ARTICLE

Reminiscence Therapy in Virtual Reality: A Virtual Reality Application with Local Content to Help Mild Dementia

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ABSTRACT

Dementia poses a serious threat to the way of life of the elderly and impacts their daily activities. We have therefore developed an interdisciplinary project applying virtual reality (VR) and the reminiscence therapy approach to cope with mild dementia, using the HTC Vive VR system and the Leap Motion sensor software system. The scene of our application is constructed with reference to a Hong Kong public housing flat in the 1970s, and two different modes are available, namely the cognitive assessment mode and explorer mode. This project enables the occupational therapy students to develop a good understanding of the content creation process in virtual reality, including virtual asset, movement and interaction design, which constitute to the effective delivery of therapy for people with dementia.

Compared to paper-and-pencil tests, VR provides a more ecologically valid testing and training scenario. With VR, total control and high consistency of stimulus delivery to enhance the reliability of results can be easily achieved. It also provides several benefits for occupational therapy students. First, the students will not be negatively affected by the complicated physical environment. Second, all the actions in VR can be recorded for further analysis. Third, solid evidence is obtained instead of relying on self-evaluation paper-and-pencil assessments. This Article describes the development and implementation of a VR application in rehabilitation. It illustrates the design and development flow, and provides a solution to evaluate the quality of interdisciplinary work in engineering and health science.

Keywords: Mild dementia, virtual reality, reminiscence therapy, interdisciplinary project

INTRODUCTION

We need to bring to students' eyes, and attention, the pragmatic and latest cutting-edge technologies, so they can observe, think, and be excited to come up with new ideas, especially in the health science and engineering fields (Ng, 2017). The maturity of mixed reality technologies is evident in this decade and is gaining attention. Birt et al. (2018) applied mixed reality in medical and health education. Their research linked cross-discipline knowledge acquisition and the development of a student's tangible skills across multimodal classrooms. It was concluded that the new pedagogy benefitting students should not only focus on lectures and tutorials. It should also incline towards those learning methods that are more conversational, self-paced, and highlight visual interaction. Students can instantly engage with the learning, which provides a better understanding of the teaching materials (Moro, 2017a). Additional support and scaffolding are required to improve and develop new learning strategies for the next generation of students (Moro, 2017b). In this aspect, Kim and Choi (2021) reviewed 57 publications on the use of smart glasses in applied sciences. It was found that smart glasses are most often used in the healthcare field after 2014. The use of mixed reality technologies can reduce cognitive load (Young, 2014), which leads to enhanced learning outcomes (Wickens et al., 2013). It brings positive impact to healthcare education, and also encourages students to adopt mixed reality technologies, build the application and help others. As a result, an interdisciplinary project-based education could be initiated. Project-based education offers students an excellent opportunity to practice and transform the learned skills into their own idea (Hasen, 2001). However, bringing mixed reality technologies to other domains remains difficult (Rentsch et al., 2003). It is common that the planning and implementation of such projects adopts an ad-hoc or agile software approach, making it hard to evaluate the project's success, especially for student projects (Bu et al., 2022). The scale of their projects is relatively limited. The lack of measurements in interdisciplinary projects also prevents students from gaining confidence.

In this project, we use dementia as our focus to demonstrate healthcare and engineering students adopt cutting technologies, design the content, build the application and evaluate the design of the treatment. We describe the development and implementation of a virtual reality (VR) application to facilitate rehabilitation studies. It illustrates the design and development flow, and provides solutions to evaluate the quality of interdisciplinary work in engineering and health science.

LITERATURE REVIEW

Background of dementia and the need of using VR in dementia treatment

We explore the different aspects of applying VR therapy to treat dementia. Alzheimer's disease (AD) is one of the most frequent diseases of old age and mild dementia (CDR=1) has taken up to over 80% of dementia cases (Ritchie & Lovestone, 2002). 24 million people worldwide have been diagnosed with dementia today, and these figures are expected to double every 20 years to 42 million by 2020 and 81 million by 2040 respectively. Dementia cases will triple globally by 2050, and 1 in 85 people will be affected by Alzheimer's disease (Gabelli, 2015). As dementia poses a serious threat to the way of life and daily activities of the elderly, it is crucial to identify the disease as early as possible in order to deliver the appropriate treatment in time. To ensure a proper dementia diagnosis, cognitive assessment plays a crucial role. "Confirmation of the presence of dementing disease permits initiation of planning, organizing ongoing care, taking suitable steps towards long-range planning for financial and social well-being for both patient and family care partners" (Borson, 2013). Although traditional cognitive assessments are the fundamental ways to identify the onset of disease, these assessments present clear limitations. Evidence reveals that the Mini Mental State Examination, one of the widely used neuropsychological tests, is not sensitive to early signs of mild dementia. Weak correlations (0.22-0.50) between scores on MoCA subtests and cognitive performance were found, and the paper-and-pencil test poses difficulties for illiterate subjects as they can be easily disturbed by the environment, such as noise (Koski et al., 2009). To extenuate the limitations, VR technology is the better alternative that should be explored.

VR has been widely used in rehabilitation nowadays because it can bridge the gap between on-site training and real-life tasks in daily living. Virtual reality therapy (VRT) allows the clients to enter a computer-generated world and receive cognitive treatment with ease and convenience. It is safe, confidential, and economical. Carbonell-Carrera and Saorin (2017) also stated that VRT can help clients to develop spatial thinking and navigation without negative effects. Participants can engage in a 'real-life' environment and thus deepen their participation. Compared to running pen-and-pencil tests, VR provides more ecologically valid testing and training scenarios. Total control and consistency of stimulus delivery to enhance the reliability of results are evident. Also, when compared to real-life and real-equipment scenarios like an actual cooking setting, VR requires a much lower cost to implement. A final important point to note is that there is a higher capacity for a complete performance recording and enhanced motivation for the participants as well.

Background of reminiscence therapy and virtual reality therapy

Reminiscence therapy is one of the methods to deal with dementia, by improving the cognitive functions of the elderly. It is a non-pharmacological intervention and methodology to help clients to recall past experiences and evoke their memories. This process can stimulate their mental activities and strengthen their cognitive memory. A meta-analysis (Huang, 2015) also confirmed that "reminiscence therapy is effective in improving cognitive functions and depression symptoms in elderly people with dementia" (Huang, 2015, p. 1087). However, some constraints and problems exist in the implementation of reminiscence therapy. First, providing a suitable and immersive environment to relate to the elderly's experience is challenging. In order to facilitate therapy delivery, some rehabilitation centres have attempted to set up a simulated environment in the daycare centres for the elderly. The outcome is not very satisfactory. The attendance rate is not high as it is hard for the elderly with dementia to travel. As a result, most of the reminiscence therapy activities being delivered are confined to listening to the client's favourite music, or looking at old photos or magazines in the daycare centres. As such, the effectiveness of reminiscence therapy may not be fully realised. Second, ensuring a standardised specification of physical equipment and corresponding measurement is complicated. Reminiscence therapy requests the elderly to operate some common household appliances that they used in the past. It helps to recall their memory. However, it is difficult to maintain the aged household appliances, such as cooking facilities, in good and workable condition. Also, different rehabilitation centres may provide different equipment. As a result, the quality and measurement cannot be standardised. Advances in technology may help to solve these issues and bring about better alternatives in delivering reminiscence therapy. A research article (Lazar et al., 2014) pointed out that technology can facilitate therapy delivery, particularly, "in allowing the digital transfer of materials for reminiscence therapy to the therapist" (p. 575). Technology "can also bridge geographic distance and address transportation barriers" (Lazar et al., 2014, p. 575). In addition, a study on how multimedia technology helps with dementia (Astell et al., 2004) compared the traditional reminiscence therapy with a multimedia computer system. The result showed that the multimedia computer system increases interaction and facilitates communication. Another study on YouTube for reminiscence therapy (O'Rourke et al., 2011) also showed that digital-based reminiscence therapy sessions are more enjoyable than traditional reminiscence therapy.

Today, virtual reality therapy (VRT) is another innovative paradigm that "provides effective modality of therapy by allowing patients to be exposed to similar stimuli as their real-world experiences using a computer-generated virtual reality" (North & North, 2016) to deal with some psychological disorders. Table 1 demonstrates some studies using this concept for phobic disorders and most of them were successful, including the treatment of acrophobia, claustrophobia, fear of flying, public speaking, and driving. Therefore, we can tell that VR is a suitable technology for non-pharmacological therapy, and can be positively and effectively adopted in reminiscence therapy. Among all the therapies, fear therapy is a good start in VRT as lighting and rendering algorithm were not very well developed in earlier iterations. Patients can feel fear even when the graphics is not realistic.

Table 1

Therapy using computer-generated virtual environment for phobic disorders

Phobic Disorders	**Research**	**Results**
Acrophobia	(Freeman, 2018)	Immersive VR is highly effective for reduction of fear of heights.
Claustrophobia	(Botella, 1998)	Subjects coped with their fear of closed spaces gradually.
Fear of flying	(North & Rives, 2003)	Subjects can comfortably take a flight.
Fear of public speaking.	(Harris, 2002)	Subjects gained greater confidence in real-world speaking experiences.
Fear of driving	(Schare, 1999)	Subjects consistently reported less anxiety for driving.

Due to the improvements in rendering computer graphics and the availability of 360-degree scene reconstruction, virtual environments can provide extensive possibilities in different situations. In these few years, VRT has been applied to explore relaxing environments for mindfulness practice. Ma et al. (2022) investigated whether VR-based mindfulness training can improve mental health outcomes and notably, mindfulness levels amongst adults by using 106 articles. The result revealed that VR-based mindfulness training can reduce anxiety and depression, improve sleep quality, emotion regulation, and generate mood improvement. Table 2 summarises some studies using VRT for mindfulness practices. Besides feeling fear, VRT can also present a relaxing environment for clients. A comfortable environment can also help the clients build stronger relationships in virtual environments and enhance their learning. This successful experience provides evidence for us to develop reminiscence therapy in VR. In this paper, we try to explore another application area, dementia, which is different from the research work in the past. In previous investigations, the focus is only on providing the relaxing or fear scenarios, and VR technology is only used as a visualisation tool without interaction. In this research, we try to provide a familiar environment for patients to recall the memory in their past experience. We design the interaction, gameplay, and the assessment tools inside the VR environment.

Table 2

Therapy using computer-generated virtual environment for mindfulness practice

Research Focus	**Research**	**Results**
State mindfulness and positive affect	(Seabrook E, 2020)	State mindfulness and positive affect significantly increased after using the VR mindfulness app.
Effectiveness of meditation	(Kaplan-Rakowski, 2021)	VR meditation would be more effective than video meditation.
Panic attacks	(Seol et al., 2017)	A clear decrease in the levels of anxiety and depression.
Sleep quality	(Lee & Kang, 2020)	VR group reported significantly higher subjective sleep quality.
Nature connectedness	(Sneed et al., 2021)	VR group reported significantly stronger beliefs about their connection to nature
Promoting ecological behavior	(Deringer, 2021)	Virtual reality of nature is as effective as actual nature in promoting ecological behaviour

PROJECT METHODOLOGY

Overview of the reminiscence therapy in VR

Our proposed VR application, unique and creative in design, is a simulation game tailored for reminiscence therapy. The main scene in the game simulates a typical early home environment with home appliances, necessities, and some games in a Hong Kong public estate (Figure 1). The game is designed to be used by a supporting therapist, say, a social worker with basic computer skills who knows how to operate a VR device and is a reminiscence therapist. The VR head-mounted display can be either a HTC Vive or HTC Vive Pro, with two base stations and two controllers. A Leap Motion sensor for hand and finger motion detection (Figure 2) is recommended to aid the elderly's actions, particularly the grabbing action in the VR device as they may not be familiar with using the controller. It will be a good alternative input method to support interaction of the game. In the end, the learning curve of using VR devices can be decreased. The following movie (Figure 1) presents the interaction and the game flow of each part.

Figure 1. Game scene and assets

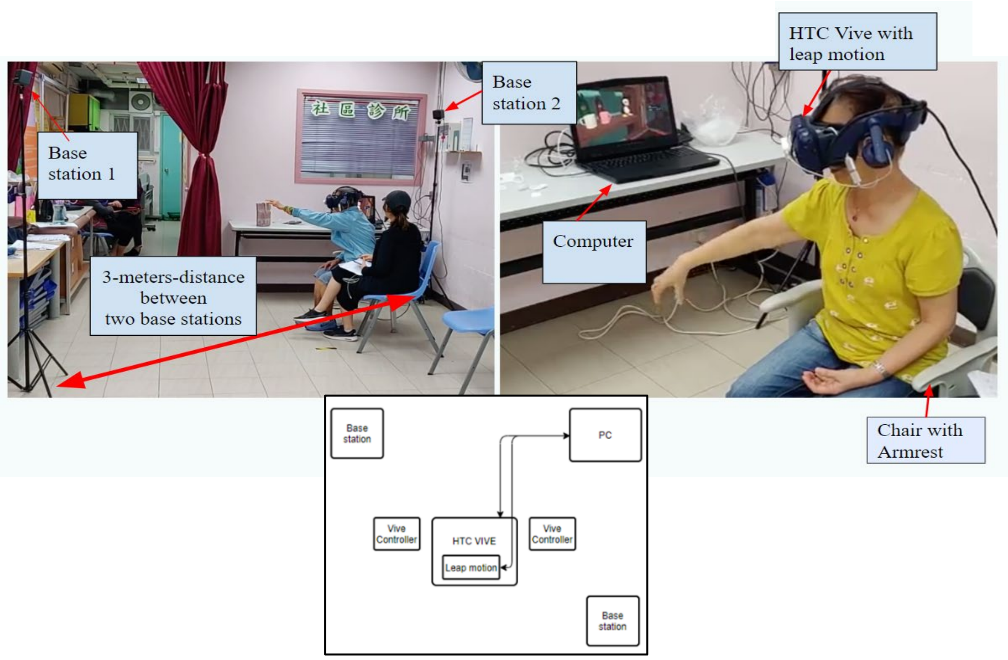

Figure 2. Block diagram of the hardware structure

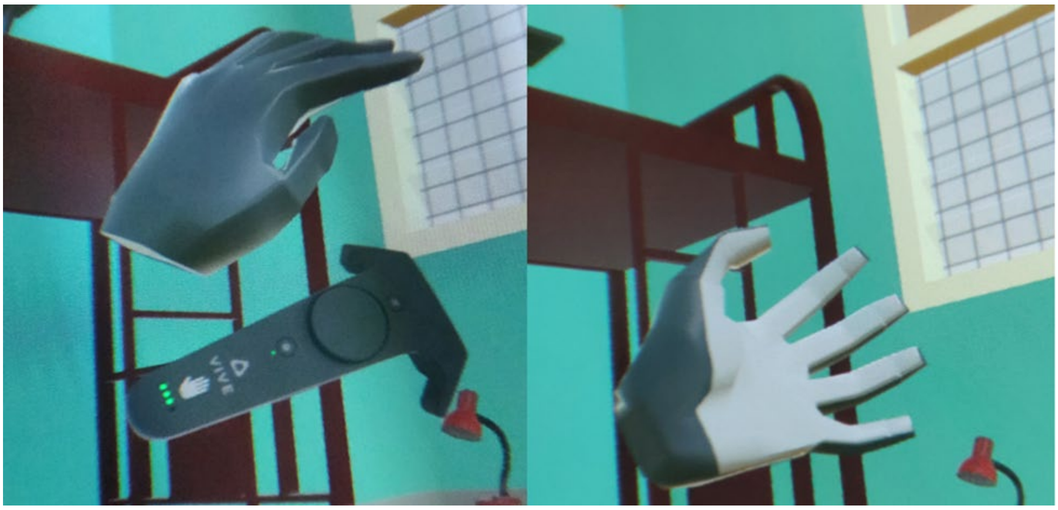

Figure 3. Vive controller model with leap motion hand model

Cognitive assessment mode

The cognitive assessment mode is designed to examine the importance and applicability of VR in cognitive assessment by literature review. Our design includes four assessments examining the four cognitive domains (Immediate Recall, Topographic Memory, Prospective Memory, and Comprehension), which distinguish between people diagnosed with mild dementia and people with normal cognitive functioning without exacting a manpower burden. The total assessment time is 12 minutes.

Assessment 1 focuses on Immediate Recall. In this assessment, the elderly would need to get specific objects out of a cabinet after receiving a request via phone call. They have to identify the shape, size, and colour correctly. The total score for this task is 6, with 2 marks awarded for each correctly identified item. 1 mark is awarded for a correct mapping to the right category, and 2 marks for the correct item picked. The golden assessment, Montreal Cognitive Assessment (Nasreddine, 2005) is used to compare our design.

Topographic Memory is the focus of Assessment 2, and it requires the elderly to remember the sequence of four photos shown to them. They need to list them in the correct order after 15 seconds. This task scores 3 marks in total. 0 is given for the incorrect sequence and 3 marks for correct answers. The golden assessment, Rivermead Behavioral Memory Test (RBMT) (Wilson, 1985) is used to compare our design.

Assessment 3 works on Prospective Memory. The elderly are informed that they need to go shopping, and they have to get their wallet next to the television after watching a Mark Six Lottery Program video. It serves as a distraction to achieving the purpose of testing prospective memory. If they succeed in picking up the wallet without any hints, they get 2 marks. 1 mark is given if they want and obtain a verbal cue. Again, the golden assessment in this task is the subtest for delayed recall in the Rivermead Behavioural Memory Test (RBMT).

Assessment 4 is about Comprehension and requires the elderly to prepare a Chinese dish, following prescribed instructions. Six different instructions related to meal preparation are provided. The tasks included single-step commands, two-step commands, and three-step commands. The total score for this task is 6 marks with six different instructions. The golden assessment, Neurobehavioral Cognitive Status Examination (NCSE) (Kiernan et al., 1987), is used to compare our design.

Explorer mode

A scene of a Hong Kong public housing flat in the 1970s was developed in our VR application. Commonly seen items in the 1970s, such as a kerosene stove, record player, television and aeroplane olive are created virtually at the scene to evoke memories for the elderly (Figure 4). We have sought advice from domain experts from the hospital authority and different non-government organisations in Hong Kong during the process of designing the virtual objects and related interactions. Content validity was measured with an index scoring (S-CVI) of 0.790 and that implies a satisfying content validity. Objects that are engaging, attractive, and familiar to the elderly are included to draw their attention. For example, a kerosene stove was a necessary household item and cooking tool for nearly every family in Hong Kong in the 1960s, and they knew very well how to install it. We researched and learned that the kerosene stove produced by Wing Cheong Metal Manufactory was the most popular one in Hong Kong, so we adopted its design in creating the 3D model. A kerosene stove has five components (installation sequence shown in Figure 5), and the elderly can install it by building up the components correctly and putting a stockpot onto it. Other assets, such as an old model radio, a vinyl record player, and an old model television with Mark-Six Lottery, are built inside the VR application. The old assets and the associated interaction would help the elderly recall their memory in the immersive environment.

Figure 4. Kerosene stove in the Explorer Mode

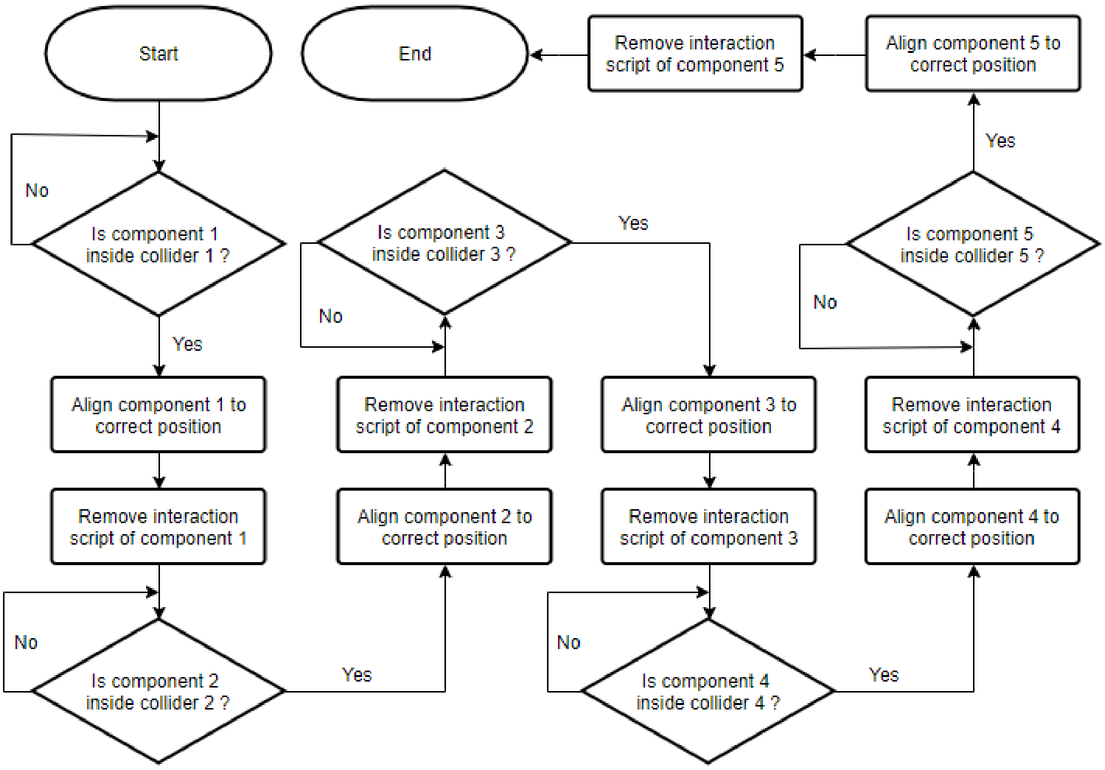

Figure 5. Mechanism of the kerosene stove interaction

EVALUATION

It is difficult for the supervisors to determine how far students' interdisciplinary projects are successful. Evaluation and comments from the actual clients are, therefore, necessary and can offer insights to and boost confidence of the students. However, there is a lack of a common evaluation standard for examining the VR application in health science. Among all, running a User Acceptance Test (UAT) is one common method to evaluate the usability of an application by computer science students. It can review whether the user understands and manages the functions. Yet there is a drawback, since performing a UAT cannot fully reflect the effectiveness of the therapy and the content design. In this session, we will describe how we can fruitfully evaluate the gameplay design, scene, and game assets to fulfil clinical needs.

Evaluation of the cognitive assessment mode

To evaluate the gameplay design in the cognitive assessment mode, 19 participants with mild dementia were recruited for the study, accompanied by 18 participants with normal cognitive levels as a control. They were recruited by purposive sampling in Smart Club of Evangelical Lutheran Church Social Service Hong Kong, Chung Hok Elderly Centre, Yan Oi Tong Clarea Au Elder Garten, and South Kwai Chung Social Service Centre. The experimental group inclusion criteria were: (1) aged 65 or above; (2) elderly with sufficient cognitive and motor competency to complete the whole assessment; (3) a score of 1 on the Clinical Dementia Rating Scale (Hughes, 1982).

Selection of participants

Considerations have been taken to minimise the effect of cybersickness while using the VR devices. Exclusion criteria are set as follows: (1) severe visual and hearing impairment; (2) susceptibility to motion sickness; (3) impaired upper limb functions; (4) psychiatric disorders, e.g., depression; and (5) neurological pathologies, e.g., photosensitive epilepsy/ delirium. This study adopts a cross-sectional study (Barnett, 2012) as it carries out at one-time point. It is correlational exploratory research aiming to study the relationship between the results of VR assessment and traditional assessment and hence validating the VR tool. After the subjective recruitment exercise, 5 male and 14 female participants were in the dementia group while 6 male and 12 female participants were in the healthy control group.

Setting of measurement

We employ Golden Assessments to compare the result of the VR cognitive test. They included subtests in HK-MoCA, RBMT, and NCSE. The reliability and validity of the Golden Assessment are elaborated below.

The HK-MoCA Immediate Recall subtest was used as a Golden Assessment for Immediate Recall for VR Scene 1. It is proven with good reliability. Pearson's R correlation was excellent between the two evaluations ($r = 0.92$, $p < 0.01$). It is also excellent with Cronbach's alpha reported (Alpha = 0.83) on the standardised items. (Hoops et al., 2009). It is a good overall assessment for the detection of any cognitive disorder with ROC Area under the Curve (Area = 0.87) (Wong et al., 2009).

Two subtests in the Rivermead Behavioral Memory Test (RBMT) use Topographic Memory as a golden assessment for VR Scene 2 and Prospective Memory for VR Scene 3. RBMT shows an excellent result with intraclass correlation coefficient (ICC) = 0.990-0.997. The test-retest reliability is high ($t = 3.4$, $p = 0.002$). It shows an excellent internal consistency (Cronbach's alpha = 0.859). It also has a significant correlation with the HK-MoCA (Fong et al., 2019).

The Neurobehavioural Cognitive Status Examination (NCSE) was used as a golden assessment for comprehension for VR Scene 4. It shows a range of correlation coefficients from 0.62 to 0.96. The internal consistency is excellent with Cronbach's alpha at 0.88. It also manifests a significant correlation with Western Aphasia Battery and others (Thomas, 1997).

Hypothesis

Shapiro-Wilk Statistics were used to test for the normality of data, while Levene's test was used in testing the homogeneity of variance. To compare the cognitive test score differences between two groups, independent *T*-test was used for any parametric statistics while the Mann-Whitney U test was used for any Nonparametric statistics. To test the relationship between the VR scores and traditional cognitive test scores, Pearson's R or Spearman's Rho test was used. For all tests, an alpha level of statistical significance was set at $p < 0.05$.

There are four research questions in total: (1) are there any significant differences in VR cognitive assessment scores between the group with dementia and the healthy control group?, (2) are there any significant predictors among all the variables?, (3) are there any significant correlations between VR total score and HK-MoCA total score?, and (4) are there any significant predictor among all the variables?. The hypothesis is that the results are statistically significant.

Result and analysis

Descriptive statistics of the VR scores of both the dementia and the healthy control groups are shown in Table 3. The higher the score, the better the cognitive performance.

Table 3

Descriptive statistics of the VR scores of the dementia and healthy control groups

Domain	**Measures**	**Healthy (*n* = 18)**		**Dementia (*n* = 19)**	
		Mean	**SD**	**Mean**	**SD**
	VR – Total score	14.167	2.33	7.895	3.49
	HK-MoCA – Total score	23.056	3.96	12.737	3.98
Immediate recall	VR Scene 1 – Picking toys	5.111	1.13	2.842	1.50
	MoCA 5 – Immediate recall	4.000	1.08	2.947	1.31
Topographic Memory	VR Scene 2 – Route matching	2.167	1.15	0.737	1.10
	RBMT – Route finding	4.167	0.79	2.474	1.78
Prospective Memory	VR Scene 3 – Picking toys	1.556	0.51	0.789	0.54
	RBMT – Prospective memory	1.056	0.64	0.632	0.50
Comprehension	VR Scene 4 – Preparing meals	5.333	0.77	3.526	1.39
	NCSE – Comprehension	5.278	1.07	4.053	1.43

For all data, the mean scores of the healthy control group are higher than that of the group with dementia. Poor performance was observed in the group with dementia. This matches their cognitive functional level.

The results of Shapiro-Wilk Statistic was statistically significant for all four subscores in VR Scenes 1, 2, 3, 4, which indicated that it could not meet the criterion of normality. Therefore, Mann-Whitney U Test (non-parametric statistics) was used for four subscores. The results are shown in Table 4.

Table 4

Result of Shapiro-Wilk Statistic

Test Statistics	**VR Scene 1**	**VR Scene 2**	**VR Scene 3**	**VR Scene 4**
Mann-Whitney U	45.000	64.500	65.000	40.500
Z	-3.935	-3.416	-3.626	-4.093
Asymp.Sig. (2-tailed)	.000	.001	.000	.000

As the significant level of all four VR scenes are less than 0.05, there are significant differences in all VR scene scores between the healthy control group and the group with dementia. However, no causal relationship can be established due to the cross-sectional design.

Correlation analysis

Pearson Correlation score is then used for testing the correlations of the VR total score and MoCA total score between the two groups. High correlation is observed if the value of correlation is more than 0.7 (Hinkle & Stephen, 2003). The following table shows the result of the analysis.

Table 5

Results of Pearson Correlation score

Correlations		**MoCA**	**VR Total Score**
MoCA	Pearson Correlation ®	1	.748
	Sig. (2-tailed) (p)		.000
	N	37	37

As $r = 0.748$ and $p < 0.001$, there is a significant correlation in VR cognitive assessment and MoCA test. This result implies that those with a higher MoCA total score tends to have a higher VR total score. By using the VR total score, mild dementia can be diagnosed.

To examine the correlations between VR subtest and the Golden Assessment, Spearman's Rho is used as a matter that criterion of normality is not met. Cohen (2013) revealed 0.40 to 0.69 of the value of coefficient that indicates a moderate correlation of two variables. Results are shown in Table 6.

Table 6

Results of Correlations for VR- Scenes 1, 2, 3, and 4

Correlations		**MoCA- Immediate Recall**
VR-Scene 1	Correlation Coefficient	.550
	Sig. (2-tailed)	.000
	N	37

Correlations		**RBMT-Route Finding**
VR-Scene 2	Correlation Coefficient	.432
	Sig. (2-tailed)	.008
	N	37

Correlations		**RBMT – Prospective Memory**
VR-Scene 3	Correlation Coefficient	.406
	Sig. (2-tailed)	.013
	N	37

Correlations		**NCSE – Comprehension**
VR-Scene 4	Correlation Coefficient	.553
	Sig. (2-tailed)	.000
	N	37

Our study found that there is a moderate and positive correlation between MoCA Immediate Recall and VR Scene 1 in the sample ($r_s = 0.550$, $p < 0.001$). A higher VR Scene 1 score tends to have a higher MoCA immediate recall score. There is a moderate and positive correlation between RBMT route finding and VR Scene 2 in the sample ($r_s = 0.432$, $p = 0.008$). A higher VR Scene 2 score tends to have a higher RBMT route finding score. There is a moderate and positive correlation between RBMT Prospective Memory and VR scene Scene 3 in the sample ($r_s = 0.406$, $p = 0.013$). A higher VR Scene 3 score tends to have a higher RBMT prospective memory score. There is a moderate and positive correlation between NCSE Comprehension and VR Scene 4 in the sample ($r_s = 0.553$, $p < 0.001$). A higher VR Scene 4 score tends to have a higher NCSE Comprehension score.

Evaluation of the explorer mode

High levels of fidelity (realism) in health simulations require extra production time in 3D model and higher computation power to render (Zendejas et al., 2013). However, fidelity tends to be imprecise (Norman et al., 2012). To evaluate the effectiveness of the virtual scenes and assets in the Explorer mode, this project contacted six experts and social workers from the hospital authority and Sheng Kung Hui Welfare Council in Hong Kong for review. The content validity approach is used to quantify the experts' agreement on item relevance by computing the content validity index (CVI) by a minimum of three experts (Lynn, 1986). The purpose of this content validity is to evaluate the effectiveness of using this application for reminiscence therapy. The first task is to prepare a questionnaire for each section of the game. Each section represents an interaction. The questionnaire contains a list of statements for experts to rate. A 4-point scale is used to avoid having a neutral and ambivalent midpoint (Waltz & Bausell, 1981) and a 4-point scale of rating (Strongly Disagree, Disagree, Agree, and Strongly Agree) is used. The second task is to invite some experts to rate each statement. After that, an item-level content validity index (I-CVI) for each section and a scale-level content validity index (S-CVI) for the game will be calculated. The steps of the content validity approach are listed as follows.

1. Define purpose
2. Prepare content validly questionnaire
3. Conduct expert panel
4. Collect and calculate results

To analyse the effectiveness of each interaction independently, we divide the questionnaire into seven sections, including the kitchen (Section A), balcony (Section B), living room (Section C), music (Section D), toys (Section E), general (Section F), and design of VR (Section G). Sections A-F contain 16 statements each. Section G contains 9 statements. Each statement has a 4-point scale of rating, including Strongly Disagree, Disagree, Agree, and Strongly Agree. The statements are related to the purposes of reminiscence therapy (Bender, 1999). The design of VR (Section G) is used as an example to illustrate the calculation of effectiveness.

Table 7

Statements of Sections G

Item	Description
Item 1	Overall, the design of the VRT is realistic.
Item 2	Overall, the VR Reminiscence Therapy Game is understandable.
Item 3	Overall, the VR Reminiscence Therapy Game is representative of real Reminiscence Therapy setting.
Item 4	Overall, the elements (Tasks & Environment) in the VR Reminiscence Therapy Game are relevant to the target group (65 or above).
Item 5	The VR Reminiscence Therapy Game is useful in the clinical setting.
Item 6	The VR Reminiscence Therapy Game is safe and appropriate for target group (65 or above).
Item 7	The VR Reminiscence Therapy Game saves more space than real setting.
Item 8	The VR Reminiscence Therapy Game requires fewer set-ups than real setting.

To validate the statements, an item-level content validity index (I-CVI) needs to be calculated. The rating of Strongly Disagree and Disagree will fall into non-relevant, while Agree and Strongly Agree will fall into relevant for calculating. According to Lynn (1986), all must agree with the statement to consider it a possible rating in any expert panel in the content validity with five or fewer experts. This means the I-CVIs should be 1 for an appropriate statement. But if there are six or more experts, Lynn (1986) recommended that the standard can be changed to I-CVIs and no smaller than 0.78. Because we invited six experts in this content validity expert panel, so we set the criterion of >79% to be appropriate, 66-79% to be needs revision and < 66% to be eliminated for the statements.

Table 8

The I-CVIs results of each item in Section G

Items	Relevant	Non-Relevant	I-CVIs	Interpretation
1	6	0	1	Appropriate
2	5	1	0.833333	Appropriate
3	6	0	1	Appropriate
4	6	0	1	Appropriate
5	5	1	0.833333	Appropriate
6	3	3	0.5	Eliminated
7	5	1	0.833333	Appropriate
8	5	1	0.833333	Appropriate
9	6	0	1	Appropriate

Average I-CVI of section G is 0.87037 [Total no. of relevant ÷ (no. of item × no. of expert) = 47 ÷ (9x6)]. For Section G, only Item 6 is eliminated with I-CVIs 0.5. The best average I-CVI is Section G (0.87037). This means the general design of VR is appropriated. S-CVI is calculated by the average of other sessions. The overall S-CVI of the game is 0.719. The main concern from the experts is Item 6 [The VR Reminiscence

Therapy Game is safe and appropriate for target group (65 or above)]. There are two main elements. First, the head-mounted displayed may be too heavy and the refresh rate may be not enough for the elderly. As a result, the elderly may feel dizzy and tired during the treatment. Second, the haptic effect of the HTC VIVE controller or the contactless Leap motion sensors is not nature. It requests an extra cognitive load. To improve these two elements, we suggest using the LED CAVE system and replacing some of the virtual objects to physical objects with motion tracking markers if the budget is available.

LIMITATIONS

Limitation of the cognitive assessment mode

There are several limitations to our study. First, the sample size is relatively small to commence. There is an average of five years' difference between the healthy group and the group with dementia in our test. Moreover, the gender ratio between the two groups does not equal 1:1 but is around 1.4 in the study. The demographic of education level is also not normally distributed, resulting in a dichotomy outcome. To date, the recordings playing are manipulated by testers. This can be a cause of lacking inter-rater reliability.

We see room for improvement. A larger sample size with a balanced gender ratio between the two groups is needed. In future studies, it is necessary to recruit more levels of cognitive impairments for a better ROC cut-off curve. Moreover, it is better to establish a percentile rank for different levels of cognitive impairments with different VR scores. It is hoped that there can be automatic administration of tests. As suggested by Crawford et al. (2010), the equivalent percentile ranks for the three optimal cut-off scaled scores can be 57% for older adults at risk for MCI, 30% for those with mild dementia, and 10% for those with moderate dementia. The future development of VR cognitive assessment can differentiate the severity of dementia.

Limitation of the explorer mode

The overall S-CVI of the game is 0.719. Although it is lower than the criterion of > 79%, the game can be improved based on the S-CVI and the comments of the experts. As the movement area of HTC Vive is only 3m x 3m, teleport is implemented for the movement. However, the expert mentioned that the teleport methods in VR are too complicated for the elderly as it is not a natural movement for humans, and involves the fade-in and fade-out effect. The elderly may feel dizzy during the movement. It is replaced by the action of a therapist outside the VR who controls with a keyboard and makes announcement to the elderly. As a result, the elderly can sit comfortably to play the game and be trouble-free.

CONCLUSION

This paper illustrates an interdisciplinary project to improve the paper-and-pencil assessment of rehabilitation by using mixed reality technologies. It is different from the previous research works of VRT that focus on providing fear or a relaxing environment only. In this case, we use VR technology as a visual replacement, but we explore another possible application area in VRT. We use VR technologies to design the interaction, gameplay, and the assessment tools for dementia treatment. The development and implementation of a VR application is described with a complete design and development flow. The uniqueness of this Article is to provide an example for the healthcare students to design an intervention with cutting-edge technologies rather than using the cutting-edge technologies in learning. It also provides a solution to evaluate the quality of interdisciplinary work in engineering and health science.

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