Information Systems Frontiers
https://doi.org/10.1007/s10796-024-10479-w

Development and Usability Testing of Virtual Reality (VR)-Based Reminiscence Therapy for People with Dementia

Joyce S.Y. Lau[1] · Yuk Ming Tang[2,3] · Grace Gao[1,2] · Kenneth N.K. Fong[1] · Billy C.L. So[1]

Accepted: 24 February 2024

Abstract
The prevalence of dementia is increasing due to a longer life expectancy and an ageing population. Cognitive impairment affects patients' daily lives and places a financial and healthcare burden on them and their families. Reminiscence therapy (RT) is a non-pharmacological approach that has been found to enhance the quality of life for older adults with or without dementia. There is an urgent need for more functional and effective treatments, such as virtual reality (VR), which are becoming increasingly popular. VR in RT is a relatively new field, and this paper proposes a conceptual model for developing proof-of-concept virtual reality-based reminiscence therapy (VR-RT) for people with dementia, based on the 4Is: immersion, interaction, imagination, and impression. This model is intended to offer an alternative therapeutic experience for older adults with dementia. This paper demonstrates VR-RT in accordance with the results from the proposed 4Is model, to depict different periods of the olden days of scenes, such as restoring the historical objects and appearance of the citizens. The proposed VR-RT is then evaluated with the occupational therapists (OTs) through pilot testing. The findings reveal that VR-RT based on the proposed model may elicit a positive attitude and motivation in older adults with dementia. The proposed 4Is model serves to offer essential features for VR development, followed by a survey to identify suitable reminiscence materials and themes tailored to older adults with dementia. A pilot test with OTs revealed that VR-RT has the potential to improve the conditions of people with dementia. The research contributes valuable insights and lays the groundwork for future development of VR-RT for people with dementia.

Keywords Virtual reality · Cognitive training · Reminiscence therapy · Dementia · 4Is

1 Introduction

1.1 Background Information on Dementia

With a longer life expectancy and an increased number of older people in the population, the increased prevalence of dementia is alarming. It is anticipated that the ageing population will rise from 600 million in 2000 to 2 billion by 2050 (Jahanbin et al., 2014). Rather than being a single disease, dementia is an umbrella term referring to a spectrum of symptoms associated with a major neurocognitive disorder (Diagnostic and Statistical Manual of Mental Disorders (5th ed.), 2013) and a decline in cognition (Crowe, 2015), including memory, communication and problem-solving functions (Gaugler et al., 2016). Alzheimer's disease (AD), is the most common cause of dementia (Wilson et al., 2015). Since life expectancy and advances in healthcare are consistently increasing, cognitive impairment is becoming a progressively fundamental problem in today's society (Behrens

✉ Yuk Ming Tang
yukming.tang@polyu.edu.hk

Joyce S.Y. Lau
syjoyce.lau@polyu.edu.hk

Grace Gao
grace-sl.gao@connect.polyu.hk

Kenneth N.K. Fong
kenneth.fong@polyu.edu.hk

Billy C.L. So
billy.so@polyu.edu.hk

[1] Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China

[2] Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong, China

[3] School of Business, Shenzhen Institute of Technology, Shenzhen, China

Published online: 04 March 2024

et al., 2020). Additionally, dementia can affect people of all ages, yet, the prevalence appears to increase in older age groups and the majority of the affected population is aged 65 or above (Gaugler et al., 2016). In short, cognitive impairment is associated with the natural ageing process, and as ageing is a significant risk factor for dementia, accentuated cognitive impairment can serve as a symptom of dementia, a condition with potentially devastating consequences for individuals. For instance, it may place a significant financial burden on patients, their families and caregivers due to the long-term medication, hospitalization, and home-based healthcare and consequently affects their quality of life (QoL) (Kandiah et al., 2019) and aggravate the healthcare burden in society. Therefore, a vast amount of research has investigated a range of imperative interventional tools to address the prevalence of dementia in the population.

1.2 Reminiscence Therapy and Implications of Using Virtual Reality

Reminiscence therapy (RT) is a non-pharmacological therapy that involves 'helping to recall patients' past events, feelings, and thoughts to create and facilitate the feeling of pleasure, enhance the quality of life, and adapt to the current situation. By doing all the above, the patients can maintain the integrity of their characters by reviewing their past (Jahanbin et al., 2014), in order to enhance individuals' quality of life and decrease dementia-related behavioral symptoms (Berg-Weger & Stewart, 2017; Macleod et al., 2021). RT has long been considered a positive experience for older adults, whether they have dementia or not. This is because the active engagement in guided memory use appears to be beneficial for older adults who experience memory problems (Dinius et al., 2023). As a result, RT is often utilized for memory-specific training (Wu et al., 2023). Additionally, it has been investigated that RT is easier to be carried out by a therapist or nurse compared with other cognitive therapies (Li et al., 2017). This can include a wide variety of activities such as group and individual activities, and structured themed groups (Blake, 2013).

Group reminiscence therapy (GRT) is a form of RT that provides patients with the opportunity to interact and share their own life experiences with a group of people (Zhang et al., 2018). Through promoting interaction and sharing experiences among members, patients can learn how to communicate in groups and develop bonding. This can help the patients develop a sense of identity and belonging (Zhou et al., 2012). GRT can also be considered as an alternative method to help alleviate a feeling of loneliness and psychiatric symptoms, including cognitive decline, depression, and anxiety (Elias et al., 2015). This method can be used to treat older adults who have been significantly impacted by the restrictions on human social interaction during the COVID-19 pandemic (Lau et al., 2022). Therefore, there is an urgent need to develop new treatments that can be more practical and effective even considering the pandemic conditions (Yahara et al., 2021).

With the rising demand for remote care due to COVID-19, there has been an increasing interest in Digital Therapeutics (DTx). DTx is a new non-pharmacological approach that uses digital technologies including the Internet of Things (IoT), Artificial Intelligence (AI), and VR (Niki et al., 2021). The reason for the growing interest in DTx is that it can prevent the spread of emerging and re-emerging infections without compromising the quality of healthcare (Yahara et al., 2021). Recently, the approach utilising DTx has been considered for RT (Niki et al., 2021). Healthcare research with the use of VR is currently being conducted in the field of rehabilitation. VR is a general term for technology that works on human sensory organs to build an artificial three-dimensional (3D) environment that looks and feels similar to reality (García-Betances et al., 2015). This has led to the combination of VR and RT to stimulate cognitive function in older adults by projecting realistic images to help them recall memories (Tominari et al., 2021).

Besides, VR technology has progressively increased in its popularity as a promising tool to help facilitate RT. One of the reasons is the utility of VR in creating 3D objects and establishing complex realistic virtual environments. VR provides users with the chance to interact with objects that may be difficult to obtain in the physical world such as cultural heritages and the chance to experience locations that no longer exist anymore such as historical scenes. Another reason is that VR systems can have different levels of immersion and interaction, and further modulate the feeling of presence (Xu & Wang, 2020). This allows users not only to passively view the scenes (Cipresso et al., 2018) but also to walk around in these scenes to gain more experience in RT (Siriaraya & Ang, 2014).

1.3 Virtual Reality (VR) Components

In a VR system, virtual image spaces do not have to be limited by location or time. They can be set based on different requirements. VR can be utilized in various fields, including military, educational, and entertainment equipment development (Tsao et al., 2019). A standard interactive VR system includes three elements, which are "Immersion", "Interaction" and "Imagination" (3Is) (Bamodu & Ye, 2013). Immersion is the experience of being fully engaged and present in a digital world, achieved through the stimulation of the human sensory system. Interaction involves the methods of communicating with the system. In VR, this is typically achieved using three-dimensional environments

to create an effective, responsive, and engaging experience. Imagination pertains to the system designer's creative thinking and execution of a specific goal. These features can present a fully simulated virtual experience to the users (Nadia et al., 2018). Building upon the principles of the 3Is (Immersion, Interaction, and Imagination), this paper introduces an additional "I" referred to as "Impression". In this context, Impression pertains to the process of comprehending users' significant memories to identify the key elements that influence reminiscence. The utilization of the Impression in the development process is explained in Sect. 2.1.

Nevertheless, there are still several deficiencies of the conventional RT. First is the difficulty to reappear the reminiscence scenes in reality to produce the desired intervention outcomes. Yet, most reminiscence treatments are not fully immersive and are usually affected by environmental disturbance. Virtual Reality (VR) offers an immersive approach (Leong et al., 2023) for proliferating conventional treatment in reminiscence. In recent decades, VR technology has been widely adopted in various fields such as digital health (Chan et al., 2023), medical training and teaching (Cheung et al., 2023), rehabilitation (Fong et al., 2022; Toh et al., 2023), etc. and has gradually gained recognition for being a suitable tool for RT (Xu & Wang, 2020). In fact, VR in RT is still relatively new to the field (Clay et al., 2020), and researchers have limited experience and resources in designing appropriate content and identifying the research scope. Additionally, there is no systematic or strategic approach for VR content development to provide effective training in various fields.

As such, this paper has three major objectives:

Objective 1: To propose a model for generating virtual reality-based reminiscence therapy (VR-RT) content for serving dementia.

Objective 2: To support the VR-RT content development.

Objective 3: To validate the effectiveness of using the proof-of-concept VR-RT.

We present the following two key research contributions as follows:

1. A novel research model is proposed for VR content development that comprises four key elements: immersion, interaction, imagination, and impression, named 4Is.
2. A virtual reality-based reminiscence therapy (VR-RT) that is based on 4Is to produce content creation to offer a better therapeutic experience to the older adults with dementia.

The first research contribution serves as a strategic developmental means to identify appropriate VR content elements to achieve Objective 1. Building upon this research model, the second research contribution is the introduction of a VR-RT that utilizes the 4Is framework to create content that enhances the therapeutic experience for older adults with dementia. The objective is to propose and develop a proof-of-concept VR-RT (Objective 2). To validate the effectiveness of the content creation in the VR-RT, surveys and data analysis will be conducted (Objective 3). This step involves gathering feedback and analysing data to ensure that the VR-RT content aligns with the intended therapeutic goals. Additionally, interviews will be conducted with occupational therapists (OTs) to further validate the proposed VR-RT. The insights and expertise of OTs will provide valuable input regarding the therapeutic aspects and practical implementation of the VR-RT approach.

2 Methods

The proposed conceptual VR content development model based on 4Is is to provide and improve the digital experience for people with dementia. The execution of the study involves the following tasks:

1. Strategic Developmental Means

This step focuses on the strategic development of the VR content development model based on the 4Is. It involves a comprehensive analysis of existing VR technologies and therapeutic approaches, identifying elements for improvement and tailoring the model to meet the specific needs of individuals with dementia.

2. Proof-of-concept VR-RT

It is created based on the 4Is model that involves designing and developing a prototype VR-RT experience that incorporates immersive environments, interactive elements, imaginative scenarios, and impressions. It aims to demonstrate the feasibility and potential effectiveness of the VR-RT approach.

3. Surveys and data Analysis

Surveys are conducted to gather data related to the core elements that could help the target group elicit their memories based on cultural relevance. The data is collected from a sample of participants aged 40 or above, local residents, and healthy subjects, and then analysed to identify the themes that can guide the content creation process.

4. Interviews for Validation

Instead of testing individuals with dementia directly, a group of five local OTs is recruited for user testing. They provide insights and feedback based on their professional expertise. The feedback obtained from the interviews helps refine and modify the VR-RT design to ensure its appropriateness and effectiveness. The intention is to maximize the efficiency of the chosen approach while minimizing unnecessary expenses or wastage.

2.1 Conceptual Model Development (4Is)

A conceptual model (4Is) is devised in order to include the significant features of VR to serve those with dementia. The model is modified from the "3Is" for a standard VR system (Tsao et al., 2019) to "4Is". "Impression", the fourth "I", is added to the 3Is model to produce a novel model, as demonstrated in Fig. 1.

A standard VR system(3Is) is deployed in the proposed VR-RT. Immersion enables the users to realise themselves being a part of the virtual world and their actions within the virtual environment through sensory and perceptual elements, such as auditory information (Bermúdez i Badia et al., 2016). Interaction provides a range of manipulations on virtual objects including touching, grasping, or throwing, in addition to haptic feedback by using the VR handles (Chen et al., 2021), so as to improve the efficiency of the interactivity and VR experience (Wang et al., 2021). Imagination enables VR to simulate a real-life scene and fabricate imagination in the users' minds (Chen et al., 2021) through sensory cues such as visual cues (Cowan & Ketron, 2019).

In addition to the 3Is, the proposed impression, the fourth "I", refers to the process of understanding the users' significant memories to identify the influencing components for reminiscence. This has been shown that the memories from childhood to young adulthood are better preserved than recent memories (Xu & Wang, 2020). Since the themes and materials that have been used in RT are different among countries due to cultural differences, they should reflect the history, personal background, experiences, and shared and collective memories of the users during their childhood and young adulthood (Yen & Lin, 2018). Cultural relevance is key in aiding the outcomes of reminiscence (Cappeliez, 2017). Culture can be characterised by personal memory, which refers to an individual's recollection of past events or experiences stored in their mind, whilst collective memory represents the shared memory and experiences of a group, which can include historical events and cultural traditions. These aspects will be the focus of VR-RT content creation in the subsequent section. Providing reminiscence materials and themes that are closely related to the users' personal experiences and background, helps them to recall long-term memory (Lau & Agius, 2021), which is the part of memory that holds information for an extended period. In this case, the visualisation and results of RT may vary depending on the type of culture which is employed within the virtual environment. Therefore, a survey is conducted for design consideration to further understand users' significant memories, enabling the users to experience a suitable VR reminiscence therapy (Yen & Lin, 2018). This approach allows the developers and designers to curate a VR experience that resonates with the users' cultural identities and experiences, enhancing their reminiscence experience and potentially eliciting stronger emotional connections. The data extraction from the surveys and data analysis (Objective 2.2) will then be the core visual content elements to generate different periods of Hong Kong.

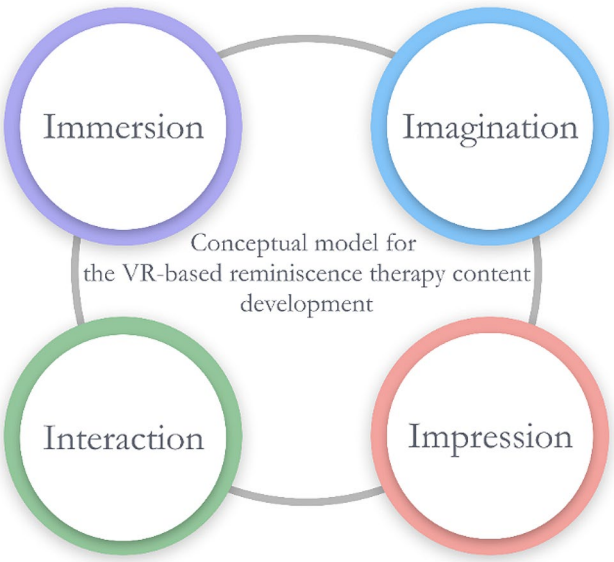

Fig. 1 A conceptual model (4Is) for constructing VR-RT

2.2 VR Content Development

Recently, VR and AR content have been used for many healthcare and biomedical applications (Taghian et al., 2023a, b). In order to design the VR content and elements to be included in the RT, the local context, i.e. Hong Kong cultures, involved in the VR RT is investigated through a survey. The survey is used not only to investigate the collective memory of local people, and historical culture, but as well as other elements that are essential for VR-RT.

2.2.1 Data Collection

In the first phase, an online survey was administered to collect feedback from participants of diverse age groups (40–49; 50–59; 60–69; 70–79; and 80+) to collect potential items for constructing the VR scene.

Table 1 Participants' demographic characteristics

Variables	Classification	n	%
Sex	Male	53	52.5
	Female	48	47.5
Age	40–49 years old	16	15.8
	50–59 years old	22	21.8
	60–69 years old	27	26.7
	70–79 years old	28	27.7
	80 + years old	8	7.9
Place of residence	Kowloon	36	35.6
	Hong Kong Island	25	24.8
	New Territories	40	39.6
Educational status	Primary Education	9	8.9
	Secondary Education	52	51.5
	Higher Diploma/Associate Degree	5	5.0
	Bachelor's Degree	27	26.7
	Postgraduate	8	7.9
Cognitive status (known diagnosis regarding memory impairments)	Yes	0	0
	No	101	100

A systematic review explains and summarises that different types of autobiographical memories (AMs) are located in different age ranges, where the important memories are encoded from 10 to 30 years old; word cueing is dated from 5 to 30 years old; the life scripts are created between 6 and 39 years old (Munawar et al., 2018). This phenomenon can be discerned in those over the age of 40. The number of important memories which are encoded decreases from late adolescence to the age of 40 (Koppel & Rubin, 2016; Munawar et al., 2018). Furthermore, the AMs in response to life script is culturally relevant (Koppel & Rubin, 2016). Thus, the participation criteria in this survey are set as follows.

- Aged 40 or above.
- A local resident to provide feedback based on the local context.
- A healthy participant (i.e. without a known history of dementia or mild cognitive impairment according to their medical records).

2.2.2 Survey

The survey is divided into two sections. The first section, as summarised in Table 1, collects the demographic information of the participants including sex, age, place of residence, education level, and cognitive status. Figure 2 illustrates the number of males and females for different age groups. The second section contains the core questions as listed in Table 2. There are 23 questions in the core section, covering participants' perceptions of Hong Kong people's collective memories, historical events, landmarks and cultures. The questions focus on the period between the 1940 – 2000 s in the local context, which covers the childhood and young adulthood of the different age groups. Besides, participants' preferences in the local cultures and lifestyles are also investigated. Questions 1 to 15 are used to support the design of the VR content for understanding the impression and imagination of the participants towards the reminiscence content, while questions 16 to 23 are designed to provide favourable items to enhance users' enjoyment through the immersion of the reminiscence scenes. The interaction elements are included based on the final VR content so as to provide interaction and feedback to the target users.

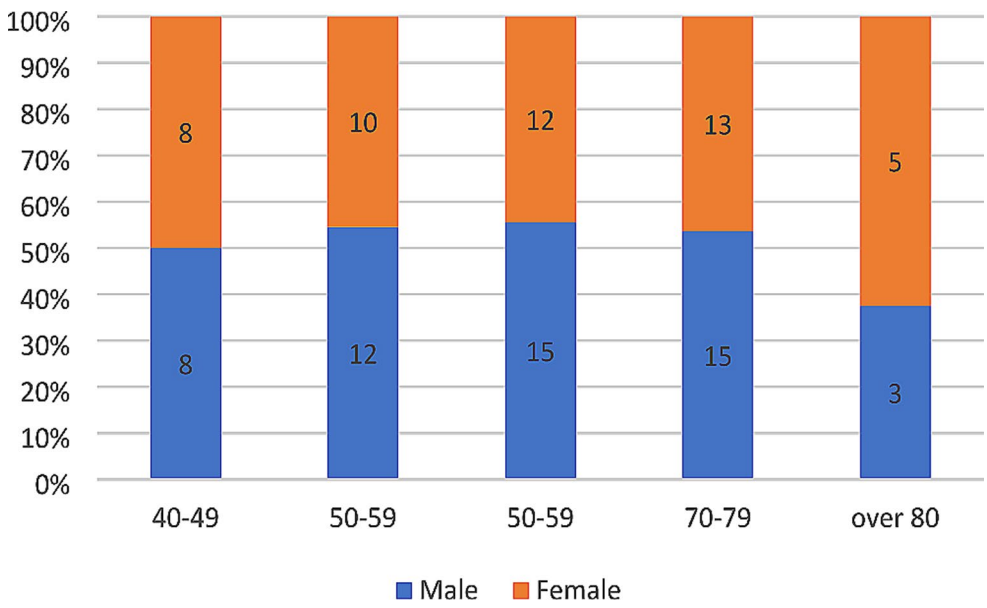

Fig. 2 Number of males and females for different age groups

Table 2 Items in the core section of the survey

Items	No.	Questions	References
Impression and Imagination	Q1	Martial arts can best represent Hong Kong's cultures	(Chao et al., 2018)
	Q2	The Clock Tower is a collective memory of Hong Kong people	(Chan, 2019)
	Q3	The Avenue of Stars can best represent Hong Kong culture	(Lim, 2006)
	Q4	The Tsim Sha Tsui Bus Terminus is a collective memory of Hong Kong people	(Chan & Lau, 2009)
	Q5	Bruce Lee is a Hong Kong icon	(Bowman, 2019)
	Q6	Hong Kong movie is the reason for the popularity of Hong Kong	(Yeh, 2018)
	Q7	Cantonese pop is the reason for the popularity of Hong Kong	(Fung & Chik, 2020)
	Q8	Street newsstand is a collective memory of Hong Kong people	(Chow, 2013)
	Q9	Rickshaw is a collective memory of Hong Kong people	(Fung, 2005)
	Q10	The Kowloon–Canton Railway (KCR) Terminus in Tsim Sha Tsui is a collective memory of Hong Kong people	(Chan, 2015)
	Q11	The Mobile Softee is part of a collective memory of Hong Kong people	(Ingham & Fung, 2015)
	Q12	The Star Ferry is a collective memory of Hong Kong people	(Xu et al., 2022)
	Q13	The Peak Tram is a collective memory of Hong Kong people	(Leung et al., 2011)
	Q14	The Peak Tower can best represent Hong Kong	(Huang & Wang, 2018)
	Q15	The Tramway is the collective memory of Hong Kong people	(Choi & Cui, 2006)
Immersion	Q16	I enjoy listening to Cantonese Pop	(Fung & Chik, 2020)
	Q17	I enjoy watching Hong Kong Kung Fu movies	(Yen & Lin, 2018)
	Q18	I enjoy watching Cantonese opera	(Yung, 2019)
	Q19	I enjoy riding the Star Ferry	(Xu et al., 2022)
	Q20	I enjoy taking the Tramway	(Choi & Cui, 2006)
	Q21	I enjoy purchasing ice-cream at the Mobile Softee	(Ingham & Fung, 2015)
	Q22	I enjoy viewing the Clock Tower	(Chan, 2019)
	Q23	I enjoy going to the Peak Tower	(Huang & Wang, 2018)

2.2.3 Data Analysis

The survey data were processed using version 26.0 of the IBM SPSS Statistics (SPSS, Inc., Chicago, IL, USA). Descriptive statistics analysis was conducted in SPSS, which involves the measures of frequency, central tendency and dispersion. Reliability and validity tests were carried out in SPSS to determine whether the items in the core questions are eligible for analysis.

Participants($N = 101$) in the survey are required to complete the core questions using a seven-point Likert scale, which is a scale that assesses the attitudes, opinions or perceptions concerning different social phenomena (Suyatmi & Wibowo, 2016). Their responses were analysed by calculating the mean and were interpreted as follows: Strongly Disagree in the point range of 1.00–1.85, Disagree 1.86–2.71, Slightly Disagree 2.72–3.57, Neutral 3.58–4.43, Slightly Agree 4.44–5.29, Agree 5.30–6.15, and Strongly Agree 6.16–7.00 (Pimentel, 2019).

2.2.4 Content Building

The VR content is developed using several key software packages. First, the background is generated through the Blender GIS addon, while the 3D models are built on Blender, and part of the models are imported from 3D modelling libraries. MakeHuman was used to create the 3D human characters. To establish the VR content and interactions, Unity 3D version 2019.4.16 was used as the platform for VR development (Wang et al., 2021). The VR interaction was created using the SteamVR Unity Plugin. The whole system adopted the HTC VIVE Pro for visualizing and examining the developed VR content before proceeding to the evaluation.

2.3 Validation

After the content of VR-RT is developed, a pilot test is carried out to validate the content design. The evaluation aims to further refine the overall developed VR content based on the interview results before conducting the clinical trials for people with dementia.

2.3.1 Semi-Structured Interviews with OTs

In this phase, five registered and experienced local occupational therapists (OTs) (one male; four females) are chosen for user testing. A previous study conducted by Lau et al. (2021) employed a comparable selection process to include OTs in their research. The study mentioned that it adopted a user testing strategy, i.e. five OTs used in this study, recommended by Nielsen Norman Group (Alroobaea & Mayhew,

Table 3 Interview questions

No.	Interview Questions
1	For the target group, based on your experience, how would you describe their adaptability to the VR-based reminiscence therapy content?
2	For the target group, based on your experience, how would you describe their emotional response to the VR-based reminiscence therapy content?
3	For the target group, based on your experience, do you think this VR-based reminiscence therapy content provides a sense of familiarity for the age group?
4	What suggestion(s) would you give to improve this VR-based reminiscence therapy content in the future?
5	What do you think are the differences between using VR-based reminiscence therapy and conventional reminiscence?

Fig. 3 Scenario of the VR setup and the validation experiment

2014) is ensure a cost-effective result for subsequent iterative design modifications. Such strategies may include techniques like small-scale user testing or utilizing existing resources to gather user feedback, allowing researchers to obtain valuable insights without incurring excessive costs associated with a large-scale approach. This alignment in the selection process and user testing strategy highlights the use of established methodologies and best practices in the field, contributing to the rigor and reliability of the research findings. Each of the OTs is required to fill in a pre-interview questionnaire to capture their background information and is interviewed regarding their feedback on VR-RT. The interview aims to seek the OTs' insights and feedback for design modifications to meet the end users' (people with dementia) needs. Five semi-structured interview questions were asked to gain empirical evidence for content validation as listed in Table 3. Throughout the interview, recordings were performed for each session to record the OTs' responses.

2.3.2 Data Collection Procedure and VR Setup

Ethical Approval was obtained from Hong Kong Polytechnic University's Departmental Research Committee (Reference Number: HSEARS20220325005). Written consents were also obtained from all the participants before commencing the pilot test. Related documents including an information sheet, consent form and pre-interview questionnaire, as shown in Table 3, were distributed to the participants throughout the course of the pilot test. The procedure of the overall experiment session was explained step by step to the OTs. Prior to conducting the pilot test, OTs were handed both the information sheet and the consent form, in which were notified that their participation in the project was voluntary. They have a right to withdraw from the study without negative consequences, and all information related to them remains confidential. Considering the VR setup, as demonstrated in Fig. 3, all required devices were at their disposal on the days of the pilot test, as well as to test if the VR application, software, and recording devices were well functioning. A procedure of the pilot test is introduced to all OTs, detailing the possibility of physical harm during the VR experience, such as headaches, eye strain, dizziness, nausea or any other discomfort. In the beginning, the OT assisted in using the HTC VIVE Pro head-mounted display and was asked to enter three VR scenarios. The OT was invited to test and freely narrate their thoughts while experiencing VR-RT. The duration of the pilot test for each OT is around 30 to 45 min. The researcher assisted the OT verbally when necessary while they were navigating within the VR environment. Photos and video recordings are captured for documentation and following evaluation.

2.3.3 Data Analysis

The qualitative data derived from the semi-structured interviews conducted with the OTs($N=5$) was subjected to a direct quoting and narrative elaboration by systematically categorizing the information into the predetermined "I"s from the conceptual model, namely 4Is (Immersion, Interaction, Imagination and Impression). Semi-structured interviews were conducted with the OTs to gather valuable insights and perspectives regarding the proposed VR-RT intervention. The use of a semi-structured format allowed for flexibility in exploring relevant topics while ensuring consistency across interviews. Given that the primary focus of this research study is to evaluate the usability of the application in clinical settings, the results from the OTs can offer valuable meaningful information into the intricate implications of the clinical environment. These insights can inform the future development and optimization of the application

to better meet the needs and demands of healthcare professionals and patients.

3 Results

3.1 Survey

In total, 101 participants ($N = 101$) completed the survey. All participants voluntarily took part in the survey and fulfilled the participation criteria.

The validity of the 23 survey items in the core section was then measured as shown in Table 4. It was found that Pearson = α correlation coefficients of 19 items were significant at the 0.05 level. This implies that 19 items were valid, whilst the remaining four items were invalid including Q7, Q13, Q18 and Q20. Thus, those four items were opted out for subsequent data analysis, and summarised in Tables 4 and 5.

Regarding the reliability of the remaining 19 survey items, Cronbach's alpha was calculated to determine the internal consistency based on the correlations between different items that produce similar scores. The resulting value of Cronbach's Alpha is 0.653. Based on the criteria of Cronbach's alpha values, it indicates that the items were acceptable in terms of reliability (Mohd Arof et al., 2018).

Table 4 Reliability and descriptive analysis of each question item

	Items	Pearson Correlations	Mean (SD)
Impression and Imagination	Q1	0.306**	5.32 (1.039)
	Q2	0.284**	6.02 (0.990)
	Q3	0.483**	4.13 (1.246)
	Q4	0.314**	5.81 (0.821)
	Q5	0.435**	5.75 (1.053)
	Q6	0.449**	5.74 (0.956)
	Q7	0.194	Invalid
	Q8	0.208*	4.13 (1.369)
	Q9	0.291**	3.74 (1.398)
	Q10	0.261**	5.47 (1.411)
	Q11	0.399**	4.57 (1.219)
	Q12	0.267**	5.65 (0.854)
	Q13	0.112	Invalid
	Q14	0.603**	3.44 (0.984)
	Q15	0.346**	4.78 (0.867)
Immersion	Q16	0.439**	4.14 (1.631)
	Q17	0.223*	5.03 (1.417)
	Q18	0.021	Invalid
	Q19	0.230*	5.54 (0.995)
	Q20	0.024	Invalid
	Q21	0.477**	4.12 (1.478)
	Q22	0.335**	5.76 (0.961)
	Q23	0.626**	3.31 (1.231)

** correlation is significant at the 0.01 level; * correlation is significant at the 0.05 level

To determine the essential elements, features, and locations of the VR reminiscence scenes, a descriptive analysis is performed to compare the scores between different age ranges as shown in Table 5. Results have revealed that Tsim Sha Tsui (an ionic tourist location in Hong Kong) can include most of the VR elements in the RT. Further elaboration of the results is explained in the following sections.

3.2 VR Content

3.2.1 Impression and Imagination

In the proposed 4Is conceptual model for VR content development, computer graphics and realism is one of the prerequisites for providing immersive and realistic impressions and imagination to the participants. As such, the visual design is essential in the development of VR scenes, while the aforementioned findings have revealed that the period between childhood and young adulthood that is related to personal life experiences or collective memories, is better preserved than recent memories. Based on these reasons, a survey was used mainly to investigate the collective memories so as to provide an effective RT context to most of the local older adults. The survey results reveal that Hong Kong's Tsim Sha Tsui harbour is an iconic location to reappear in the collective memories of overall participants, enabling them to reminisce.

A descriptive analysis of 3Is of VR content based on different age groups provides the fundamentals of developing the content of old Hong Kong and is summarised in Table 6. Whilst three scenes set in different periods including the 1940s, between the late 1960s and early 1970s, and the 2000s were selected for the VR content, which is illustrated in Figs. 4 and 5, and 6 respectively.

In Scene I, the rickshaw and the Kowloon-Canton Railway (KCR) Terminus in Tsim Sha Tsui are created. These are identified as resonant features for the age group of 80 or above when compared to the younger group in the survey results. Similarly, the age group groups: 50–59 years old, 60–69 years old, and 70–79 years old, have been revealed in the data results that they are likely to share similar responses towards perception and preferences. In this case, the 3D virtual objects in Scene II are the nostalgic posters that are associated with martial arts and Hong Kong old movies, and the Kowloon-Canton Railway (KCR) Terminus in Tsim Sha Tsui. The survey results also showed that the posters and magazines related to Cantonese pop, and the Mobile Softee truck are familiar to the age group of 40–49, and thus these 3D models were implemented in Scene III. In short, visualisation as one of the cues can fulfil the *"imagination"* of the 4Is conceptual model that the content in VR-RT uses to fabricate imaginative scenes or objects in the users' minds.

Table 5 Descriptive analysis of impression, imagination, and immersion of VR content based on different age groups

	Age Group	40–49	50–59	60–69	70–79	80+
	Items	Mean (SD)				
Impression and Imagination	Q1	4.56 (1.590)	5.36 (0.848)	5.59 (0.747)	5.75 (0.645)	4.25 (0.707)
	Q2	5.38 (1.360)	5.68 (0.780)	5.93 (0.874)	6.54 (0.693)	6.75 (0.707)
	Q3	5.13 (1.784)	5.09 (0.750)	4.15 (0.602)	3.07 (0.539)	3.13 (0.641)
	Q4	5.44 (1.031)	5.68 (0.780)	5.56 (0.641)	6.25 (0.645)	6.25 (0.886)
	Q5	5.06 (1.526)	5.86 (0.774)	6.04 (0.649)	6.21 (0.686)	4.25 (0.886)
	Q6	5.19 (1.047)	5.68 (0.780)	6.07 (0.675)	6.21 (0.686)	4.25 (0.886)
	Q7	Invalid				
	Q8	3.88 (1.746)	3.27 (1.162)	3.74 (0.984)	4.82 (0.863)	5.88 (1.126)
	Q9	3.62 (1.746)	2.82 (1.006)	3.15 (0.864)	4.50 (0.962)	5.88 (0.641)
	Q10	3.81 (1.377)	5.41 (1.221)	5.44 (1.340)	6.11 (0.916)	6.75 (0.463)
	Q11	5.88 (0.957)	4.73 (0.985)	5.00 (0.679)	3.71 (0.897)	3.13 (1.246)
	Q12	6.00 (0.894)	5.50 (0.913)	5.52 (0.975)	5.64 (0.678)	5.88 (0.641)
	Q13	Invalid				
	Q14	3.94 (1.340)	4.09 (0.684)	3.26 (0.903)	3.00 (0.720)	2.75 (0.463)
	Q15	4.69 (1.352)	5.00 (0.816)	5.00 (0.679)	4.61 (0.685)	4.25 (0.707)
Immersion	Q16	5.81 (0.911)	4.95 (1.618)	4.33 (1.000)	3.00 (1.054)	1.88 (0.835)
	Q17	4.38 (1.544)	5.32 (1.129)	5.56 (1.050)	5.29 (1.301)	2.88 (1.126)
	Q18	Invalid				
	Q19	5.56 (1.209)	5.64 (0.790)	5.44 (1.121)	5.57 (0.997)	5.50 (0.756)
	Q20	Invalid				
	Q21	5.88 (1.088)	5.09 (1.019)	4.04 (0.808)	2.86 (0.932)	2.63 (0.916)
	Q22	5.75 (1.125)	5.41 (0.959)	5.63 (0.884)	6.04 (0.922)	6.25 (0.707)
	Q23	4.06 (1.652)	3.68 (0.780)	3.56 (1.121)	2.64 (0.911)	2.25 (1.035)

Table 6 Corresponding age groups of each scene

Age Groups	Scene	Time Periods	Visual Contents
80 years old or older	I	The 1940s	the rickshaw and the Kowloon–Canton Railway (KCR) Terminus
70–79 years old 60–69 years old 50–59 years old	II	Between the late 1960s and early 1970s	posters that are associated with martial arts and Hong Kong movies, and the Kowloon–Canton Railway (KCR) Terminus
40–49 years old	III	The 2000s	posters and magazines related to Cantonese pop, and the Mobile Softee truck

3.2.2 Immersion

Audio is a sensory feature to enhances a sense of being presence, creating an immersion in VR-RT. This feature may arouse users' a lot of interest emotionally by using a realistic soundscape with various sound sources. In Scene I, as set in the 1940s, the chimes of the clock tower were implemented to provide a more convincing representation of the environment during that time. Apart from that, ambient sounds including white noise, wave sounds, and traffic noise were added to make the environment more realistic for the participants. In Scene II, the audio clips from the 1960s movie's title sequence and ambient sounds were inserted in the background of the scene for the 50–59 years old, 60–69 years old and 70–79 years old participants. Yet, Scene III uses the Mobile Softee's jingle and the ambient sounds for the age group of 40–49 to offer a resonated scene. With regard to "*immersion*" in 4Is, auditory stimuli are to advance the immersive VR experience, which is demonstrated in the proposed VR-RT.

3.2.3 Interaction

Interaction is an action taken by the user and the message or feedback produced from the machine. Haptic feedback is one of the examples of increasing participants' interactivity during digital experiences. A pair of hand controllers are used to enable the user to receive messages and manipulate the 3D virtual objects. For example, Scene I provides an action to the age group of 80 or above to take a receipt from a rickshaw worker using the controller as a task; Scene II offers the 50–59 years old, 60–69 years old and 70–79 years old participants to grab a Hong Kong movie poster from the promotor; and Scene III allows the age group of 40–49 to interact with the main character in the scene by taking a Cantonese pop singer poster. To demonstrate the *"interaction"* of 4Is, the hand controllers are the hardware to enable the user to manipulate the 3D models and experience "touch", namely haptic feedback.

Fig. 4 Scene I: the 1940s in Hong Kong

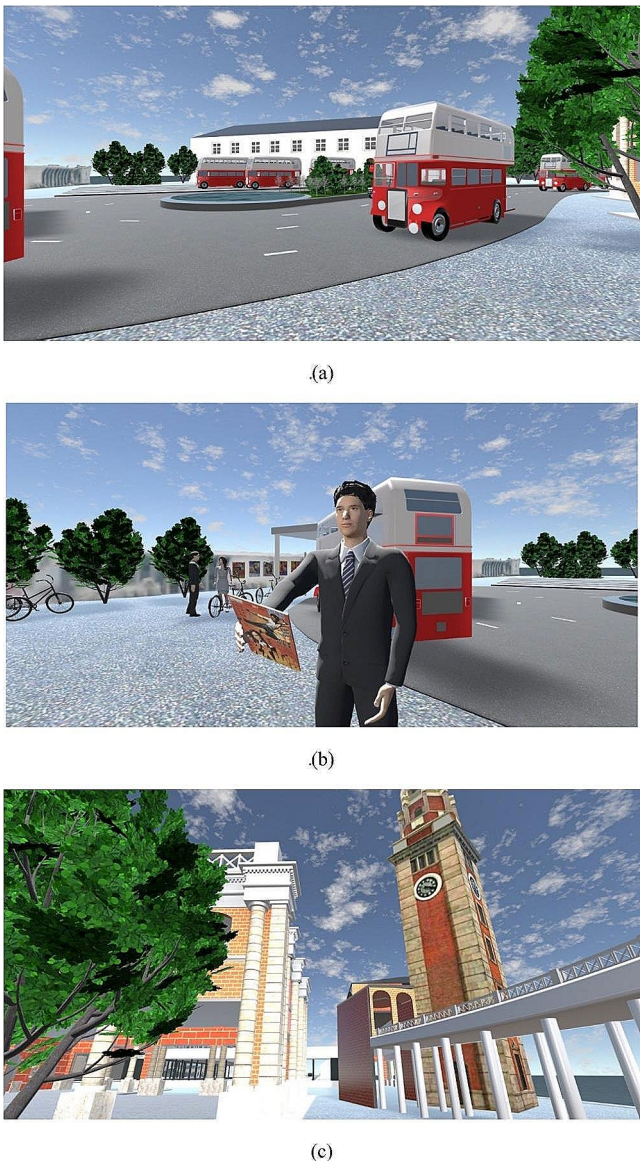

Fig. 5 Scene II: between the late 1960s and early 1970s of Hong Kong

3.3 Evaluation of VR-RT Based on 4Is

To evaluate and improve the content design of VR-RT based on the proposed 4Is model, a pilot test was carried out to collect feedback from the OTs. The OTs were referred to as P1-P5 for anonymity purposes. All the recordings and photos were treated as strictly confidential. The evaluation is mainly to collect qualitative feedback during the participation of the OT in the immersive VR environment. It is noteworthy that it is a preliminary stage in gaining insights from the OTs for further improvements in VR-RT where the content will be undergoing the iteration process. An exhaustive evaluation is not carried out in this paper, but general direction and comments are given. The results are organised by gathering the similarity of interview responses based on the predefined concepts, i.e. Immersion, Interaction, Imagination, and Impression, and then elaborated as follows.

3.3.1 Immersion

VR-RT allows the OTs to view the architectures and nostalgic objects from a spatial perspective and experience the depth and volume of the virtual environment via the stereoscopic display at full scale. The OTs expressed that "*VR can provide different aspects of simulation at the same time*" (P5), including the simulated 3D virtual objects from the past and positional sound effects. Given the realism of the 3D features and real-life body movements (P2 & P4), they

(a)

(b)

(c)

Fig. 6 Scene III: in the 2000s of Hong Kong

acknowledged that "*unlike the traditional ones, this is like you are really in this scene"* (P5). Furthermore, the current developed VR-RT is designed for standing position, allowing the immersion to be at a standing height. The OTs are concerned that some patients may have a high risk of falling due to the fact that the immersive experience may cause unawareness of the physical world. Sitting position may be more encouraged, so as to minimize patients' risk of getting injuries. Furthermore, the OTs pointed out that *"sometimes if you wear it for a long time that might be too heavy for them to turn around and move around"* (P1), which may distress older adults. The duration of VR-RT should not be long for the patients. Therefore, this is noted that further protection should be set up around the testing area or have physical support when using the VR devices, as well as keep the training within 10 to 15 min.

3.3.2 Interaction

The OTs overall have positive comments about the core items used in VR-RT. They have pointed out that the novelty of VR content, which reappears in the olden days of Hong Kong may excite people with dementia (P1-P2). One of the OTs shared that "*conventional reminiscence training with the use of the video tapings and TV program channels are common, but it is not something you can interact with. Now, they can try to interact with the person inside and the views are just like they are in the environment and if the, I mean this one can be more advanced and it is more like the real-life one, then I think they will be quite happy. Yeah, they are really going back to the past."* (P4). Thus, according to the comments from OTs, showed that the use of a simulated environment and the ability to interact with the content in the VR-RT can provide the patients with "*a greater enjoyment"* (P1) than other conventional RT.

The ease of use and controllability of the VR devices can enable the patients to easily navigate VR-RT within their learning capability (P1, P2, and P5). However, its difficulty may vary from person to person depending on their cognitive ability. To address this issue, detailed guidance is needed to support them in understanding the procedure and how to operate the controllers. VR-RT offers a small number of interactions for the patients to minimize the complexity of the physical actions so that the patient can easily adapt to them. Also, teleportation was not applied as it was concerned that patients may feel discomfort and experience side effects such as nausea and disorientation. Furthermore, the patients might be frustrated if they find out some of the objects are static. The OTs also mentioned that without the opportunity to explore the VR content by moving around, the patients might have difficulties in realising themselves, *"they might be confused about when you first place them in such a VR environment and they could not recognize where they are standing, where they, um, where's the place so they may get confused"* (P1). In addition, the OTs noted that having the option to move around can motivate the patients to engage more in the VR, *"explore the hidden parts of this environment and try to make more interaction"* (P3).

3.3.3 Imagination

The OTs drew attention to several considerations around the time of day used in VR, which is highly related to *imagination.* The alignment with reality and the personal background of the patient are important factors to consider when determining the time setting of the

environment to elicit their *imagination*. It was mentioned that the time of day in the VR should be in sync with the real world so that it would not affect the daily routine of the patients. Moreover, since the patients may have different lifestyle backgrounds such as their careers, which could influence what time is more familiar to them. The patients may even have some medical conditions such as sundowning that could impact the decision of the time setting of the environment. Thus, a deep understanding of the patient's background is required when determining the time of day used in the VR.

3.3.4 Impression

Besides, the OTs commented that they appreciated the familiarity that the VR content can provide to the patient, especially the details in *"The Outlook of the human"* (P1), which was able to reflect the time period set in the scenes. One of the OTs emphasized that *"the dressing of the people might provide the most stimulating experience for the older adults because dressing or clothes are the objects, they wear every day when they are young in the past"* (P3). However, the OTs recommended that adding more virtual objects and improving the realism enable the patients to realise themselves in the particular period of Hong Kong much more. The OTs also noted that the cultural relevance within the VR-based reminiscence therapy content is a significant feature to enable the patients to be familiar with the scene and aid in stimulating their long-term memory.

4 Discussion

Based on research findings, the proposed proof-of-concept VR-RT has overall positive feedback the VR content produced a sense of familiarity. This implies that the proposed 4Is, particularly involving *impression* as one of the features of VR-RT may be a useful instrument to guide the designer or developer to construct a cultural relevance and tailor-made VR content for people with dementia. However, there are several limitations and improvements that can be conducted in the future.

4.1 Participation and Sample Size

The survey was carried out regionally, and the proposed VR-RT contains mutually exclusive contents only based on Hong Kong cultures. This indicates that the research findings cannot be a basis for generalization. Furthermore, the interviews with five registered OTs in evaluating the VR contents cannot represent all the OTs' points of view. The data results may vary due to their different experiences and work environments. Testing with people with dementia can acquire more insights by gaining the actual usability testing results. Therefore, testing with the patients in future research can help provide a more in-depth understanding of their needs which can help make the VR content for reminiscence therapy more tailored to them. In prospective investigations, the examination of the effects of VR-RT on individuals with dementia may incorporate pre- and post-test analysis. Initially, a comprehensive pre-test assessment is conducted to establish baseline measures of cognitive and physical functions. This assessment may encompass a variety of standardized measures, including the widely recognized Mini-Mental State Examination (MMSE) (Arevalo-Rodriguez et al., 2015), among others. Subsequently, participants engage in a designated period of VR-RT intervention, after which a post-test assessment is administered to gauge the extent of improvements in the targeted outcomes. This systematic approach of pre-test and post-test analysis allows for the evaluation of the impact and potential benefits of VR-RT on individuals with dementia, thereby informing future research and therapeutic advancements in this domain.

4.2 Deeper Level of Assessment of the Difference in Perceptions and Preferences in Terms of Other Variables

This research has investigated the reliability and validity of the survey items, and other data analytics such as the age differences in perceptions and preferences. Further studies should also be conducted to investigate the difference in perceptions and preferences in terms of other variables such as gender, educational levels and place of residence as the target group's perceptions and preferences may vary based on the different demographic information. Thus, by obtaining deeper insights into the target group, the content of VR-RT can be revised so that it can improve its quality.

4.3 Clinical Trials on People with Dementia

Future research should utilize the refined version of VR-RT on people with dementia. The proof-of-concept of VR-RT was only tested on OTs on behalf of the actual patients in this research. A clinical trial design is one of the future research objectives to investigate how people with dementia interact with the content and explore how the VR content can be further modified to create a pleasing experience with a specific therapeutic effect for them.

Despite the rise of utilizing VR for RT, researchers have not yet understood the full scope of the parameters of the VR technologies. Their studies on VR-based RT suggest that they have limitations in providing universal materials for all users. In the existing studies on VR-based RT, researchers utilised pre-determined VR content corresponding to the childhoods and young adulthood of their participants. However, while there were significant age differences between some of the patients, researchers still chose to use the same content for all patients. By using generic themes and scenes for all ages, some of the VR images might not have been familiar to some patients. This may not be effective in helping them recall personal memories, thus it lacks resonance.

5 Conclusions

To conclude, the purpose of the proposed 4Is is first to offer the essential features to the VR development stage. Then, the survey involved quantitative questions is to achieve a better understanding of participants' significant memories. After the responses had been received, the data analysis was conducted in order to identify suitable reminiscence materials and themes for each group so that the VR content could be developed and tailored to each group.

In this research, 4Is were devised from the literature to aid the development of VR-RT so that the VR content can be more personally suited to the target groups. The conceptual model includes four key features such as *"Immersion"*, *"Interaction"*, *"Imagination"* and *"Impression"*. A pilot test on a proof-of-concept VR-RT with the OTs and subsequent non-exhaustive evaluation may reflect that VR-RT has the potential to be applied in newer treatments for people with dementia to improve the patient's conditions.

The OTs believed that the patients would have a positive attitude toward the application of VR technology and would be excited to be involved. This research has contributed valuable insights and has laid the groundwork for future works in further the development of VR-RT for people with dementia.

Acknowledgements Not applicable.

Authors' Contributions All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by Joyce SY Lau, Yuk Ming Tang and Grace Gao. The first draft of the manuscript was written by Grace Gao. Joyce SY Lau and Yuk Ming Tang revised the manuscript. Kenneth NK Fong and Billy CL So formulated the research goals and supervision.

Funding No funds, grants, or other support was received.

Open access funding provided by The Hong Kong Polytechnic University

Data Availability Access to relevant research data is available via the authors.

Declarations

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable.

Competing Interests The author declares that they have no relevant financial or non-financial interests to disclose.

References

Alroobaea, R., & Mayhew, P. J. (27–29 Aug. 2014). How many participants are really enough for usability studies? 2014 Science and Information Conference.

Arevalo-Rodriguez, I., Smailagic, N., i Figuls, M. R., Ciapponi, A., Sanchez-Perez, E., Giannakou, A., & Cullum, S. (2015). Mini-Mental State Examination (MMSE) for the detection of Alzheimer's disease and other dementias in people with mild cognitive impairment (MCI). *Cochrane Database of Systematic Reviews*, (3).

Bamodu, O., & Ye, X. (2013). Virtual reality and virtual reality System Components. *Advanced Materials Research*, *765-767*, https://doi.org/10.2991/icsem.2013.192.

Behrens, A., Graessel, E., Pendergrass, A., & Donath, C. (2020). Vitamin B—Can it prevent cognitive decline? A systematic review and meta-analysis. *Systematic Reviews*, *9*(1), 111. https://doi.org/10.1186/s13643-020-01378-7.

Berg-Weger, M., & Stewart, D. B. (2017). Non-pharmacologic interventions for persons with dementia. *Missouri Medicine*, *114*(2), 116–119.

Bermúdez i Badia, S., Fluet, G. G., Llorens, R., & Deutsch, J. E. (2016). Virtual reality for Sensorimotor Rehabilitation Post Stroke: Design principles and evidence. *Neurorehabilitation Technology*, 573–603. https://doi.org/10.1007/978-3-319-28603-7_28.

Blake, M. (2013). Group reminiscence therapy for adults with dementia: A review. *British Journal of Community Nursing*, *18*(5), 228–232. https://doi.org/10.12968/bjcn.2013.18.5.228.

Bowman, P. (2019). *Bruce Lee: Cult (Film) icon*. Routledge.

Cappeliez, P., & Webster, J. D. (2017). Introduction to the special section: Reminiscence through a cultural lens. *The International Journal of Reminiscence and Life Review*, *4*(2), 46–47. https://journals.radford.edu/index.php/IJRLR/article/view/140/74.

Chan, C. S. (2015). Consistency in an ever-changing City: An Old Clock Tower in Contemporary Hong Kong. *Cross-Currents: East Asian History and Culture Review*, *1*(15). https://cross-currents.berkeley.edu/e-journal/issue-15/curatorstatement.

Chan, C. S. (2019). Belonging to the City: Representations of a colonial clock tower in British Hong Kong. *Journal of Urban History*, *45*(2), 321–332. https://doi.org/10.1177/0096144218769894.

Chan, L., & Lau, D. (2009). Our Fading Daily Life and It's History: The Demolition of The Origin of Public Transport in Hong Kong - Tsim Sha Tsui Transport Interchange. http://www.ourbusterminal.org/doc/tstbt-unesco-paper-ver2.pdf.

Chan, Y. K., Tang, Y. M., & Teng, L. (2023). A comparative analysis of digital health usage intentions towards the adoption of virtual reality in telerehabilitation. *International Journal of Medical Informatics*, *174*, 105042.

Chao, H., Delbridge, M., Kenderdine, S., Nicholson, L., & Shaw, J. (2018). Kapturing Kung Fu: Future proofing the Hong Kong Martial Arts Living Archive. *Digital Echoes: Spaces for Intangible and Performance-based Cultural Heritage*, *249*, 264. https://doi.org/10.1007/978-3-319-73817-8_13.

Chen, Y., Wang, X., & Xu, H. (2021). Human factors/ergonomics evaluation for virtual reality headsets: A review. *CCF Transactions on Pervasive Computing and Interaction*, *3*(2), 99–111. https://doi.org/10.1007/s42486-021-00062-6.

Cheung, V. Y. T., Tang, Y. M., & Chan, K. K. L. (2023). Medical students' perception of the application of a virtual reality training model to acquire vaginal examination skills. *Int J Gynecol Obstet*, *161*, 827–832. https://doi.org/10.1002/ijgo.14670.

Choi, H. S. S., & Cui, M. (2006). Re-thinking the Hong Kong Tramway as a rooted but future orientated form of sustainable transportation. *Urbanie and Urbanus*. https://www.hkiud.org/articles/uu/202001-UU.pdf#page=52.

Chow, W. (2013). Experience on implementing performance-based design in Hong Kong. *Procedia Engineering*, *62*, 28–35. https://doi.org/10.1016/j.proeng.2013.08.041.

Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). The past, Present, and future of virtual and augmented reality research: A Network and Cluster Analysis of the literature [Original Research]. *Frontiers in Psychology*, 9. https://doi.org/10.3389/fpsyg.2018.02086.

Clay, F., Howett, D., FitzGerald, J., Fletcher, P., Chan, D., & Price, A. (2020). Use of immersive virtual reality in the Assessment and Treatment of Alzheimer's Disease: A systematic review. *Journal of Alzheimer's Disease*, *75*, 23–43. https://doi.org/10.3233/JAD-191218.

Cowan, K., & Ketron, S. (2019). A dual model of product involvement for effective virtual reality: The roles of imagination, co-creation, telepresence, and interactivity. *Journal of Business Research*, *100*, 483–492. https://doi.org/10.1016/j.jbusres.2018.10.063.

Crowe, S. F. (2015). Assessing the Neurocognitive disorders of the Diagnostic and Statistical Manual of Mental disorders (Fifth Edition). *Australian Psychologist*, *50*(1), 1–5. https://doi.org/10.1111/ap.12104.

Diagnostic and statistical manual of mental disorders (5th ed.). (2013). American Psychiatric Association. https://doi.https://doi-org.ezproxy.frederick.edu/10.1176/appi.books.9780890425596.

Dinius, C. J., Pocknell, C. E., Caffrey, M. P., & Roche, R. A. (2023). Cognitive interventions for memory and psychological well-being in aging and dementias. *Frontiers in Psychology*, *14*, 1070012.

Elias, S. M. S., Neville, C., & Scott, T. (2015). The effectiveness of group reminiscence therapy for loneliness, anxiety and depression in older adults in long-term care: A systematic review. *Geriatric Nursing*, *36*(5), 372–380. https://doi.org/10.1016/j.gerinurse.2015.05.004.

Fong, K. N. K., Tang, Y. M., Sie, K., Yu, A. K. H., Lo, C. C. W., & Ma, Y. W. T. (2022). Task-specific virtual reality training on hemiparetic upper extremity in patients with stroke. *Virtual Reality*, *26*(2), 453–464. https://doi.org/10.1007/s10055-021-00583-6.

Fung, C. M. (2005). *Reluctant heroes: Rickshaw Pullers in Hong Kong and Canton, 1874–1954* (Vol. 1). Hong Kong University.

Fung, A., & Chik, A. (2020). *Made in Hong Kong: Studies in Popular Music*. Routledge.

García-Betances, R. I., Waldmeyer, M. T. A., Fico, G., & Cabrera-Umpiérrez, M. F. (2015). A succinct overview of virtual reality technology use in Alzheimer's disease. *Frontiers in Aging Neuroscience*, *7*, https://doi.org/10.3389/fnagi.2015.00235.

Gaugler, J., James, B., Johnson, T., Scholz, K., & Weuve, J. (2016). 2016 Alzheimer's disease facts and figures. *Alzheimer's & Dementia*, *12*, 459–509. https://doi.org/10.1016/j.jalz.2016.03.001.

https://julac-hkpu.primo.exlibrisgroup.com/openurl/852JULAC_HKPU/852JULAC_HKPU:HKPU%3Fsid%3Dproquest%2626auinit%3D%26aulast%3DSuyatmi%26atitle%3DResearch%2BInstrument%2BTesting%2Bfor%2BStrategic%2BManagement%2Bof%2BInformation%2BTechnology%2BPrivate%2BUniversity%2Bof%2BXYZ%26stitle%3DInternational%2BInformation%2BInstitute%2B%28Tokyo%29.%2BInformation%26btitle%3D%26id%3Ddoi:%26title%3DResearch%2BInstrument%2BTesting%2Bfor%2BStrategic%2BManagement%2Bof%2BInformation%2BTechnology%2BPrivate%2BUniversity%2Bof%2BXYZ%26volume%3D19%26issue%3D9B%26date%3D2016%26spage%3D4025%26isbn%3D%26genre%3Darticle%26

Huang, W. J., & Wang, P. (2018). All that's best of dark and bright: Day and night perceptions of Hong Kong cityscape. *Tourism Management*, *66*, 274–286. https://doi.org/10.1016/j.tourman.2017.12.006.

Ingham, M., & Fung, M. K. (2015). -k. *In the mood for food: Wong Kar-wai's culinary imaginary*.

Jahanbin, I., Mohammadnejad, S., & Sharif, F. (2014). The effect of group reminiscence on the cognitive status of elderly people supported by ilam welfare organization in 2013; a randomized controlled clinical trial. *Int J Community Based Nurs Midwifery*, *2*(4), 231–239.

Kandiah, N., Ong, P. A., Yuda, T., Ng, L. L., Mamun, K., Merchant, R. A., Chen, C., Dominguez, J., Marasigan, S., Ampil, E., Nguyen, V. T., Yusoff, S., Chan, Y. F., Yong, F. M., Krairit, O., Suthisisang, C., Senanarong, V., Ji, Y., Thukral, R., & Ihl, R. (2019). Treatment of dementia and mild cognitive impairment with or without cerebrovascular disease: Expert consensus on the use of Ginkgo biloba extract, EGb 761(®). *Cns Neuroscience & Therapeutics*, *25*(2), 288–298. https://doi.org/10.1111/cns.13095.

Koppel, J., & Rubin, D. C. (2016). Recent advances in understanding the reminiscence bump: The importance of cues in Guiding Recall from Autobiographical Memory. *Current Directions in Psychological Science*, *25*(2), 135–149. https://doi.org/10.1177/0963721416631955.

Lau, S. Y. J., & Agius, H. (2021). A framework and immersive serious game for mild cognitive impairment. *Multimedia Tools and Applications*, *80*(20), 31183–31237. https://doi.org/10.1007/s11042-021-11042-4.

Lau, S. Y. J., Ganesan, B., & Fong, K. (2022). The impact of Serious games on physical activity, Cognitive Training and Mental Health for the Ageing Population during COVID-19: Implications and future trajectories. *Journal of Global Health Neurology and Psychiatry*, e2022007. https://doi.org/10.52872/001c.34710.

Leong, S. C., Tang, Y. M., Toh, F. M., & Fong, K. N. K. (2023). Examining the effectiveness of virtual, augmented, and mixed reality (VAMR) therapy for upper limb recovery and activities of daily living in stroke patients: A systematic review and meta-analysis. *J NeuroEngineering Rehabil*, *19*, 93. https://doi.org/10.1186/s12984-022-01071-x.

Leung, D., Law, R., & Lee, H. A. (2011). The perceived destination image of Hong Kong on Ctrip. Com. *International Journal of*

Tourism Research, *13*(2), 124–140. https://doi.org/10.1002/jtr.803.

Li, M., Lyu, J., Zhang, Y., Gao, M., Li, W., & Ma, X. (2017). The clinical efficacy of reminiscence therapy in patients with mild-to-moderate Alzheimer disease: Study protocol for a randomized parallel-design controlled trial. *Medicine*, *96*(51), e9381. https://doi.org/10.1097/md.0000000000009381.

Lim, K. F. (2006). Transnational collaborations, local competitiveness: Mapping the geographies of Filmmaking in/through Hong Kong. *Geografiska Annaler Series B Human Geography*, *88*(3), 337–357. https://doi.org/10.1111/j.1468-0459.2006.00226.x.

Macleod, F., Storey, L., Rushe, T., & McLaughlin, K. (2021). Towards an increased understanding of reminiscence therapy for people with dementia: A narrative analysis. *Dementia (London)*, *20*(4), 1375–1407. https://doi.org/10.1177/1471301220941275.

Mohd Arof, K., Ismail, S., & Saleh, A. L. (2018). Contractor's performance Appraisal System in the Malaysian construction industry: Current practice, perception and understanding. *International Journal of Engineering & Technology*, *7*, 46. https://doi.org/10.14419/ijet.v7i3.9.15272.

Munawar, K., Kuhn, S. K., & Haque, S. (2018). Understanding the reminiscence bump: A systematic review. *PLoS One*, *13*(12), e0208595. https://doi.org/10.1371/journal.pone.0208595.

Nadia, Z., Pasaribu, Y. M., & Djati, I. D. (2018). Expectations and Ideal VRUI from user's perspective, Case studies: VR Interface in ITB Electric Car's (Molina) virtual exhibition. *J Comput*, *13*, 721–732. https://doi.org/10.17706/jcp.13.6.721-732.

Niki, K., Yahara, M., Inagaki, M., Takahashi, N., Watanabe, A., Okuda, T., Ueda, M., Iwai, D., Sato, K., & Ito, T. (2021). Immersive virtual reality reminiscence reduces anxiety in the Oldest-Old without causing Serious Side effects: A Single-Center, pilot, and randomized crossover study [Original Research]. *Frontiers in Human Neuroscience*, *14*, https://doi.org/10.3389/fnhum.2020.598161.

Pimentel, J. (2019). Some biases in Likert scaling usage and its correction. *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, *45*, 183–191. Retrieved 04/20, fromhttps://www.gssrr.org/index.php/JournalOfBasicAndApplied/article/view/9874.

Siriaraya, P., & Ang, C. S. (2014). Recreating living experiences from past memories through virtual worlds for people with dementia. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. https://doi.org/10.1145/2556288.2557035.

Suyatmi, & Wibowo, F. W. (2016). Research Instrument Testing for Strategic Management of Information Technology Private University of XYZ. *International Information Institute (Tokyo) Information*, *19*(9B), 4025–4032. http://ezproxy.lb.polyu.edu.hk/login?url=https://www.proquest.com/scholarly-journals/research-instrument-testing-strategic-management/docview/1860273377/se-2?accountid=16210.

Taghian, A., Abo-Zahhad, M., Sayed, M. S., & El-Malek, A. H. A. (2023a). Virtual and augmented reality in biomedical engineering. *BioMed Eng OnLine*, *22*, 76. https://doi.org/10.1186/s12938-023-01138-3.

Taghian, A., El-Malek, A. H. A., Sayed, M. S., & Abo-Zahhad, M. (2023b). Developing an integrated medication adherence system: Exploring the potential of i-Ware's augmented reality goggles and mobile application. *IET Smart Cities*, *5*(3), 230–242. https://doi.org/10.1049/smc2.12062.

Toh, S. F. M., Fong, K. N. K., Gonzalez, P. C., & Tang, Y. M. (2023). Application of home-based Wearable technologies in Physical Rehabilitation for Stroke: A scoping review. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *31*, 1614–1623. https://doi.org/10.1109/TNSRE.2023.3252880.

Tominari, M., Uozumi, R., Becker, C., & Kinoshita, A. (2021). Reminiscence therapy using virtual reality technology affects cognitive function and subjective well-being in older adults with dementia. *Cogent Psychology*, *8*, https://doi.org/10.1080/23311908.2021.1968991.

Tsao, Y. C., Shu, C. C., & Lan, T. S. (2019). Development of a reminiscence therapy system for the Elderly using the integration of virtual reality and augmented reality. *Sustainability*, *11*(17). https://doi.org/10.3390/su11174792.

Wang, Q. J., Escobar, B., Da Mota, F. A., P., & Velasco, C. (2021). Getting started with virtual reality for sensory and consumer science: Current practices and future perspectives. *Food Research International*, *145*, 110410. https://doi.org/10.1016/j.foodres.2021.110410.

Wilson, R. S., Boyle, P. A., James, B. D., Leurgans, S. E., Buchman, A. S., & Bennett, D. A. (2015). Negative social interactions and risk of mild cognitive impairment in old age. *Neuropsychology*, *29*(4), 561–570. https://doi.org/10.1037/neu0000154.

Wu, Y., Zhang, X., Yu, T., Sui, X., Li, Y., Xu, H., & Li, F. (2023). Effects of reminiscence therapy combined with memory specificity training (RT-MeST) on depressive symptoms in older adults: A randomized controlled trial protocol. *BMC Geriatrics*, *23*(1), 398.

Xu, J., & Wang, B. (2020). Efficacy of VR-Based reminiscence therapy in improving autobiographical memory for Chinese patients with AD. 339–349. https://doi.org/10.1007/978-3-030-51038-1_47.

Xu, J., Yan, L., & Mak, C. K. (2022). Destination residents' Expected Tourist experiences of unconventional attractions and their intention to recommend. *Journal of China Tourism Research*, *18*(3), 510–532. https://doi.org/10.1080/19388160.2021.1871693.

Yahara, M., Niki, K., Ueno, K., Okamoto, M., Okuda, T., Tanaka, H., Naito, Y., Ishii, R., Ueda, M., & Ito, T. (2021). Remote reminiscence using immersive virtual reality may be efficacious for reducing anxiety in patients with mild cognitive impairment even in COVID-19 pandemic: A Case Report. *Biological &/And Pharmaceutical Bulletin*, *44*(7), 1019–1023. https://doi.org/10.1248/bpb.b21-00052.

Yeh, E. Y. (2018). *Early film cultures in Taiwan, Hong Kong, and Republican China: Kaleidoscopic histories*. University of Michigan Press.

Yen, H. Y., & Lin, L. J. (2018). A systematic review of reminiscence therapy for older adults in Taiwan. *Journal of Nursing Research*, *26*(2), 138–150. https://doi.org/10.1097/jnr.0000000000000233.

Yung, S. S. (2019). The rise of Cantonese Opera by Wing Chung Ng. *Theatre Journal*, *71*(4), 534–535. https://doi.org/10.1353/tj.2019.0101.

Zhang, H., Liu, P., Ying, J., Shi, Y., Wang, S., Zhang, M., & Sun, J. (2018). Evaluation of MESSAGE communication strategy combined with group reminiscence therapy on elders with mild cognitive impairment in long-term care facilities. *International Journal of Geriatric Psychiatry*, *33*(4), 613–622. https://doi.org/10.1002/gps.4822.

Zhou, W., He, G., Gao, J., Yuan, Q., Feng, H., & Zhang, C. K. (2012). The effects of group reminiscence therapy on depression, self-esteem, and affect balance of Chinese community-dwelling elderly. *Archives of Gerontology and Geriatrics*, *54*(3), e440–447. https://doi.org/10.1016/j.archger.2011.12.003.

Joyce S. Y. Lau received her BSc and PhD degrees from Brunel University London, United Kingdom. She is currently a Postdoctoral Fellow at the Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, working at the Research Centre for Assistive Technology. Her expertise lies in gaming technologies, digital products, and assistive technology research.

Yuk Ming Tang received his B.Eng., M.Phil., and Ph.D. degrees from The Chinese University of Hong Kong. He is currently a Senior Lecturer at the Hong Kong Polytechnic University. He holds key roles in two laboratories and three advanced research centers focused on product design, artificial intelligence, and immersive technologies. Dr. Tang has published over five book chapters and 60 journal articles. His research interests encompass virtual reality, mixed reality, artificial intelligence, blockchain, digital twins, sustainable management, technologies for industry 4.0, and healthcare applications.

Grace Gao obtained her Bachelor of Engineering in Product Engineering with Marketing from the Hong Kong Polytechnic University and completed her Master of Science in Mechanical and Automation Engineering at the Chinese University of Hong Kong. She is currently a PhD student at the Hong Kong Polytechnic University in the Department of Rehabilitation Sciences. Her research interests involve virtual reality, artificial intelligence and wearable technology.

Kenneth N. K. Fong is Professor and Associate Head (Research, Innovation, and Knowledge Transfer) of the Department of Rehabilitation Sciences, Director of the Research Centre for Assistive Technology, Management committee member of the Research Institute in AIoT, The Hong Kong Polytechnic University. His background training is in occupational therapy. His research interests are mechanism of human performance particularly in the integration of cognitive and motor performances, neurorehabilitation, and environmental issues and assistive technology for people with disabilities.

Chun Lung SO received his BSc (Hons) in Physiotherapy degree and MSc in Manipulative Physiotherapy degree from the Hong Kong Polytechnic University (PolyU). He also received his MSc in Sports Medicine and Health Sciences and Ph.D. degree in Orthopaedics and Traumatology from the Chinese University of Hong Kong. Currently, he is an Assistant Professor and Laboratory Coordinator of Gait and Motion Laboratory of the Department of Rehabilitation Sciences (PolyU). Dr. So has published 40 journal articles. His research interests include virtual reality applications in healthcare education and occupational health; digital twins in sports coaching and rehabilitation.