionnaire Measures. The Before questionnaire consists of *empathy* and *emotion*. *Empathy* is measured using the State Empathy Scale (SES) [100] which has subscales for affective empathy, cognitive empathy, and associative empathy. The SES has 12 items rated on 5-point Likert Scale, yielding overall scores between 1 (Strong Disagree) and 5 (Strongly Agree). *Emotion* is measured using the Self-Assessment Manikin (SAM) [16], which has 3 affective dimensions for pleasure, arousal, and dominance. The SAM is rated via 3 bipolar adjective pairs (unhappy and happy, relaxed and stimulated, submissive and dominance) on 5-point scales, yielding overall scores between 1 and 5. The After questionnaire consists with the Before questionnaire, with four extra *emotion* statements emphasising on the semantic difference. These statements are directly linked to the AR experience, such as "I experienced similar emotions as patients when experiencing the AR prototype.".

5.1.2 hypotheses. Based on previous findings, we presented a priori hypotheses that our AR dementia education simulation is effective in inducing understanding of PwD on psychological and physical level. The first hypothesis has three sub-hypotheses, i.e. H1AF, H1C, and H1AS. The first hypothesis describes an increasing empathy level:

H1 Empathy towards PwD is higher after the AR experience *vs* baseline.

H1AF Affective empathy-related SES scores are higher in After *vs* baseline.

H1C Cognitive empathy-related SES scores are higher in After *vs* baseline.

H1AS Associative empathy-related SES scores are higher in After *vs* baseline.

The second hypothesis describes the emotional response towards the AR experience. It has three sub-hypotheses, i.e. pleasure, arousal, and dominance level that are stimulated:

H2 The AR experience stimulates emotional response.

H2P The pleasure dimension of SAM shifts towards the "unhappy" direction in After *vs* baseline.

H2A The arousal dimension of SAM shifts towards the "aroused" direction in After *vs* baseline.

H2D The dominance dimension of SAM shifts towards the "submissive" direction in After *vs* baseline.

5.2 Participants and Procedure

We recruited sixteen participants via online contact with a hospital in Japan using a snowball sampling method, between July 7, 2021 and July 30, 2021. Ranging from 26 to 58, participants' average age was 38.75 years old (M=38.75, SD=10.42). Gender-wise, 13 of them

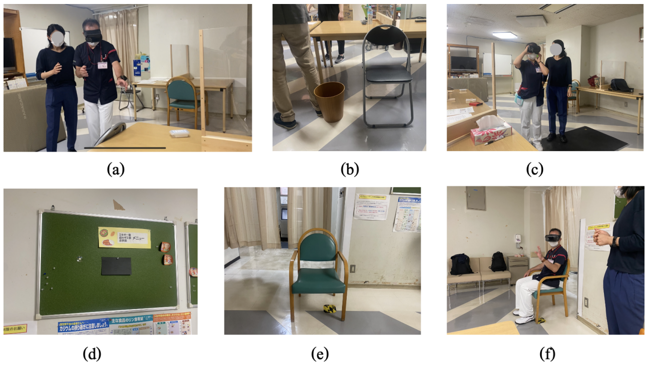

Figure 5: (a) A participant is performing Task 1 of finding a chair and sitting; (b) The black chair used for Task 1, which was perceived as a black hole by one participant; (c) A participant is performing Task 3 of identifying the carpet and pinboard; (d) The pinboard used for Task 3; (e) The chair used for Task 4, which is intentionally distinguished from the one used for Task 1; (f) A participant is sitting on the chair as required for Task 4.

were female, and 3 were male. The participants were registered nurses (7), registered doctors (2), registered occupational therapists (1), registered physiotherapist (1), and medical operation staff (5). All participants worked in the same hospital where the experiment was conducted, and were familiar with the hospital environment. One participant had eye disease at the time of the study. Eight participants had previous experience in trying XR in any format. Consent to use data was obtained from all participants for this IRB-approved study.

Participants gave informed consent before the experiment started on paper, and filled in the Before questionnaire. Each of them was asked to conduct the tasks described in section 4.5.3. Afterwards, participants filled in the After questionnaire and conducted the interview. The experience session lasted about 7 minutes, while the following questionnaire and interview session lasted about 20 minutes.

Two participants joined the same session as nurse and PwD role. Each participant experienced the AR experience first, and then acted the nurse role for the next participant. The first nurse role and the last PwD role were performed by researchers. The process of asking participants to act the nurse role immediately after experiencing the AR prototype was designed to reinforce the hypothesised empathy brought by the AR experience. We hypothesise that playing the nurse role immediately afterwards can lead to self-reflection on communication and caring skills.

Details of the tasks are described here:

Task 1: Find a chair and sit on it. The participant is asked to find a chair in the room and sit on it without guidance (see Figure 5. (a)), which takes approximately 30 seconds.

Task 2: Stand up and walk straight. After sitting down, the nurse role immediately inquire about the participant's feeling about task 1. After the 1-minute within-task interview, the nurse role then assists the participant to stand and walk in a straight line. An empty bin is placed next to the chair (see Figure 5. (b)). The participant is expected to avoid kicking the bin without notice, and walk to the center of the room. The participant is subsequently asked about what they can see on the floor. This task lasts for about 1 minute.

Task 3: Read the pinboard. After the participant steps on the black carpet, they are asked to identify the objects on the pinboard on the wall.

Task 4: Assisted sitting on chair. The participant is asked to sit on a different chair under the assistance of the nurse role (see Figure 5. (e) and (f)), which lasts for approximately 30 seconds. A different chair is used to avoid bias on user behaviour.

5.3 Results

In this section, we delve into the result of the study, segmented into *empathy*, *emotion*, and *"Feeling What My Patients Feel"*.

5.3.1 Empathy. We performed one-tailed paired t-tests to check whether affective, cognitive, and associative empathy towards PwD were enhanced through the AR experience (see Figure 6.). A power analysis using G*Power version 3.1.9.7 [34] indicates the paired t-tests were able to detect large effects (Cohen's d = 0.652) at $\alpha = 0.05$ with a power of 0.8. Shapiro-Wilk tests were performed to check normality. There were two affective empathy-related statements, two cognitive empathy-related statements, and three associative empathy-related statements included on both Before and After questionnaires. To further understand the effect of semantic difference, we added three affective empathy-related statements and one cognitive empathy-related statements. We used the baseline score (3) as hypothesised mean for the four semantic t-tests.

The affective empathy level was significantly higher in After compared to Before in the two statements (Q1: $t = 4.000, p < 0.001**, d = 0.998$; Q4: $t = 3.782, p < 0.001**, d = 1.124$). The cognitive empathy level was significantly higher in After compared to Before in the two statements (Q2: $t = 8.944, p < 0.001**, d = 2.236$; Q3: $t = 5.839, p < 0.001*, d = 1.460$). The associative empathy level was significantly higher in After compared to Before in the two statements (Q5: $t = 3.303, p = 0.0024*, d = 0.826$; Q6: $t = 3.171, p = 0.0032*, d = 0.793$, Q7: $t = 2.300, p = 0.0181*, d = 0.575$).

We also tested the four statements emphasising the semantic difference. The three affective empathy-related statement yielded higher score than the baseline (After Q1: $t = 4.259, p = 0.0003**, d = 1.065$, After Q6: $t = 7.251, p < 0.001**, d = 1.813$, After Q10: $t = 6.249, p < 0.001**, d = 1.562$). Likewise, the cognitive empathy statement showed significantly higher score than baseline (After Q4: $t = 7.268, p < 0.001**, d = 1.817$). Therefore, we accept **H1AF**, **H1C** and **H1AS**.

5.3.2 Emotion. We performed one-tailed paired t-tests to understand how participants processed emotional stimuli in response to the AR experience on the pleasure, arousal, and dominance dimensions. Shapiro-Wilk tests were performed to check normality. On the pleasure scale, participants were significantly less happy after the experiment (Before Q8A-After Q1.12A: $t = 2.55, p = 0.0111*, d = 0.638$). On the arousal scale, participants' emotional response was not significantly greater after the experiment (Before Q8B-After Q1.12B: $t = -0.5222, p = 0.695, d = -0.131$). On the dominance scale, participants' emotional response was also not

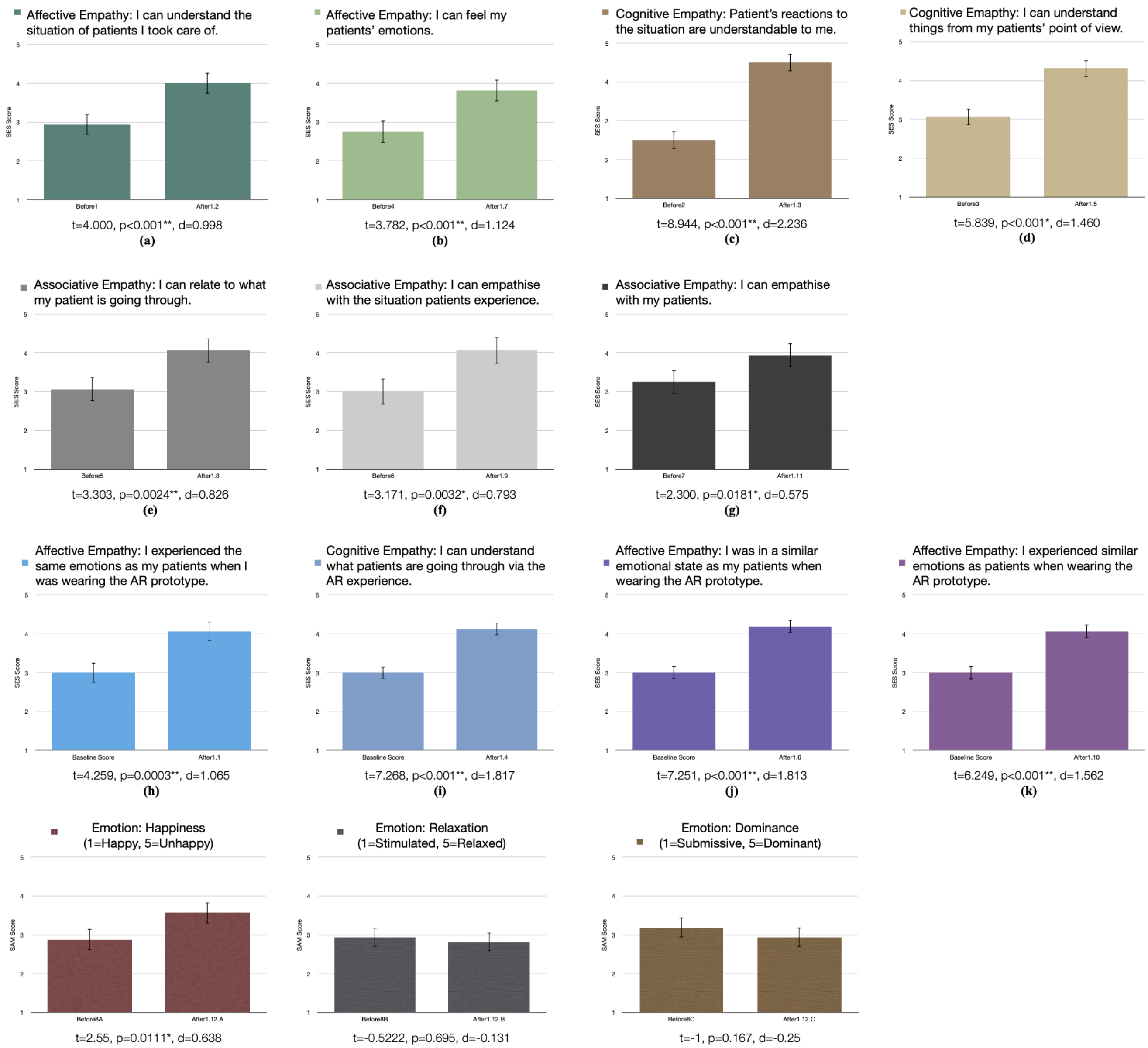

Figure 6: (a)(b) Results for Before and After Affective Empathy; (c)(d) Results for Before and After Cognitive Empathy; (e)-(g) Results for Before and After Associative Empathy; (h)-(k) Results for Semantic Difference on Affective Empathy and Cognitive Empathy; (l)-(n) Results for SAM Emotions.

significantly less positive after the experiment (Before Q8C-After Q1.12C: $t = -1, p = 0.167, d = -0.25$). Therefore, we accept **H2P**, but reject **H2A** and **H2D**.

5.3.3 "Feeling What My Patients Feel". In this study, all participants were able to complete the experience, and we further discuss our observations during and after the experience session.

Even sitting on the chair became challenging and time-consuming. We found participants' behaviours and feedback on the sitting task aligned with the pilot study result, as all participants had to touch the cushion multiple times to confirm its position to sit down, a behaviour they reported commonly observed in the aging population (P2, P3).

No one noticed the bin on the floor. When standing up from the chair in task 1, all participants accidentally kicked the bin next to the chair (see Figure 5. (b)), because they were focusing on transiting to the next task. One participant elaborated: *"when you can see only a small area of things you become really focus on it, it's impossible to notice unless people warn you"* (P1).

Only figures and characters in highly contrasting colors are recognisable. All participants were confused by the pinboard since they could not see the black piece of paper, and could only identify the objects in contrast colors (see Figure 5. (d)). Nonetheless, being able to identify the shape of the object does not guarantee understanding the actual content. One participant *perceived the figure of curry as a yellow oven and still could not identify whether it is curry or bread* (P5).

Spontaneously Explored the Hospital Environment Wearing AR. Participants also realised the AR prototype could be used to improve their hospital environment. One participant pointed out: *"If they really see this, the normal lighting in this room is too dark, we should turn the light brighter."* (P11). Another participant *requested to carry the HMD to walk around the hospital aisle* because they want to know *what can be improved* (P5). Multiple participants highlighted that: *"we should also let their family members try this, they would want to know"* (P3, P4, P10).

The experience also connected to their lived experience with PwD. Multiple participants *perceived the wallpaper on the ceiling as flying insects, and remembered it was what PwD repeatedly told them* (P6, P10, P11). As a result, participants could related to patients' emotion: *"No matter how detailed you describe to me, I couldn't see it, so I couldn't understand what you said. That was upsetting."* (P2). The elicitation of self-reflection and the corresponding intention for service improvement was likewise, again observed. One participant said *"being walked by the 'impatient' helper felt not like walking but running, it was really scary.[...]I think we should adapt more to the PwD's pace."* (P5).

We also found participants' answers to the questionnaires differed by their perspectives. Two participants demonstrated high excitement before the experiment because they *never experienced XR* (P2, P14). One participant was very happy after the experiment as they explained: *"Isn't it a good thing that we have this kind of device now? it should be very helpful."* (P14).

6 DISCUSSION

In this section, we summarise our key findings to answer our research questions. We further discuss the potential of XR simulations in clinical education and highlight the key challenges for the design of dementia education simulations that we observed.

RQ1: What are the design considerations for XR-enabled dementia education? In our work, we found that simulations of dementia education need to be designed in an easy-to-operate manner, leveraging a realistic point of view while providing freedom of exploration and playfulness. The balance between providing an exciting novel experience and educating about the real challenges in daily dementia care needs to be well considered. Our research suggests that a condensed and thorough PwD lived experience that can sparkle reflection is of the primary interest of our participants. This further suggests that in professional educational settings, it may be beneficial to focus on designing the baseline of simulations and give participants the freedom to interpret the simulated experience by themselves. Additionally, because dementia affects people across the globe, factors like culturally appropriate dementia care, as well as the need for customisation of the simulation, should be taken into consideration.

RQ2: How do medical workers perceive XR-enabled dementia education?

Our data suggests that while the participants experienced negative feelings towards the sensory changes, they were generally positive about the implementation of the simulation. Participants highlighted how the obstacles they experienced during tasks elicited memories about the lived experience, self-reflection on care provision, and potential improvement. Regarding the clinical setting implementation, our results emphasise participants' preference for short sessions that allow interactions with other participants to spark in-depth discussion and comprehensive understanding, and most importantly, bringing the feeling of fun. Our participants showed positive attitudes towards having such experience under education process in hospital settings. Therefore, we conclude that our simulation has the potential to support clinical dementia education in provoking self-reflection and understanding.

RQ3: How effective is a simulation of dementia stakeholders' lived experience in impacting its user, and what is its potential in dementia care?

Our findings show that the simulation can raise empathy in the form of affection, cognition and association. Participants showed increased affective reaction towards PwD's experience, demonstrated improved ability in adopting PwD's point of view, and better associated with PwD's daily life. Although the simulation was not a pleasant experience for participants, the arisen empathy and the consequential increased understanding of PwD compensated the negative emotional response in its overall effectiveness. For this reason, participants showed optimism in investigating broader applications of it, including universal design and expanding its end-user range from professional medical workers to the general public, including the PwD's family. We want to mention that, currently in the disability and HCI community, the acts of empathising people with disabilities using simulation has been criticised[57], and our findings support Bennett and Rosner's commitments[12] of designing experience to empathise with people with disability in a way that foregrounds lived experience and historicity.

6.1 Using XR Technology as a Tool in Clinical Education

Our work attempted to involve end users in the design process from the first design decision, and approached by inviting them to experience XR before and after our initial prototypes. For initial prototypes testing in Phase II, users walked in and observed the environment wearing the AR prototype; the corresponding sensory and depth perception changes led to the difficulty in daily task performing in an environment that they had been familiar with, which induced comprehension towards PwD and provoked self-reflection. For the VR prototype, users lay down on the bed to experience a PwD morning checkup, the sensory changes added to the communication scenario recollected the importance of communication skills, which elicited thinking on the provision of care services. The decision of compressing them into one revised AR prototype with communication component is grounded in the capability of AR to distribute synchronously multisensory changes to the real world, which vouches for understanding the perception of individuals with multisensory changes flexibly, and is therefore powerful in understanding PwD in the clinical setting. Our finding aligns with Huang et al. [49]'s finding that the cognitive demand of AR and VR varies as VR draws attention to the visual information, while AR is effective in conveying information in nonvisual channels. In our context, dementia education is a complex process where medical workers pursue knowledge in pathology, BPSD treatment, delirium, communication skills etc. The revised AR experience allows users to have a peek at the world of PwD perceive. This received positive responses because it matched with medical workers' lived experience while providing a new perspective to look at past-encountered PwD problematic behaviours, which drives them to think about how BPSD was triggered and how care service can be improved. Therefore, we suggest that for implementing XR technology in the area of professional education, the distinction between AR and VR likewise their different learning effects should be taken into consideration.

In our case of clinical dementia education, in which convenience and flexibility of the learning material format are widely valued [75], we compromised with the hospital settings and decided to not use VR motion tracking or AR object tracking functions in the initial prototypes, instead focused on simulating the sensory changes using HMD and earphone. Our result of the thought-provoking experiences is in line with Slater et al. [102] and Yu et al. [120]'s findings that in virtual events users emotionally response to dynamic elements (e.g. real-time shadows), contrary to quality of graphic rendering. We highlight that our choice of device and scenario development contributed to a case study of the potential of AR that serves as an educational tool in dementia care. This further suggests the potential of implementing XR technology in clinical education, with balanced technology choice and practicability.

6.2 Challenges for Simulating Lived Experience in the Dementia Setting

Besides the considerations for design, implementation, and technology effectiveness, we also noticed several challenges for simulating lived experience in the dementia care setting.

6.2.1 Respect and Reconcile Individual Differences. There is a current disconnect between digital designers and people with disabilities in the creation of accessibility methods [112]. In our case, PwD are individuals whose communication ability is usually diminished, and we underline that translating medical workers' rephrase into design decisions was a key challenge we faced. Because dementia differs in terms of disease, symptoms and performance [70], medical workers have distinct experience with each PwD. Meanwhile, because individual's emotional threshold and empathic ability also differs, medical workers' response to their PwD and standpoint on the XR-enabled experience also differs. We highlight that, to respect this difference, designing a vague experience that allows space for personal interpretation is necessary.

Additionally, because dementia has variable manifestations, another key challenge we faced was selecting the subset, stage, and symptoms to simulate. We decided to focus on the common sensory changes of earlier to medium-stage AD because of its prevalence among dementia [6] and we emphasise that our XR simulations contribute to the general understanding of AD. Furthermore, because sensory changes are experienced by many other parties with disease, e.g., diabetes and autism, we underline that our work provides a case study of the potential of XR simulations in understanding individuals with sensory processing disorder.

6.2.2 Ethical Concerns of Using XR Simulation to Understand Dementia. There is increasing adoption of simulation technology to understand individuals with disabilities [55]. However, it could be ethically problematic to users [57, 76]. Here, we discuss the ethical concerns based on the findings in our studies.

In our studies, several participants expressed mild fear or anxiety before wearing the devices, this supports previous findings that disability simulation can be mentally stressful for participants [57]. We underscore that *safety of the user* is a primary concern for disability simulation as such simulation is designed to experience disadvantages. Likewise, the potential of physical risk (e.g. dry eye [119], motion sickness and tripping over) might discourages participants [61], which in our case we minimised by having another individual accompany and preparing to terminate the experience at anytime. We suggest the following measures for users' mental and physical safety in experiencing disability simulation: guaranteeing the safety of the experience environment; providing detailed information about the simulation experience beforehand; allowing participants to choose the level of simulation and terminate at anytime.

Another ethical concern is *authenticity of the simulation.* In our case, we referred to dementia stakeholder's lived experience for scenarios, and clinical papers on symptoms and pathology for sensory changes. Because XR can provide highly persuasive sensory information, its users might take the information received as ground truth [101], we insist the scientific rigour of disability simulations should be taken into consideration.

The third point is *the management of the simulation experience.* We proved the empathy effect of the AR experience and appointed it to the clinical dementia setting; nonetheless, considering the effectiveness of XR simulation in manipulating emotion [95], using it outside the designed scenarios could be harmful to users. Therefore, we suggest that the use of disability simulation XR experience should be managed carefully by individuals with thorough understanding of the purpose and application scenarios.

7 LIMITATIONS AND FUTURE WORKS

Our studies have a few limitations that should be considered when interpreting the results. In Phase I and Phase II, we collected data from 5 participants due to the disadvantage of longitudinal study [118], while a larger sample size would provide deeper insights into dementia care and technology preferences. Having participants from other roles (e.g. doctors, occupational therapists, clinical assistants) could also contribute to broadening viewpoints. In Phase III, we recruited 13 female and 3 male. While this projects the gender disparity in the nursing industry in Japan [89], a balanced gender ratio in participant selection could give more insights from the Japanese male nurse group. We also consider the design of the pilot study – all participants experience AR then VR – a limitation. A balanced order between AR and VR with instant interviews after each trial would be more controllable. However, it was designed in the manner of prioritising group discussion and observation of others, which we hypothesised can stimulate critical thinking better than individual experience in nursing education.

To address the limitations, a future direction of our work is to explore more dementia stakeholder's opinions on the AR experience, and its user case of supporting dementia-friendly environmental design, which can provide insights about the potential of AR simulation in multiple facets to support dementia care. In this study, we were able to elicit memories, reflections, and empathy, yet how this experience can support nursing service improvement remains unknown. We expect a long-term study on the effectiveness of our system to support dementia care service. Finally, we seek for other types of symptoms for the future development of our PwD simulation.

8 CONCLUSION

Dementia care is challenging for medical workers because of the lack of knowledge in PwD. We propose a system that uses an AR-based application in an HMD to perform physical tasks to allow medical workers to experience the daily obstacles PwD faces. The results we gathered are indicative of the possibility of using AR simulation in dementia education, and its effectiveness in eliciting reflections and empathy. Our work serves as a first step in using AR simulation to support clinical dementia education. We hope the overall findings from this work can encourage and assist future development of novel technology in supporting clinical education.

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