Fully-immersive virtual reality instrumental activities of daily living training for mild dementia: a feasibility study

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Background: The purpose of this study was to confirm whether fully-immersive virtual reality instrumental activities of daily living training is safe and feasible for people with mild dementia.

Methods: The virtual reality program contents include simulation of instrumental activities of daily living training. Feasibility was assessed by means of responses to a self-report satisfaction questionnaire and the Simulator Sickness Questionnaire; and by analyzing the level of participants' immersion. Researchers assessed the instrumental activities of daily living scores, cognitive functioning, and mood changes pre- and post-intervention.

Results: A total of seven participants with mild dementia were recruited. The mean immersion score was 50.42±7.89 points, and the mean adherence was 83.71±6.10 points. Overall, the participants found the activities satisfying. Six participants experienced negligible side effects and one exhibited moderate side effects. After the training, the instrumental activities of daily living scores improved significantly (P=0.042). Performance on the Word List Delayed Recall test and Trail Making Test B showed improvements in all participants.

Conclusions: Fully-immersive, virtual reality-based, instrumental activities of daily living training is feasible for people with mild dementia and provides them with a high level of satisfaction and immersion. This program can help improve their capacities to carry out activities of daily living, their cognitive functioning, and mood. However, further research is needed for fully-immersive virtual reality instrumental activities of daily living training before it can be considered as a treatment option in people with mild dementia.

Keywords: Virtual reality; instrumental activities of daily living; mild cognitive impairment

Introduction

According to the World Alzheimer Report of 2018, 50 million people worldwide live with dementia, and the number increases every year (1).

This disorder is most common in older people. It is recognized as one of the greatest problems of the 21st century (2). Disability, particularly the loss of ability to

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perform activities of daily living (ADL), is a defining feature leading to a higher caregiver burden and eventually the need for alternative care or nursing home placement (3).

The Instrumental Activities of Daily Living (I-ADL) performance provides reliable measures of functional levels and dementia severity (4).

It is possible that I-ADL impairment may accelerate decline in the cognitive functioning of people with dementia (3).

The most important goal of rehabilitation is, therefore, to maintain independent daily living as long as possible through I-ADL training, even after the onset of cognitive deficiency. Hence, the onset of mild dementia, is a good time to begin training. This is because cognitive rehabilitation is based on relatively well-preserved cognitive abilities (5). Consequently, such individuals may benefit from interventions.

I-ADL training in hospitals is limited due to constraints on time and space. Although it would be best for clinicians to observe and evaluate their performances of the I-ADL, they currently have to rely on surveys of patients and care givers.

Multisensory virtual reality (VR) platforms, which help people experience real-life situations, are advanced, adaptable, and easy to use (6-10). These technologies can be used for cognitive rehabilitation in people with dementia (11,12).

It has been reported that immersive VR can improve cognitive functioning (13-15) because it presents goal-oriented tasks and enhances neuroplasticity by means of repetition (16).

However, only a few studies have been conducted on cognitive training using fully-immersive type for people with mild dementia (7,17). Moreover, most VR studies focused on cognitive improvement, but not on improving the I-ADL (18).

The purpose of this study is, therefore, to confirm whether VR is safe, feasible, and effective in I-ADL training. We present the following article in accordance with the TREND reporting checklist (available at https://apm.amegroups.com/article/view/10.21037/apm-22-847/rc).

Methods

Participants

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Asan Medical Center (No. 2020-1861) and informed consent was taken from all the patients. Based on previous studies (19,20), an estimate of at least seven to ten participants are needed to confirm feasibility.

From July 2021 to February 2022, people with mild dementia who visited the outpatient clinic in the Department of Rehabilitation Medicine at the Asan Medical Center were prospectively enrolled.

Participants were included on the basis of: (I) a Korean mini-mental state examination (K-MMSE) score >17, or a Global Deterioration Scale (GDS) score of 2–5; (II) a mild dementia diagnosis by a neuropsychological assessment conducted by a neuropsychologist; and (III) the physical ability to perform the VR training (Berg balance scale score >41, with a minimum of one good grade result for an upper extremity manual muscle test).

A total of seven participants were enrolled and underwent the screening process.

Intervention

This study evaluated the feasibility of a fully-immersive VR I-ADL training program.

Our research team and bHaptics jointly developed this training program. We presented the contents of the most necessary tasks for people with mild dementia based on the items outlined in the I-ADL. On the other hand, bHaptics was in charge of the technical implementation.

Participants were subjected to 10 sessions (2 or 3 times a week) of fully-immersive I-ADL training over 4 weeks.

Highlight box

Key findings
- Fully-immersive, virtual reality-based, instrumental activities of daily living (I-ADL) training is feasible for people with mild dementia and provides them with a high level of satisfaction and immersion.

What is known and what is new?
- Most of the VR studies in people with mild dementia have been developed for cognitive improvement. However, this study is focused on the I-ADL. This is the first study to directly provide I-ADL contents for participants who were having difficulties carrying out their daily life activities.

What is the implication, and what should change now?
- Although the maintenance of I-ADL is important for people with mild dementia, I-ADL training is not easy to implement in a resource-limited environment, such as a hospital. Therefore, we believe that this study on the intervention using VR can be of great help in the future.
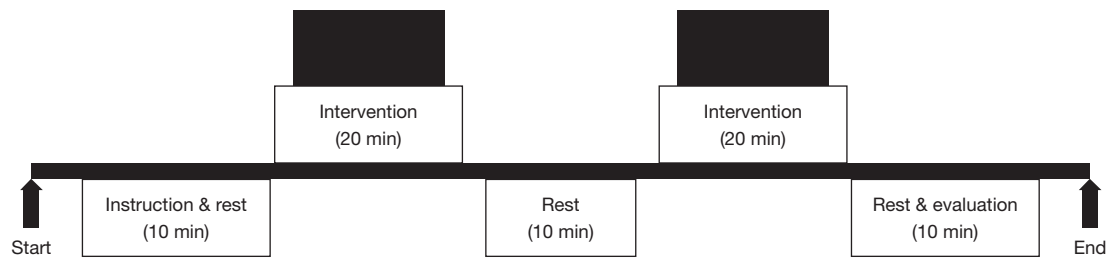
Figure 1 VR intervention diagram. Design for the VR training. The total training duration was 70 min (two 20-min VR training sessions, and three 10-min resting sessions), held 2–3 times a week for 4 weeks. VR, virtual reality.

Each session lasted for 70 min, including instruction time regarding VR devices and resting time between VR training, as described in *Figure 1*.

The program was led by an occupational therapist. Participants were presented with missions that related to daily activities corresponding to items in the I-ADL. Each mission had subtasks for the participants to perform. Five different VR missions were used (*Figure 2*). Participants could choose those with which they struggled in daily life.

If a participant failed to perform a task during their mission, a hint was provided. If the participant was successful, he or she moved on to the next task (*Figure 3*).

The I-ADL factors relating to the composition of each mission are described in *Table 1*.

VR program

A 360-degree video allowed participants to look in every direction to maximize the realism of situations.

A Valve Index (Valve Corporation, Bellevue, WA, USA) VR head-mounted display with Valve Index Controllers were used throughout the experiment. The controller was particularly appropriate for the experiment because it allowed the participants to grab and release virtual objects more naturally with their hands, rather than by pressing buttons. Various objects could be manipulated using Valve Index Controllers It allowed participants to interact with the environment and move animated objects through their hand and arm movements.

The participants were seated next to the therapist to prevent safety problems during the VR sessions.

Feasibility

We evaluated the participants' satisfaction with the VR I-ADL training using a self-report questionnaire based on a 10-point Likert-type scale. There were four items in the questionnaire: overall satisfaction, motivation, stability, and fatigue. Higher scores indicated more positive results.

To assess immersion, researchers asked the participants to respond to a presence questionnaire that consisted of nine items, each scored out of seven points (Appendix 1). To evaluate the participants' tolerance for VR, the researchers measured adherence, which was calculated as average actual execution time [actual duration of execution (min)/20 min (1 session) × 100 (%)] for all sessions. We also asked the participants to respond to the Simulator Sickness Questionnaire (SSQ) (Appendix 2) that determined the subjective severity ratings of 16 symptoms on a scale from 0 (no perception) to 3 (severe perception) after the VR intervention. The ratings for the individual symptoms were grouped into three non-mutually exclusive categories representing symptoms for nausea (N), oculomotor disturbance (O), and disorientation (D). The score of each category was defined as the sum of its symptom scores. Higher scores indicated stronger perceptions of the symptoms. Based on a large sample of SSQ data gathered from military pilots, it is suggested that total scores can be associated with negligible [<5], minimal [5–10], significant [10–15], or concerning [15–20] symptoms (21-23).

Outcome

Cognitive functioning was assessed by psychology specialists according to standardized methods. Global cognitive functioning was assessed with the K-MMSE (24).

Cognitive functioning was evaluated in detail with the Korean Version of the Consortium to Establish a Registry for Alzheimer's Disease Assessment Packet (CERAD-K), which is a reliable and valid equivalent of the English version of the CERAD clinical and neuropsychological assessment batteries (25). The battery includes verbal fluency, Boston

Figure 2 VR mission. Participants could choose one of the following five missions: (A) cooking food; (B) getting ready to go out; (C) ordering food; (D) grocery shopping; (E) cleaning. VR, virtual reality.
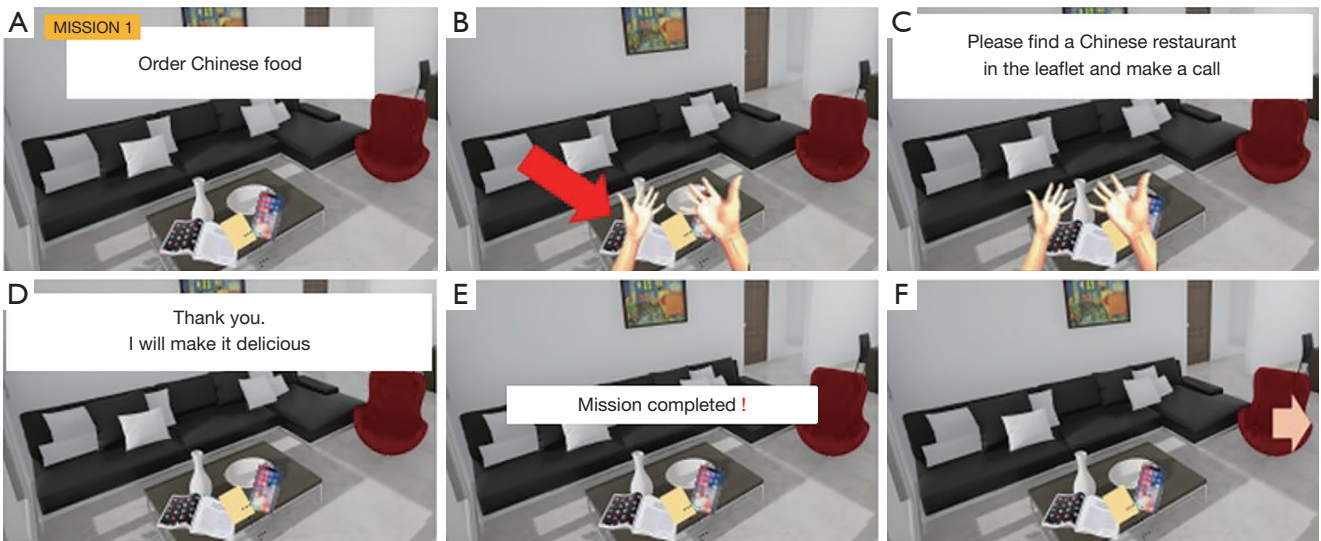
Figure 3 VR flow. Participants performed the mission in the following order: (A) mission presentation; (B) execution of sub-task; (C) failure in sub-task (hints for each step); (D) sub-task success; (E) mission success/fail; (F) move on to the next mission. VR, virtual reality.

Table 1 Virtual reality I-ADL training mission contents

Missions	Places	Factor of I-ADL	Stage of mission	Sub-task
Cleaning	House (kitchen, living room)	Home establishment and management	3	Separate garbage; wipe the table; tidy up the desk
Grocery shopping	Grocery store	Shopping; financial management	4	Getting ready to go grocery shopping; grocery shopping; pay money; organization purchased things
Cooking (instant noodle)	House (kitchen)	Home establishment and management; meal preparation and clean up	4–5 (the stage is different by grade)	Ready to cook instant noodle; boiling water; cooking instant noodle; table setting; washing and organizing dishes
Going to the hospital	House	Health management and maintenance	4	Choosing the right clothes for the season; picking seasonal items; choosing essential things; do a safety check
Ordering food	Food court	Shopping; financial management	2	Ordering food; importing ordered food to seat

I-ADL, instrumental activities of daily living.

naming test, word list memory, constructional praxis, word list recall, word list recognition, constructional recall, and trail making tests.

The Seoul-IADL (S-IADL) was used for the I-ADL evaluation. It is a reliable assessment for the functional disabilities of Korean people with dementia. Particularly, the S-IADL has a higher sensitivity and greater specificity than other I-ADL instruments, making it useful for the early detection of dementia (26). S-IADL consists of 15 I-ADL items, and each item is rated from 0 (no impairment) to 3 (severe impairment), with a highest possible total score of 45 points. Both participants and caregivers answered the questionnaire.

Each participant's mood was assessed by the Beck Depression Index (BDI), which contains 21 items that are rated on a four-point scale from 0 (symptom absent) to 3 (symptom severe) (27).

Statistical analysis

Baseline characteristics and assessment data are expressed in terms of the mean and standard deviation (SD) for continuous variables. The Wilcoxon signed-ranks test was used to evaluate differences in the I-ADL, and BDI, both pre- and post-intervention. A P value <0.05 was considered statistically significant. SPSS Statistics 25.0 for Windows (IBM Corp, Armonk, NY) was used for all analyses.

Results

A total of seven participants with mild dementia were enrolled in this study.

There were no dropouts with serious side effects.

Table 2 describes the demographics of the study population, dementia type, global cognitive functioning, and baseline physical functioning.

Feasibility

During the VR program, the researchers observed the participants' acceptability, immersion, and tolerance (*Table 3*). The acceptability score (emotion, motivation, security, fatigue) was evaluated as high. The mean immersion score was 50.42±7.89 points. The mean adherence (an indicator of VR tolerance) was 83.71±6.10 points. In the SSQ, another indicator of tolerance, only one participant revealed a moderate motion sickness side effect, and six participants exhibited minimal or negligible side effects (*Figure 4*).

Outcome

The answers to each item of the I-ADL were consistent between the caregiver and participant. I-ADL scores improved significantly after VR training. Positive changes were also observed on the BDI (*Table 4*).

In the CERAD-K, improvement was observed in Word List Delayed Recall test and the Trail Making Test-B (TMT-B) between the pre- and post-intervention in all participants (*Table 5*). Two participants, however, failed to complete the TMT-B test due to impairments in their cognitive functioning. Thus, only five people successfully completed the TMT-B test. There were no significant

Table 2 Characteristics of participants

No.	Age (years)	Gender	Dementia type	K-MMSE	GDS	BBS	MMT
1	76	Male	Vascular	18	4	51	N/N
2	57	Male	Vascular	28	3	49	N/N
3	67	Male	Vascular	22	4	53	N/N
4	69	Male	Alzheimer	25	4	51	N/N
5	69	Female	Frontotemporal	22	4	50	N/N
6	73	Male	Vascular	24	5	50	N/N
7	86	Female	Alzheimer	21	3	49	N/N

K-MMSE, Korean version of the Mini-Mental-State-Exam; GDS, Global Deterioration Scale; BBS, Berg Balance Scale; MMT, Manual Muscle Test.

Table 3 Feasibility of full-immersive VR I-ADL training (N=7)

No.	Acceptability				Presence	Adherence
	Satisfaction	Motivation	Stability	Fatigue		
1	9	9	9	9	54	94
2	9	9	10	9	33	82
3	9	9	9	9	52	81
4	10	10	10	10	54	75
5	9	8	9	8	55	83
6	9	9	8	7	50	89
7	7	7	5	7	55	82
Mean ± SD	8.85±0.89	8.71±0.95	8.57±1.71	8.42±1.13	50.42±7.89	83.71±6.10
Range	7–10	7–10	5–10	7–10	33–55	75–94

VR, virtual reality; I-ADL, instrumental activities of daily living; SD, standard deviation.

differences in other parameters, between pre- and post-intervention performances.

Discussion

We developed an I-ADL training program using a fully-immersive VR program for people with mild dementia.

We found that a 4-week course of fully-immersive VR I-ADL training was feasible and produced functional and cognitive gains.

Motivation is the most important part of rehabilitation for people with dementia (28). Hence, high satisfaction with VR treatment and good adherence is a great advantage. Manera *et al.* (7,29) reported that people with Alzheimer's disease had higher levels of satisfaction with VR exercises than with conventional exercises.

While most previous studies used semi-immersive VR techniques (30), this study showed that fully immersive VR, which utilizes an environment that is closer to reality, also shows similarly high levels of satisfaction.

In addition, most previous VR studies focused on contents that stimulated cognitive functioning (31). However, this study focused on improving I-ADL. Hence, this study is the first to provide the I-ADL contents that the participants were having difficulties with in daily life. In this study, I-ADL were significantly improved by the VR program, indicating that this training might help people with mild dementia maintain independence in daily life as
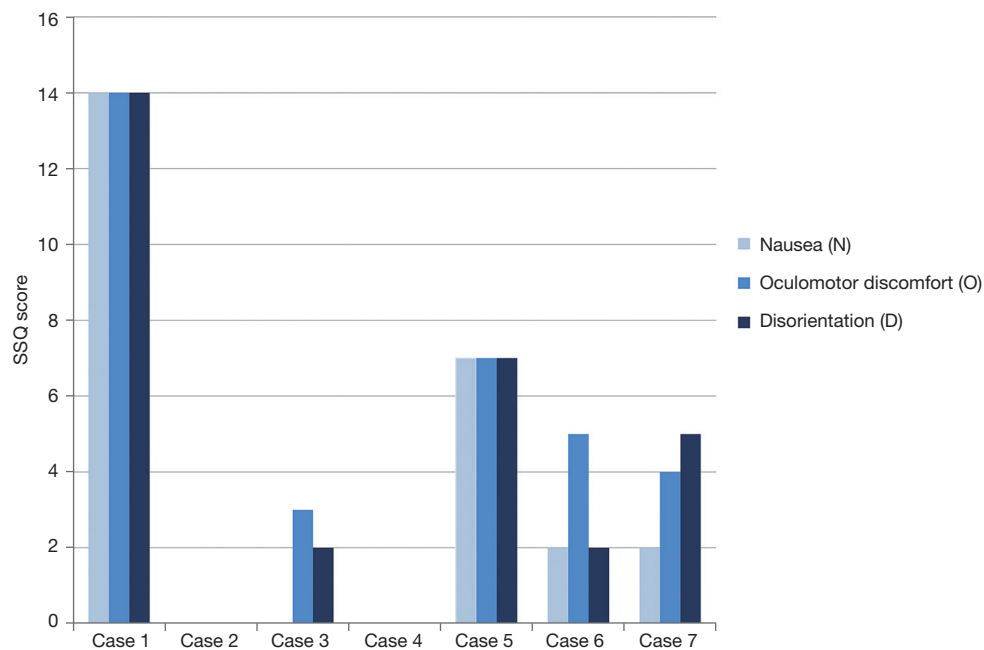
Figure 4 Simulator sickness questionnaire score. One participant showed significant side effects, and six showed minimal or negligible side effects. Symptoms were negligible [<5], minimal [5–10], significant [10–15], and concerning [15–20]. SSQ, Simulator Sickness Questionnaire.

Table 4 I-ADL and BDI score before and after VR training (N=7)

No.	I-ADL		BDI	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
1	36	36	14	12
2[†]	19	8	31	14
3	15	10	10	4
4	14	12	11	8
5	36	36	9	2
6	17	14	11	5
7	19	14	9	7
Mean ± SD	22.28±9.55	18.57±12.09	13.57±7.87	7.42±4.31
Range	14–36	8–36	9–31	2–14
P value	0.042*		0.018*	

[†], participant with marked improvement in particular. Wilcoxon signed-ranks between pre- and post-intervention; *, a significant difference between the pre-intervention and post-intervention. I-ADL, instrumental activities of daily living; BDI, Beck Depression Index; VR, virtual reality; SD, standard deviation.

long as possible. However, due to the small number and absence of a control group, the statistical significance may be overestimated in this study. Case 2 (*Table 4*) showed significantly improved I-ADL and BDI scores compared

to other cases, which may have affected the statistical significance. The high improvement levels in this participant may be due to his relatively younger age (57 years old) and higher initial MMSE score of 28, compared to other

Table 5 CERAD-K before and after VR training (N=7)

Subset	Case 1		Case 2		Case 3		Case 4		Case 5		Case 6		Case 7	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Boston naming (–/15 score)	3	1	11	12	10	9	10	10	7	9	13	14	7	6
Verbal fluency (score)	0	0	9	7	21	16	13	15	3	0	9	7	7	7
Constructional praxis (–/11 score)	11	11	11	11	11	11	11	10	11	11	10	9	8	7
Wordlist learning (–/30 score)	5	2	22	21	18	22	19	19	2	0	14	12	11	10
Wordlist delayed recall (–/10 score)	0	1	8	10	8	9	2	4	0	0	4	5	0	1
Wordlist instruction (–/10 score)	2	1	10	10	10	10	8	7	0	0	8	8	8	6
Visuo-construction recall (–/11 score)	7	5	8	11	8	11	4	2	0	0	10	10	0	0
TMT-A[§] (s)	164	178	37	32	47	45	50	33	72	68	66	66	120	165
TMT-B[§] (s)	NA[‡]	NA[‡]	100	80	267	207	105	101	NA[‡]	NA[‡]	180	163	267	207

[‡], the test could not be performed due to cognitive decline. [§], improvement was observed between the pre-intervention and post-intervention in all participants. CERAD-K, Consortium to Establish a Registry for Alzheimer's Disease Assessment Packet; VR, virtual reality; TMT A, trail making test A; TMT B, trail making test B; NA, not available.

participants. Also, given that the initial BDI was high (score: 31), pseudodementia cannot be excluded. However, considering that there is no marked improvement in the CERAD items in case 2, the improvement in I-ADL seems to be due to the effects of intervention rather than mood improvement.

Another strength of this study is that the intervention was task specific and gave the participants a meaningful task. It is known that such task specific intervention can stimulate cortical reorganization and improve functioning (20,32).

Motion sickness is a common side effect of the VR system, especially when using fully-immersive VR. This limitation has been an obstacle in applying VR training to certain people (33).

In this study, although one participant had moderate motion sickness, six participants showed minimal or negligible side effects. The participant with moderate side effects complained of symptoms only at the beginning and adapted over time. It is well known that VR is safe and acceptable in people with mild cognitive impairment and dementia. However, in a review by Papaioannou *et al.*, most studies utilized a non-immersive type (30). There is not much data on the fully-immersive type. In addition, it is known that susceptibility to motion sickness may increase with aging (34). This can be a serious problem for people with dementia. Thus, in this study, to minimize these risks, participants sat down in a chair and the therapist helped

them reduce unnecessary movements while performing the VR intervention. Because it is known that side effects may be reduced by minimizing factors that cause motion sickness such as standing and head movements (35,36).

Regarding cognition, improvement was observed in Word List Delayed Recall test and TMT-B in all participants. This is in line with the results of a systematic review (37). A recent VR study has also reported improvements in executive functioning (38) after a VR intervention. Executive functioning is usually measurable by the TMT (39). TMT-A measures psychomotor speed and visual scanning, and TMT-B measures working memory (40-42). Our results showed improvements in TMT-B but not in TMT-A, which is consistent with a previous report (43). However, two participants failed the TMT-B test due to cognitive decline. In addition, due to the small number and the multiple comparison problem, statistical significance could not be presented. Further research is needed to present statistical values with a larger number of participants. After the VR intervention, the improvements evident on the BDI scale, suggest that it might, furthermore, be helpful in improving the moods of people with mild dementia. This finding is in line with previous studies stating that psychosocial interventions through multisensory stimulation induced not only emotional and social benefits but also a conserved sense of identity for those with these disorders (44-46).

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Limitations

This study has certain limitations. First, it cannot demonstrate the usefulness of VR I-ADL training in people with mild dementia. Because the sample number was small, and it was not a comparative study. Further studies including control groups are needed to verify effectiveness. Second, some participants had difficulty using controllers. To solve this problem, time was required to explain the use of the controller in every session. Third, there is no procedure to check the validation for each VR task. However, the most necessary task for people with mild dementia was determined by referring to the S-IADL item and feasibility was checked through this study. Fourth, a positive change in mood was seen in all participants. These changes may have affected cognition and function as a secondary gain. In the future, it will be necessary to analyze the correlation of each factor. Finally, in this study, heterogenous participants were analyzed. Since the progress and prognosis of the disease is different depending on the dementia type, it is necessary to analyze the effect of the dementia type and various factors such as age, sex, and dementia severity in future studies.

Conclusions

Fully-immersive VR I-ADL training is feasible and may improve functioning, mood, and cognition in people with mild dementia. However, further studies are needed to compare conventional treatments with VR treatment.

Acknowledgments

Footnote

Reporting Checklist: The authors have completed the TREND reporting checklist. Available at https://apm. amegroups.com/article/view/10.21037/apm-22-847/rc

Data Sharing Statement: Available at https://apm.amegroups. com/article/view/10.21037/apm-22-847/dss

Peer Review File: Available at https://apm.amegroups.com/ article/view/10.21037/apm-22-847/prf

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Asan Medical Center (No. 2020-1861) and informed consent was taken from all the patients.

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Appendix 1 Presence Questionnaire

<Presence Questionnaire>

The following questions are about how you feel after watching a virtual reality video.
Please read each sentence carefully and check the number you think
represents the state you are feeling at this moment.

```
1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7
```
| Not at all true | Mostly not true | A little bit not true | Neutral | A little true | Mostly true | Very true |

	Question
1	The objects in virtual reality felt as if they were real.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
2	The scenery in virtual reality felt as if it were real.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
3	I felt as if I could grab an object in virtual reality.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
4	It felt like I was actually having the experience in the virtual reality.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
5	It was as if I was seeing what the person in the virtual reality was seeing.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
6	When the person in the virtual reality moved, I felt that I moved too.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
7	It was as if the characters in the virtual reality were actually in front of me.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
8	I felt like people in virtual reality were real people.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
9	I felt as if I was in the same space as the people in the virtual reality.
	`1 · · · · · · 2 · · · · · · 3 · · · · · · 4 · · · · · · 5 · · · · · · 6 · · · · · · 7`
Total score	

Appendix 2 Simulator Sickness Questionnaire

	SSQ symptoms	Weight		
		N	O	D
1	General discomfort	1	1	
2	Fatigue		1	
3	Headache		1	
4	Eye strain		1	
5	Difficulty focusing		1	1
6	Increased salivation	1		
7	Sweating	1		
8	Nausea	1		1
9	Difficulty concertrating	1	1	
10	Fullness of head			1
11	Blurred vision		1	1
12	Dizzy (eyes open)			1
13	Dizzy (eyes closed)			1
14	Vertigo			1
15	Stomach awareness	1		
16	Burping	1		
	Total	[1]	[2]	[3]