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NEUROPSYCHOLOGY | RESEARCH ARTICLE

Reminiscence therapy using virtual reality technology affects cognitive function and subjective well-being in older adults with dementia

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Abstract: Reminiscence therapy is garnering attention for stimulating seniors' cognitive functions. It could be inferred that that synergistic effects could be created by combining virtual reality (VR), which can project realistic images, with recall, which stimulates memory. We hypothesized that by projecting realistic memories to stimulate recall, VR-based reminiscence therapy would stimulate cognitive function better than conventional photo-based reminiscence therapy. We randomly assigned total 52 people with mild cognitive impairment to eight weeks of reminiscence therapy using either tablet VR panoramas or conventional still photos with 26 participants in each group. Before and after therapy, we tested their cognitive functions with the mini-mental state examination (MMSE), the revised PGC morale scale, multidimensional observation scale for elderly subjects, trail making tests A and B, and the word fluency test. The total scores of MMSE showed improvement for both groups, but did not show statistical significance of the VR panoramas group over the conventional still photos group. However, of the two groups, only the VR panoramas group showed considerable improvement from the baseline. In addition, the analysis of secondary outcome showed that the revised PGC morale scale scores rose considerably higher in the VR panoramas group than in the still photos group. No definite differences were observed in other scales. Contrary to our primary hypothesis, reminiscence therapy produced cognitive improvement regardless of whether its stimuli were still photos or VR panoramas.

Maho Tominari

ABOUT THE AUTHOR

Maho Tominari is a clinical nurse with a master's degree in human health sciences from Kyoto University. Her research concerns dementia care, particularly improvement of cognitive functions. She proposes to enrich the lives of dementia patients not only with medication, but also with non-pharmacological therapies.

PUBLIC INTEREST STATEMENT

People with dementia (PwD) benefit from reminiscence therapy using images to stimulate their memories of past experiences. We research care for older PwD, and hope to improve cognitive function, quality of life and activities of daily living of older PwD by using iPad VR technology reminiscence therapy. We compared the effects of reminiscence therapy using panoramic images printed on paper with those using tablet-based VR. Both methods similarly improved the cognitive functions of PwD, but the iPads dramatically improved subjective well-being of older people with no previous iPad experience. This pioneering research offers exciting possibilities for improving the subjective well-being of PwD using electronic media.

However, the greater improvement in VR participants' revised PGC morale scale scores shows enhancement of patients' subjective well-being.

Subjects: Information & Communication Technology; ICT; Nursing; Mental Health Nursing; Gerontology; Neurological Rehabilitation; Complementary & Alternative Medicine

Keywords: dementia; reminiscence therapy; virtual reality; cognitive function; well-being

1. Introduction

Dementia ranks among the world's most serious long-term health problems. According to the dementia report of the World Health Organization (2018), the number of people with dementia (PwD) was approximately 50 million worldwide in 2018. This rapidly rising number is expected to reach 82 million by 2030 and 152 million by 2050. Japan is the world's leading super-aged country, with more than 5 million dementia-afflicted people. Though Japan's total population is declining, its population of PwD is expected to increase in the future, so we must tackle the challenges posed by the rising number of PwD by creating novel care methods with the application of modern technology.

PwD often experience difficulty in remembering, which eventually interferes with their activities of daily living (ADL). Pharmacological treatment can slow the interference of dementia in ADL and behaviors (Arvanitakis et al., 2019). However, its effect is generally limited. Non-pharmacological treatments such as reminiscence therapy, music therapy, art therapy, cognitive stimulation therapy, and aromatherapy can also reduce some symptoms of dementia, by stimulating cognitive functions, ameliorating behavioral and psychological symptoms of dementia (BPSD).

Reminiscence therapy is a popular psychological intervention for PwD that uses prompts to stimulate participants' memory and involves activities which talk about their past and experiences (Woods et al., 2018). Reminiscence therapy was introduced by Butler (1963), who reported that reminiscence improved the mental health of older adults. Nowadays it is widely accepted that reminiscence therapy has three functions: social, instrumental, and interactive (Westerhof & Bohlmeijer, 2014). A recent Cochrane review of reminiscence therapy for dementia patients (Woods et al., 2018) concluded that reminiscence therapy is also effective in improving quality of life (QOL), cognitive function, communication, and mood of PwD.

Reminiscence therapy can be performed either in groups or individually (Schweitzer & Bruce, 2008). Tadaka and Kanagawa (2007) reported that group reminiscence therapy for Alzheimer's and vascular dementia patients effectively increased not only participants' reminiscence but also their adjustment to daily life. Another report revealed that group reminiscence therapy improved depression and apathy for PwD (Hsieh et al., 2010). Group reminiscence therapy immersing Alzheimer's patients in an authentic 1950's-style museum environment replicating their youth improved their autobiographical memory (Kirk et al., 2019), which is rarely attainable even by pharmacological treatment.

Regarding individual reminiscence therapy, one study conducted with institutionalized older adults demonstrated that individual reminiscence therapy improved socialization and reduced symptoms or levels of depression (Chiang et al., 2010). Personalized reminiscence therapy using personally-tailored life storybooks (books/scrapbooks made by individuals storing memories of their lives) benefited the relationships between participants, their families, and the staff in elderly homes (Subramaniam et al., 2014). Individualized reminiscence has also shown potential as an intervention to improve cognitive function and QOL (Justo-Henriques et al., 2021). Yet another study showed that immersive reminiscence therapy for Alzheimer's disease patients was effective even when practiced in group sessions. A randomized controlled trial investigating the effectiveness of structured life reviews and life storybooks (homemade books storing memories about their own lives) and found that individual reminiscence therapy was beneficial for reducing depression, encouraging communication, positive mood, and cognition (Haight et al., 2006).

Early studies used photos, objects, or stories to prompt older adults to reminisce about the old days. Recently, however, videos, films, or virtual reality (VR) headsets can be used to give the patients an even more realistic experience. Lazar's systematic review concluded that information and communication technology (ICT)-based reminiscence therapy further increased conversation between the patients and the caregivers (Lazar et al., 2014). ICT may be useful not only for patients but also for therapists, because it saves time spent in preparing for the therapies and making materials available for their patients.

VR refers to the technology with which users psychophysically experience computer-simulated environments (Dam et al., 2000; Sherman & Craig, 2003). VR technologies enable patients to step easily into "another" world. VR includes three types: non-immersive (desktop and tablet) systems, semi-immersive projection systems, and fully immersive systems (Mujber et al., 2004). Negro Cousa et al. (2019) compared participants experiencing either immersive or non-immersive VR through 360-degree photos. Immersive VR allows users to experience immersive images, but some users may experience VR sickness (Rebenitsch & Owen, 2016). While non-immersive VR is inferior to immersive VR in terms of reality, it is easier to use and poses less risk of VR sickness. Because we were concerned to avoid any side effects of VR in older adults, we used VR tablet devices with low risk of VR sickness.

Researchers expect that VR will enhance conventional non-pharmacological therapies. Current health care research with VR is largely conducted in the field of rehabilitation (Garcia-Betances et al., 2015; Man et al., 2012; White & Moussavi, 2016). VR has been used to evaluate the cognitive function of dementia patients (Weniger et al., 2011; Widmann et al., 2012). Other researchers and clinicians have begun to use VR to stimulate cognitive functions in task-completion exercises (Manera et al., 2016; White & Moussavi, 2016). VR interventions for older adults proved effective not only for physical functions but also mental functions (Benoit et al., 2015; Flynn et al., 2003; Moyle et al., 2018), suggesting that VR might be beneficial for improving cognitive function. Another recent study found that older Japanese people viewing VR showed reduced anxiety (Niki et al., 2021).

VR technology has been used in reminiscence therapy, also with healthy adults. One previous study (Chapoulie et al., 2014) using VR with healthy older participants noted challenges in preparing materials; more highly immersive VR has even improved cognitive functions of healthy adults (Ventura et al., 2019).

It is hoped that the immersive nature of VR would be more effective in awakening memories and stimulating cognitive functions, yet few researchers report using VR reminiscence therapy for PwD. One study (Rose et al., 2019) showed that VR-based reminiscence therapy for PwD improved pleasure and alertness, while another recent study found that VR-based reminiscence therapy improved symptoms of apathy in older adults (Saredakis et al., 2020).

Consequently, we hypothesized that VR images of their past would enable older PwD to recall memories and experiences of their younger days. The objective of this study is to evaluate and compare the effectiveness of these two types of reminiscence therapy (using VR panoramas and conventional still photos) from the standpoints of cognitive functions, subjective well-being, and ADL in older adults with cognitive impairment.

2. Methods

2.1. Study design and participants

This study consisted of an open-label, randomized controlled trial conducted from April 2018 to October 2018. The trial was granted registration number UMIN000030604 as a randomized controlled trial with Japan's University Hospital Medical Information Network (UMIN).

Participants were recruited from four elder-care facilities and three nursing homes in Japan from April 2018 to July 2018. We acquired data from the seven care facilities that agreed to cooperate in this research, initially for 28 subjects in each group (a control group and an intervention group). In our assessment of candidates and consideration of interviews, we included participants who met the following criteria (by self-report and/or confirmation by the staff of the facilities):

- Japanese speaking, aged 65 years or older
- clinically diagnosed with dementia on the mini-mental state examination (MMSE) (Folstein et al., 1975) scores ranging from 22 to 26 (Abushakra et al., 2017; Boada et al., 2019, 2020)
- no other psychological disorders
- no visual nor auditory impairments that would interfere with reminiscence therapy
- no exposure to reminiscence therapy over the past three months
- able to answer "Yes" or "No" to close-ended questions
- able to view images for approximately 30 minutes
- no demonstrated previous experience with tablet-type devices
- selected the participants according to their attention span, which was judged by the nursery staff during the recreation and rehabilitation time

Recently, the cut-off score of 23 points for MMSE is widely considered optimal to detect dementia. This cut-off point depends on age and education, 22 being optimal for groups with lower education (Kochhann et al., 2010), so we adopted 22 as our cut-off point and included participants with MMSE scores of 22 to 26.

2.2. Ethical consideration

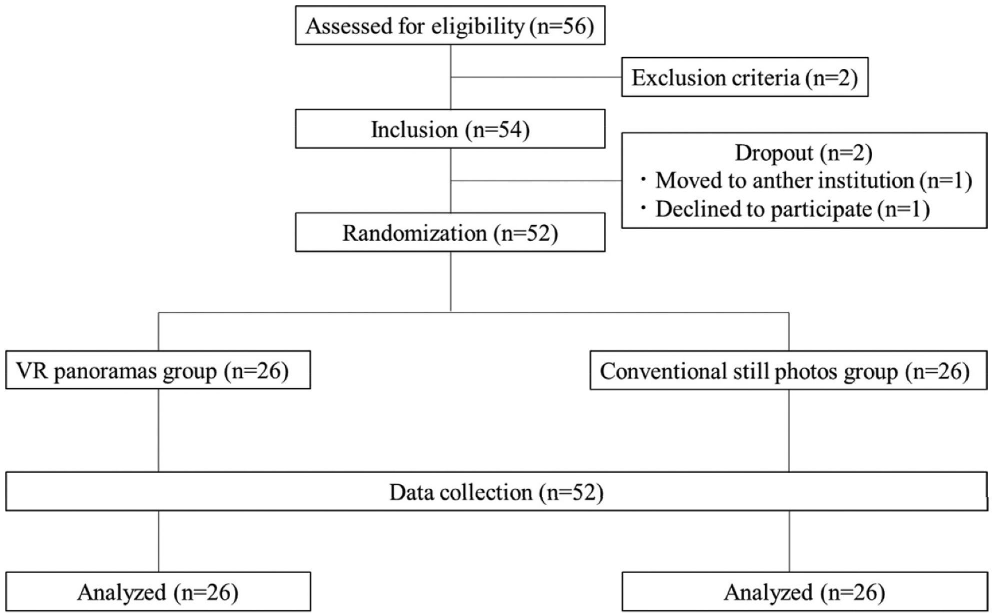
The study design, protocol, content and procedures were approved by the Medical Ethics Committee of Kyoto University Graduate School of Medicine (registration number: C1352-1). Following this protocol, the examiner provided participants with a detailed explanation of the study (its purpose, methods, risks and benefits, treatment, adverse effects, confidentiality, anonymity, conflicts of interests, and right to withdraw). We obtained the participants' written consent to enrol in this study, and excluded participants who could not get family approval as well.

2.3. Procedure

Figure 1 shows the flowchart of participant selection and inclusion. One week before the intervention, with participants' consent, we conducted neuropsychological assessments at their facilities or nursing homes in quiet private rooms where participants and the trained nurse could speak one-on-one. We conducted post-intervention assessments in a similar setting one week after the end of the intervention. In addition, we ensured that the participants who were on medication continued to take the same medication throughout our intervention. We randomly assigned them either to the VR panoramas group or the conventional still photos group based on a computer-generated random listing of the two group assignments using permuted blocks.

We selected photos of material and cultural artifacts belonging to the period from the 1940s to the 1960s-corresponding to the childhoods of our respondents-from Nippon Showa Mura, Showa Era Lifestyle Museum, and Takayama Showa Museum, with permission from the museums for the use of their images. They included scenes from plays, school classrooms, a house with a hearth or fireplace, holiday doll decorations, a shopping street, candy shops, interiors of cafeterias, and an appliance store. The selected scenes of a traditional Japanese house are actually used in

Figure 1. Flowchart of the study.



a reminiscence therapy center and museum in Japan, although they have reported no academic results nor rationale.

A certified nurse trained in reminiscence therapy conducted all eight reminiscence sessions, using 9.7 inch-tablet iPads® (Apple Inc, CA, USA) or conventional printed panoramic photos of the same subjects. Participants assigned to the VR panoramas group viewed 360-degree panoramic displays that could be enlarged or reduced freely on tablets, while for each scene, the control group viewed four printed panoramic covering 90 degrees each. Because we were concerned to avoid any side effects of VR in older adults, we used VR tablet devices with low risk of VR sickness. Examples of the equipment (tablet-type devices and photos) and conventional still photos used are shown in Figure 2A, 2B, and 2C.

The reminiscence therapies consisted of eight weekly one-on-one 30- to 45-minute sessions, wherein each participant reminisced with the trained nurse while viewing the panoramic photos either on iPads or color-printed on paper. A certified nurse trained in reminiscence therapy manipulated the screen and explored the environment with those in the VR group, so participants did not need to master iPad technology, which none had previously experienced. During the therapy, participants in both groups were prompted and encouraged to talk about the images they were observing.

2.4. Outcome measures

2.4.1. Primary outcome measure

We evaluated the effects of reminiscence therapy on patients' cognitive function using the standard Japanese translation of the MMSE, based on Folstein et al. (1975). In the MMSE, total scores range from 0 to 30 points, where a higher total score indicates a higher level of cognitive function. MMSE totals are widely used internationally in screening and assessing dementia. Although we recognize that the MMSE is not designed to measure short-term changes, but we based this decision on a previous study (Duru Aşiret & Dutkun, 2018) that also used the MMSE to evaluate the effects of individual reminiscence therapy conducted weekly for eight weeks, as we

Figure 2. A. An example of photos used in this study. B. VR panorama example (iPad) used in this study. C. Conventional still photo example used in this study.

did. Since most of our participants were octogenarians with attention spans too short to tolerate more intensive measurement tools, we used a brief set of assessment tools including the MMSE.

2.4.2. Secondary outcomes measures

To measure secondary outcomes, we used eleven subscale scores of the MMSE (including orientation to time and place, registration, attention and calculation, recall, naming, repetition, comprehension, reading, writing, and drawing), the revised PGC morale scale (Lawton, 1975), multidimensional observation scale for elderly subjects (MOSES) (Helmes et al., 1987), trail making test parts A and B (TMT-A, TMT-B) (Reitan, 1958), and the word fluency test (WFT) (Saito et al., 1992).

2.4.3. MMSE subscale scores

MMSE (Folstein et al., 1975) subscale scores consist of eleven categories, orientation to time, orientation to place, registration, attention and calculation, recall, naming, repetition, comprehension, reading, writing, and drawing. A previous study (Choe et al., 2020) has shown that MMSE subscale scores are also clinically usable measures, and we believe that assessing MMSE subscales provides useful information for predicting the cognitive functional status of our participants.

2.4.4. Revised PGC Morale scale score

The revised PGC morale scale is a 17-item questionnaire to evaluate subjective well-being for older adults, using three domains: agitation, attitude toward one's own aging, and lonely dissatisfaction (Lawton, 1975). A score of 1 or 0 is given for each item, where a higher total indicates higher subjective well-being.

2.4.5. Multidimensional Observation Scale for Elderly Subjects (MOSES)

MOSES evaluates the physical, cognitive, emotional, and social functions of older adults, using five categories: self-care, disappointment, depression, irritability/anger, and withdrawal, a total of 40 questions about behavior and symptoms (Helmes et al., 1987). Typically, each MOSES subscale score is calculated to evaluate each of these categories, where higher scores indicate better evaluations in each category. Reliability and validity in Japanese have been confirmed.

2.4.6. Trail making test-A and -B

TMT-A and TMT-B (Reitan, 1958) are used to evaluate executive function. TMT-A evaluates patients' selective attention by instructing them to connect numbers from 1 to 25, and TMT-B evaluates their ability to handle one type of information while being conscious of other information by alternately examining numbers and Japanese phonics. TMT-B requires attention and concept conversion abilities. Therefore, TMT-B is widely used as a performance function test. Participants get high scores for being able to perform the task in a short time.

2.4.7. Word Fluency Test (WFT) (in Japanese)

WFT (Saito et al., 1992) is a cognitive neuropsychological task measuring verbal and frontal lobe functions. Its Category Fluency test uses "Animals," "Fruits," and "Vehicles," and its Character Fluency Test uses words starting with the Japanese characters "*shi*," "*i*," and "*re*". In the WFT Category Fluency Test (reflecting temporal lobe function), participants have one minute to name as many objects as they can belonging to a specified category, and in the Character Fluency Test, and one minute to name words starting with a designated character (reflecting frontal lobe function). The number of words belonging to specific categories and the number of words beginning with specific characters are totalled, with higher totals indicating higher functions.

2.5. Statistical analysis

The primary measure of outcome was the change in MMSE score before and after the intervention. A sample size of 26 participants in each group was required so the study would have 80% power, using a two-sided t-test at a significance level of 0.05 to detect an effect size of 0.80. Taking possible dropouts into consideration, we decided to enrol 54 participants (27 participants in each group).

Categorical variables were expressed as numbers and percentages while continuous variables were expressed as means and standard deviations or medians and ranges as appropriate. We compared the scores between the VR panoramas group and the conventional still photos group using t-tests, and assessed changes from the baseline within the group using paired t-tests. No adjustments were made for multiple testing since the change of MMSE score was set as the

Table 1. Participants' demographic characteristics

	VR panoramas group (n = 26)	Conventional still photos group (n = 26)	*p*-value
Mean age (range)–year	85.1 (69–98)	87.0 (68–98)	0.40
Sex (female)–n (%)	19 (73.10)	21 (80.80)	0.52
Elderly care service–n (%)			1.00
Senior day care	10 (38.50)	10 (38.50)	
Nursing home	16 (61.50)	16 (61.50)	

Table 2. MMSE total and subscale scores

	VR panoramas group (n = 26)			Conventional still photos group (n = 26)			Group comparison	
	Baseline	Post-intervention	Change from baseline	Baseline	Post-intervention	Change from baseline	Difference (95% CI)	*p*-value[a]
	Mean (SD)	Mean (SD)	Difference (95% CI)	Mean (SD)	Mean (SD)	Difference (95% CI)		
Total	23.65 (1.57)	25.04 (2.09)	1.38 (0.78, 1.99)	23.69 (1.38)	24.39 (2.87)	0.69 (-0.28, 1.67)	0.69 (-0.42, 1.81)	0.22
Orientation for time	3.04 (1.34)	3.77 (0.95)	0.73 (0.24, 1.22)	2.84 (1.11)	3.39 (1.02)	0.60 (0.22, 0.98)	0.13 (-0.48, 0.74)	0.67
Orientation for place	4.50 (0.71)	4.50 (0.81)	0.00 (-0.30, 0.30)	4.39 (0.64)	4.19 (1.10)	-0.19 (-0.70, 0.32)	0.19 (-0.39, 0.77)	0.51
Registration	3.00 (0.00)	3.00 (0.00)	0.00 (0.00, 0.00)	3.00 (0.00)	2.96 (0.20)	-0.04 (-0.12, 0.04)	0.04 (-0.04, 0.12)	0.32
Attention and calculation	3.04 (1.56)	3.27 (1.40)	0.23 (-0.34, 0.81)	3.46 (1.58)	3.92 (1.32)	0.46 (-0.09, 1.01)	-0.23 (-1.00, 0.55)	0.55
Recall	1.77 (1.07)	1.96 (0.96)	0.19 (-0.25, 0.64)	1.85 (1.16)	1.58 (1.10)	-0.27 (-0.94, 0.40)	0.46 (-0.32, 1.25)	0.24
Naming	2.00 (0.00)	2.00 (0.00)	0.00 (0.00, 0.00)	2.00 (0.00)	2.00 (0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	-
Comprehension	3.00 (0.00)	3.00 (0.00)	0.00 (0.00, 0.00)	3.00 (0.00)	3.00 (0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	-

SD: standard deviation; MMSE: mini mental state examination
A dash (-) indicates that *p*-value cannot be obtained.
a) Group comparisons of changes from baseline were analyzed using t-test.

primary outcome. For our primary analysis method, we selected the t-test based on previous works using MMSE (Kirk et al., 2019; Lai et al., 2004). Thus, the results from secondary endpoints should be considered exploratory, and inference drawn from the endpoints may not be reproducible. *P*-values less than 5% were considered significant. All statistical analyses were performed using SAS version 9.4 and JMP Pro 14.0.0. (SAS Institute, Cary, NC, USA).

3. Results

3.1. Recruitment

56 PwD expressed the intention to participate in this study. Two PwD were excluded based on our exclusion criteria, and two more PwD dropped out before randomization (one moved to another institution; the other could not get their family's consent). Ultimately, 52 participants completed the trial and were analyzed. Among the 52 participants, 26 were randomly assigned to the VR panoramas group and 26 to the conventional still photos group.

3.2. Characteristics of the study participants

Table 1 shows descriptive baseline characteristics. The mean age was 85.1 (range, 69 to 98) in the VR panoramas group and 87.0 (range, 68 to 98) in the conventional still photos group. Among the 52 participants who completed the session, 32 of 52 participants (61.5% of each group) were recruited from senior day facilities, while 20 of 52 (38.5% of each group) participants lived in nursing homes. All participants completed the MMSE, but some refused to take the other examinations, so the number of examinees varied depending on the examination scales. The characteristics of the VR panoramas group and conventional still photos group were generally well balanced, as shown in Table 1.

3.3. Reminiscence therapy effects

The effects of reminiscence therapy on cognitive functions are shown in Tables 2 and 3. The detailed results are shown below.

3.3.1. MMSE

Regarding the effects of reminiscence therapy on cognitive function, the primary outcome of the total MMSE score did not achieve the primary outcome; it failed to detect any significant difference between the VR panoramas group and the conventional still photos group. The difference in mean total changes from the baseline to post-intervention between the two groups was 0.69 points (95% confidence interval [CI], −0.42 to 1.81; *p*-value = 0.22) (Table 2). The remaining results should be interpreted as exploratory. When the cognitive function was measured by the MMSE in and compared before and after the intervention within VR panoramas and conventional still photos, showed reminiscence therapy increased cognitive abilities in both groups (Figure 3).

MMSE sub-scores showed no change after intervention in "naming," "comprehension," and "reading," since most of the participants answered these questions correctly even before the intervention. Among the sub-scores for "orientation for place," "registration," "attention and calculation," "recall," "repetition," "writing," and "drawing," the mean change from baseline for "recall" was 0.46 points (95% CI, −0.32 to 1.25; *p*-value = 0.24). Both groups showed a noteworthy increase in "orientation for time." The mean changes from baseline in the VR panoramas group was 0.73 points (95% CI, 0.24 to 1.22; *p*-value < 0.01) and in the conventional still photos group it was 0.60 points (95% CI, 0.22 to 0.98; *p*-value < 0.01); the difference in mean change from baseline between the two groups for "orientation for time" was 0.13 points (95% CI, −0.48 to 0.74; *p*-value = 0.67) (Table 2 and Figure 4).

3.3.2. Revised PGC Morale Scale score

Remarkably, the difference in the degree of improvement of the revised PGC morale scale score was greater in the VR panoramas group than in the conventional still photos group. We observed a difference of the mean change from baseline to post-intervention in the group comparison of 1.68 points (95% CI, 0.50 to 2.86; *p*-value < 0.01) (Table 4 and Figure 5) which contrasted with that in the MMSE scores. In the VR panoramas group, the total mean of the revised PGC morale scale

Table 3. MMSE subscale scores (responses 1 or 0)

		VR panoramas group (n = 26)		Conventional still photos group (n = 26)	
		Baseline	Post-intervention	Baseline	Post-intervention
MMSE subscale	Score	n (%)	n (%)	n (%)	n (%)
Repetition	1	25 (96)	26 (100)	25 (96)	25 (96)
	0	1 (4)	0 (0)	1 (4)	1 (4)
Reading	1	26 (100)	26 (100)	26 (100)	26 (100)
	0	0 (0)	0 (0)	0 (0)	0 (0)
Writing	1	18 (69)	20 (77)	17 (65)	19 (73)
	0	8 (31)	6 (23)	9 (35)	7 (27)
Drawing	1	17 (65)	20 (77)	14 (53)	17 (65)
	0	9 (35)	6 (23)	12 (46)	9 (35)

MMSE: mini-mental state examination

score before the intervention was 12.56 (standard deviation [SD] = 3.90), rising to a total mean score of 13.52 (SD = 2.93) after the intervention, an increase of 0.96 points (95% CI, 0.08 to 1.84). On the other hand, the conventional still photos group's total mean of the revised PGC morale scale score before the intervention was 14.20 (SD = 2.75). It dropped to 13.48 (SD = 2.90) after the intervention, a change of −0.72 points (95% CI, −1.56 to 0.12).

By analyzing the revised PGC morale scale score, we found that the difference in mean change from baseline to post-intervention between the two groups for Question 8, "As I get older, things are (better/worse) than I thought they would be." was 0.36 points (95% CI, 0.02 to 0.70; *p*-value = 0.04); for Question 11, "I have a lot to be sad about." was 0.20 points (95% CI, 0.30 to 0.37; *p*-value = 0.02); and for Question 13, "I get mad more than I used to." was 0.16 points (95% CI, 0.00 to 0.32; *p*-value = 0.05). The effects of reminiscence therapy on the revised PGC morale scale score are shown in Table 5.

3.3.3. Multidimensional Observation Scale for Elderly Subjects (MOSES)

Supplementary Table 1 shows the results from the MOSES scale, revealing no major differences between the baseline and post intervention scores of VR panoramas group and the conventional still photos group on these five items (difference of the group comparison in "self-care" = 0.50 points; 95% CI, −0.76 to 1.76, *p*-value = 0.43), (difference of the group comparison in "disorientation" = 0.81 points; 95% CI, −0.34 to 1.95; *p*-value = 0.16), (difference of the group comparison in "depression" = 0.50 points; 95% CI, −0.28 to 1.28; *p*-value = 0.20), (difference of the group comparison in "irritability" = 0.42 points; 95% CI, −0.20 to 1.05; *p*-value = 0.18), (difference of the group comparison in "withdrawal" = 0.77 points; 95% CI, −0.37 to 1.90; *p*-value = 0.18).

3.3.4. Trail Making Test-A and -B

In comparing these two items before and after the intervention, no major difference was found (difference of the group comparison in "TMT-A" = −18.83 points; 95% CI, −61.74 to 24.07; *p*-value = 0.37); (difference of the group comparison in "TMT-B" = −13.25 points; 95%CI, −108.94 to 82.44; *p*-value = 0.76). The results of TMT-A and B are also shown in Supplementary Table 1.

3.3.5. Word Fluency Test (WFT)

No major difference was found in the measured total scores of these items before and after reminiscence intervention, (difference of the group comparison in "WFT Animals" = 0.26 points; 95% CI, −1.27 to 1.79; *p*-value = 0.74), (difference of the group comparison in "WFT Fruits" = −0.39 points; 95% CI, −1.73 to 0.95; *p*-value = 0.56), (difference of the group comparison in "WFT Vehicles" = 0.16 points; 95% CI, −1.00 to 1.32; *p*-value = 0.79), (difference of the group comparison in "WFT character *shi*" = 0.09

Figure 3. Baseline and Post-intervention boxplots of total MMSE scores for each group.

Diamonds in each boxplot represent mean scores. In the VR panoramas group, the change from the baseline of the MMSE total was 1.38 points (95% CI, 0.78 to 1.99). In the conventional still photos group, the change from the baseline of the MMSE total was 0.69 points (95% CI, −0.28 to 1.67). Two-way analysis of variance showed *p*-value = 0.45 for the group and *p*-value = 0.01 for the time points.

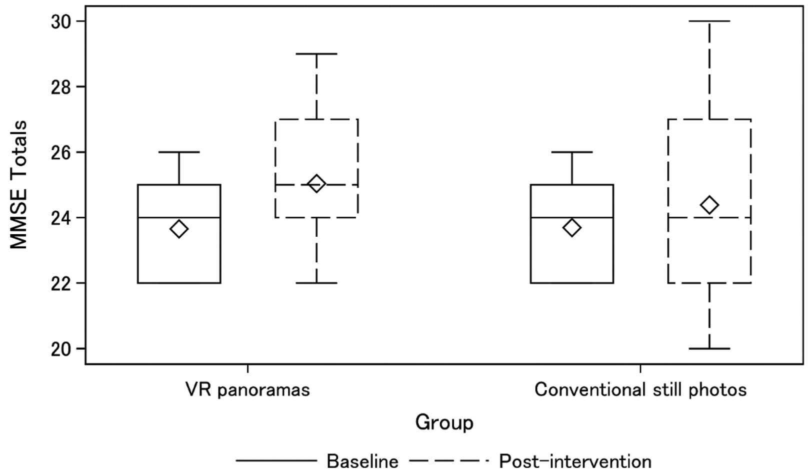
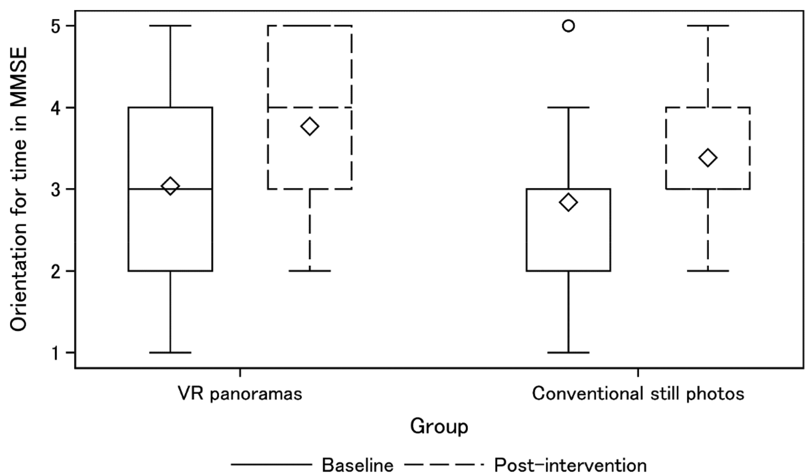


Figure 4. Baseline and Post-intervention boxplots of the orientation for time in MMSE for each group.

Diamonds in each boxplot represent mean scores. Circles show outliers. In the VR panoramas group, the change from the baseline of the orientation for time in MMSE was 0.73 points (95% CI, 0.24 to 1.22). In the conventional still photos group, the change from the baseline of the orientation for time in MMSE was 0.66 points (95% CI, 0.22 to 0.98). Two-way analysis of variance showed *p*-value = 0.19 for the group and *p*-value < 0.01 for the time points.



points; 95% CI, −1.30 to 1.47; *p*-value = 0.90), (difference of the group comparison in "WFT character *i*" = −0.06 points; 95% CI, −1.29 to 1.17; *p*-value = 0.92), (difference of the group comparison in "WFT character *re*" = 0.32 points; 95% CI, −0.75 to 1.39; *p*-value = 0.55). The effects of reminiscence therapy on linguistic cognitive function are shown in Supplementary Table 1.

4. Discussion

This study sought to improve cognition of PwD using non-pharmacological reminiscence therapy. We compared the effects of two different types of reminiscence interventions, using VR photos on iPads, and using conventional still color photos. MMSE results showed that both methods improved the cognitive functions of PwD. Although the VR panoramas group showed a more obvious increase, there was no significant difference in the magnitude of improvement between the two groups. Unexpectedly, on the revised PGC morale scale the improvement in the scores of the VR panoramas group was remarkably higher than that of the conventional still photos group. No clear differences between groups were observed before or after the intervention in either MOSES or in TMT and WFT. Since we designed our sample size based on our primary outcome, the total score of

Table 4. Revised PGC morale scale total score

	VR panoramas group (n = 25)			Conventional sill photos group (n = 25)			Group comparison	
	Baseline	Post-intervention	Change from baseline	Baseline	Post-intervention	Change from baseline	Difference (95% CI)	*p*-value[a]
	Mean (SD)	Mean (SD)	Difference (95% CI)	Mean (SD)	Mean (SD)	Difference (95% CI)		
Total	12.56 (3.90)	13.52 (2.93)	0.96 (0.08, 1.84)	14.20 (2.75)	13.48 (2.90)	-0.72 (-1.56, 0.12)	1.68 (0.50, 2.86)	< 0.01

SD: standard deviation; PGC: the Philadelphia Geriatric Center
a) Group comparisons of changes from baseline were analyzed using t-test.

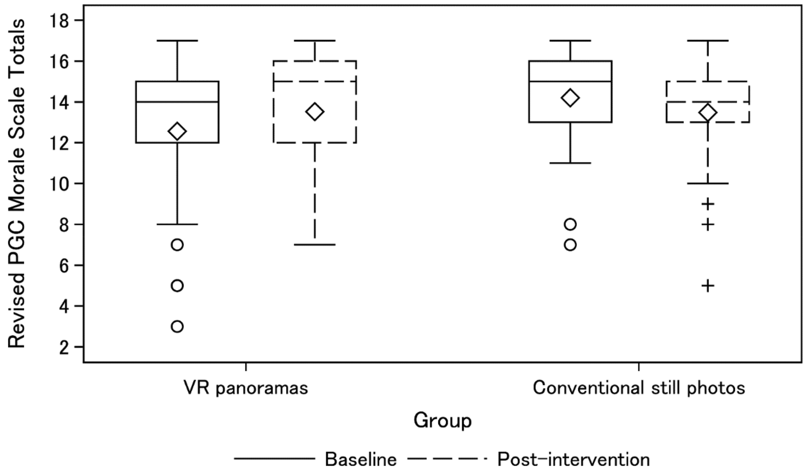


Figure 5. Boxplots of revised PGC morale scale before and after intervention for each group.

Diamonds in each boxplot represent mean scores with SD. Circles and pluses show outliers. In the VR panoramas group, the change from the baseline of the revised PGC morale scale total was 0.96 points (95% CI, 0.08 to 1.84). In the conventional still photos group, the change from the baseline of the revised PGC morale scale was −0.72 points (95% CI, −1.56 to 0.12). Two-way analysis of variance showed *p*-value = 0.21 for the group and *p*-value = 0.85 for the time points.

the MMSE, we consider the secondary outcomes of the revised PGC morale scale, MOSES, TMT, and WFT as our exploratory evaluation results.

Although we observed good tendencies in the results other than the MMSE and the revised PGC morale scale, the score changes were not notable. There may be several reasons for the insignificant changes. MMSE scores were collected from all participants, but some participants refused to take the other tests, which reduced the number of positive results. Or perhaps the intensity of the intervention may not have been sufficient to affect these indicators. In that case, we need to increase intervention sessions to get noteworthy results.

Compared to other non-pharmacological therapies, a systematic review showed that music therapy may improve emotional well-being and QOL for PwD, but found low-quality evidence on cognitive measures such as the MMSE (Van Der Steen et al., 2018). Since each non-pharmacological treatment has its own advantages and disadvantages, it is necessary to choose methods that best suit the purpose of each intervention.

In our study, reminiscence therapy improved cognitive function in both VR panoramas and conventional still photo groups. To our surprise, the level of improvement in temporal orientation was high, which was a novel finding in the area of reminiscence therapy. We suspect that this is because we targeted older adults with mild dementia, who had greater potential for recovery. Older adults with mild cognitive decline exhibit temporal disorientation from the onset of memory disturbance. Brum et al. (2009) mentioned that cognitive training improves temporal orientation. Cognitive training and reminiscence therapy are also non-pharmacological therapies. In other words, there is a possibility that reminiscence therapy can improve temporal orientation, as can physical rehabilitation (Fujiyoshi et al., 2020) and even diet (De la Rubia Ortí et al., 2018). Thus, it is conceivable that individual reminiscence therapy may also improve temporal orientation over time (Kirk et al., 2019).

Regarding the effects of reminiscence therapy, some previous research also reports appreciable improvement. Previous studies have shown that individual reminiscence therapy can improve not only the mood but also the cognitive functions of PwD (Lai et al., 2004; Van Bogaert et al., 2016; Yasuda et al., 2009). Other reports demonstrated that personalized interventions using life storybooks

Table 5. Revised PGC morale scale subscale scores

	VR panoramas group (n = 25)			Conventional sill photos group (n = 25)			Group comparison	
	Baseline	Post-intervention	Change from baseline	Baseline	Post-intervention	Change from baseline	Difference (95% CI)	*p*-value[a]
	Mean (SD)	Mean (SD)	Difference (95% CI)	Mean (SD)	Mean (SD)	Difference (95% CI)		
Question1	0.68 (0.48)	0.68 (0.48)	0.00 (−0.21, 0.21)	0.84 (0.37)	0.68 (0.48)	−0.16 (−0.36, 0.04)	0.16 (−0.12, 0.44)	0.25
Question2	0.76 (0.44)	0.80 (0.41)	0.04 (−0.15, 0.23)	0.72 (0.46)	0.88 (0.33)	0.16 (0.01, 0.31)	−0.12 (−0.36, 0.12)	0.31
Question3	0.72 (0.46)	0.84 (0.37)	0.12 (−0.06, 0.30)	0.84 (0.37)	0.88 (0.33)	0.04 (−0.04, 0.12)	0.04 (−0.29, 0.37)	0.81
Question4	0.80 (0.41)	0.88 (0.33)	0.08 (−0.09, 0.25)	1.00 (0.00)	0.92 (0.28)	−0.08 (−0.19, 0.03)	0.16 (−0.04, 0.36)	0.11
Question5	0.80 (0.41)	0.84 (0.37)	0.04 (−0.11, 0.19)	0.68 (0.48)	0.72 (0.46)	0.04 (−0.15, 0.23)	0.24 (−0.08, 0.56)	0.14
Question6	0.64 (0.49)	0.76 (0.44)	0.12 (−0.10, 0.34)	0.76 (0.44)	0.64 (0.49)	−0.12 (−0.37, 0.13)	0.24 (−0.08, 0.56)	0.14
Question7	0.88 (0.33)	0.88 (0.33)	0.00 (0.00, 0.00)	1.00 (0.00)	1.00 (0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	-
Question8	0.24 (0.52)	0.32 (0.48)	0.08 (−0.18, 0.34)	0.44 (0.51)	0.16 (0.37)	−0.28 (−0.50, −0.06)	0.36 (0.02, 0.70)	0.04
Question9	0.80 (0.41)	0.92 (0.28)	0.12 (−0.10, 0.34)	0.80 (0.50)	0.84 (0.37)	0.04 (−0.11, 0.18)	0.08 (−0.17, 0.33)	0.53
Question10	0.72 (0.46)	0.80 (0.41)	0.08 (−0.12, 0.28)	0.88 (0.33)	0.80 (0.41)	−0.08 (−0.19, 0.03)	0.16 (−0.07, 0.39)	0.16
Question11	0.80 (0.41)	0.96 (0.20)	0.16 (0.01, 0.31)	0.96 (0.20)	0.92 (0.28)	−0.04 (−0.12, 0.04)	0.20 (0.03, 0.37)	0.02
Question12	0.88 (0.33)	0.88 (0.33)	0.00 (−0.17, 0.17)	0.92 (0.28)	0.84 (0.37)	−0.08 (−0.19, 0.03)	0.08 (−0.12, 0.28)	0.42

(*Continued*)

Table5. (*Continued*)

	VR panoramas group (n = 25)			Conventional sill photos group (n = 25)			Group comparison	
	Baseline	**Post-intervention**	**Change from baseline**	**Baseline**	**Post-intervention**	**Change from baseline**	**Difference (95% CI)**	***p*-value[a]**
	Mean (SD)	**Mean (SD)**	**Difference (95% CI)**	**Mean (SD)**	**Mean (SD)**	**Difference (95% CI)**		
Question13	0.88 (0.33)	0.96 (0.20)	0.08 (−0.03, 0.19)	0.96 (0.20)	0.88 (0.33)	−0.08 (−0.19, 0.03)	0.16 (0.00, 0.32)	0.05
Question14	0.48 (0.51)	0.44 (0.51)	−0.04 (−0.26, 0.18)	0.68 (0.48)	0.56 (0.51)	−0.12 (−0.30, 0.06)	0.08 (−0.20, 0.36)	0.57
Question15	0.80 (0.41)	0.80 (0.41)	0.00 (−0.17, 0.17)	0.92 (0.28)	0.92 (0.28)	0.00 (0.00, 0.00)	0.00 (−0.16, 0.16)	1.00
Question16	0.72 (0.46)	0.84 (0.37)	0.12 (−0.02, 0.26)	0.88 (0.33)	0.88 (0.33)	0.00 (−0.17, 0.17)	0.12 (−0.09, 0.33)	0.26
Question17	0.96 (0.20)	0.92 (0.28)	−0.04 (−0.19, 0.11)	0.92 (0.28)	0.96 (0.20)	0.04 (−0.04, 0.12)	−0.08 (−0.24, 0.08)	0.33

SD: standard deviation; PGC: the Philadelphia Geriatric Center
A dash (–) indicates that *p*-value cannot be obtained.
a) Group comparisons of changes from baseline were analyzed using t-test.

have improved cognitive function and QOL as well (A. H. A. Hashim et al., 2015; A. Hashim et al., 2013; Subramaniam & Woods, 2016).

During our sessions, the intervention group using VR could freely enlarge, shrink, and adjust the angles of their panoramic images. The VR panoramas group that could tailor their images to their personal preferences seemed to enjoy more positive reminiscences which might be associated with effectiveness. Moyle et al. (2018) also observed that PwD experienced more pleasure and showed a greater level of alertness during VR sessions where participants experienced virtual forests. Their report was not reminiscence therapy, but taken together with our results, we may expect that VR experience may produce better responses.

Apart from reminiscence therapy, Benoit et al. (2015) asked healthy older volunteers to compare pictures and image-based virtual environments to assess (among other things) autobiographical memory before and after the intervention. They found that response rates for short sentences rose after the VR-based intervention, concluding that VR is well accepted even by older adults and stimulates their autobiographical memories.

Subramaniam and Woods (2016) used reminiscence therapy to evaluate digital photos and other visual materials chosen by the subjects themselves, rather than general photos of the old days chosen by the researcher as in this study. Many of their study participants showed improved depression scores, QOL, and autobiographical memories. Another report by A. Hashim et al. (2013) showed that a Muslim Alzheimer's disease patient recollected how to pray after an intervention utilizing a personalized-digital life storybook. Two years later, A. H. A. Hashim et al. (2015) demonstrated that personalized digital memory books not only enhanced reminiscence and stimulate cognitive functions. Digital applications that stimulated reminiscence and cognitive function satisfied and motivated their participants.

Although the number of reports is still few, the use of multimedia devices is now being introduced in the field of rehabilitation. However, the effectiveness for rehabilitation (Iosa et al., 2012) of electronic devices such as robots, brain-computer interfaces, or VR used in this intervention, has yet to be verified. Even less is known about the effects of electronic devices on reminiscence therapy. To our knowledge, this study is among the first intervention methods attempt to directly compare the effectiveness of tablet-based VR with that of conventional still photos in reminiscence therapy to assess changes in cognitive function for PwD.

We found that reminiscence therapy improved general cognitive function as seen in MMSE totals in both our VR panoramas and color-photo control groups. The magnitude of MMSE increase was noticeable only in our VR panoramas group, but the small number of our participants made it impossible to calculate a significant difference in cognitive function between the two groups. However, VR intervention showed advantages over the conventional intervention in other respects; those using VR showed higher subjective well-being as assessed on the revised PGC morale scale, suggesting that VR intervention may improve subjective well-being.

Among the questions of the revised PGC morale scale (Lawton, 1975), Questions 8, 11, and 13 of scale showed the greatest differences in this study, which involve all three factors that the scale measures: agitation, attitude toward one's own aging, and lonely dissatisfaction. In other words, VR reminiscence appears to have influenced all three factors that constitute the revised PGC morale scale score. However, the mechanism and process by which VR intervention affects these aspects of subjective well-being remain unknown. Future research is needed to clarify the reasons for the advantages of VR over the traditional photo prompts in improving patients' well-being.

Taken together, our finding that reminiscence therapy improved cognitive function was consistent with the results of previous studies. Our new finding was that VR panoramas increased the subjective well-being of the participants. Since subjective well-being is very important in the life and care of PwD, our findings suggest that panoramic VR may be helpful for them. Although our study is small-scale, it suggests that VR may have the potential to improve QOL by enhancing participants' subjective well-being, and these intriguing findings deserve further research in this important new area.

In this study, we found that VR intervention improved the cognitive function of patients with mild stage dementia. The next step is to investigate the possible effects on other symptoms such as BPSD, and on patients with moderate to severe dementia. In the future, we might use more personalized materials on VR-based devices, or adopt immersive VR with be stronger stimuli. More future studies are needed to examine the effective method and values of VR systems.

4.1. Limitations

Several limitations of this study should be mentioned. First, despite a disparity of up to 30 years participants' ages all, we used the same content for all. Ideally, we should have chosen content images more personally suited to the age of each participant. This intervention was conducted in an open-label manner, which also may have introduced some bias. Neither did we take into account differences in levels of dementia nor differences in fatigue occasioned by our interventions; future research might want to evaluate these variables more carefully. Finally, since we did not conduct follow-up long after the interventions, the long-term effects of such intervention remain unknown.

Regarding the effects of reminiscence therapy on types of dementia, this study included only older PwD diagnosed with mild dementia. In this study, we were not able to collect information about their types of dementia because the exact diagnoses of dementia were not recorded by the day care and nursing homes. As the effects of non-pharmacotherapy may vary with the type of dementia, ideally we should have included many more subjects with a wider range of dementias, including Alzheimer's or dementia with Lewy bodies, and should have analyzed the effects accordingly.

Our study cannot completely exclude the effects of medication for dementia from the effects of reminiscence therapy. Many participants might have been taking anti-cholinesterase inhibitors or memantine, but because their facilities did not provide this information, we were unable to determine what medications each person was taking. We did, however, ensure that there was no change in their previous medication during our intervention, making it less likely that the effects on cognition or well-being were due to their medication.

Our older patients' unfamiliarity with viewing VR tablet-type devices may have influenced our results. The participants, all born before 1955, seemed unfamiliar with using VR tablet-type devices, which have only recently become popular in Japan. Populations already familiar with manipulating tablets might display even greater satisfaction. Future studies should evaluate the effects of VR for young-onset dementia patients already accustomed to using tablet-type devices. With due precautions against adverse events, the use of more immersive VR headsets might also show greater effects.

5. Conclusions

We conclude that reminiscence therapy using either VR panoramas or conventional still photos produced similar cognitive improvement. Our finding that reminiscence therapy particularly improved temporal orientation is rather new and deserves exploration. Moreover, we discovered that VR panoramas effectively improved patients' subjective well-being. Thus, VR-based reminiscence therapy may positively impact the QOL of PwD. Since subjective well-being is very important in the life and care of PwD, our findings suggest that panoramic VR may be helpful for them. Although our study is small-scale, it suggests that VR reminiscence therapy may improve QOL by enhancing participants' subjective well-being.

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Supplementary material
Supplemental data for this article can be accessed here

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