How Dual-Tasking Using VR Affects the Elderly: A Systematic Review

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Abstract. This study systematically reviewed research that applied dual-task interventions using VR technology for balance and cognitive tasks among older adults. Ten databases were searched following the PRISMA guideline, and 18 studies were selected based on their evidence levels and risk of bias. The selected studies consisted of 10 RCTs, 6 non-randomized controlled trials, and one each of case and qualitative studies. The types of balance tasks included standing and sitting postures, and all studies utilized cognitive tasks that required concentration. A total of 30 physical assessment tools and 42 cognitive assessment tools were identified. The results showed that virtual reality interventions improved balance and cognitive abilities among older adults and had a positive effect on fall prevention. These findings suggest that VR technology can be an effective tool for improving the physical and cognitive health of older adults.

Keywords: Virtual reality · Dual-task · Cognition · Balance · Elderly

1 Introduction

VR is being used by integrating various technologies to experience realistic representations in a virtual space. Research on dual-task training using VR has been conducted on a diverse range of subjects, including individuals with Parkinson's disease, as well as children, adults, and the elderly of all genders and ages. While numerous interventions involving VR programs and devices for dual-task training have been conducted in foreign countries, research utilizing these technologies for such training is still lacking in Korea.

Dual-task training involves performing cognitive tasks while engaging in motor activities, creating a situation of cognitive-motor interference where efforts are divided between two tasks [1]. This induces a state of conflict, requiring high levels of attention and concentration during the execution of motor tasks.

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Dual-task training is easily implemented through VR technology, allowing for personalized exercise, rehabilitation, and interventions for individuals. This approach can be particularly beneficial for older adults and patients requiring rehabilitation, as it can stimulate interest and promote engagement, leading to enhanced daily functioning and recovery [2–4].

It should be noted, however, that the application of VR technology also has its disadvantages, with cybersickness being identified as a common issue among some users [5]. This is a particularly critical issue for individuals with disabilities and the elderly [6]. Head-mounted displays (HMDs) have been identified as a major cause of cybersickness [7, 8]. Therefore, for the elderly, VR programs utilizing technologies other than HMDs are more suitable.

This study aims to systematically review domestic and international research on dual tasks that combine balance and cognitive tasks using VR for older adults, examining the level of evidence, types of tasks used, validation tools, intervention duration, and effects. It intends to provide directions for VR-based dual task research in Korea and offer evidence-based approaches for researchers working with older adults.

2 Methods

2.1 Literature Selection and Study Design

This study examined the effects of dual tasks combining balance and cognitive tasks using VR devices on older adults. The literature selection process was conducted using the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines. The level of evidence of the selected studies was evaluated using the evidence level assessment developed by Abresman, Scheer, and Lieberman (2008) and divided into five levels [9].

2.2 Database and Search Terms

To find relevant studies for the topic, a three-step search strategy was employed between October and December 2022. Firstly, previous research trends were identified using medical and health literature analysis databases (PubMed, CINAHL) and Google Scholar. Secondly, search terms were selected. Lastly, systematic reviews that had been previously conducted on topics related to VR were consulted to select the paper search databases [10, 11].

For domestic databases, the search was conducted using the following search terms: "Elderly" AND "Virtual reality" AND "Balance" AND "Dual task" AND "Cognition" on the Research Information Sharing Service (RISS). For foreign databases, the search was conducted using the same search terms on ACM Digital Library, SCOPUS, PubMed, ScienceDirect, CINAHL, EMBASE, Web of Science, PsycINFO, and IEEE Xplore. Studies conducted between 1960 and December 2022 were included. After collecting all papers retrieved from each database, the final papers were selected according to the following selection and exclusion criteria. In order to ensure that the selected studies were relevant to the research topic, a set of selection criteria and exclusion criteria were used. The inclusion criteria were: (1) Studies that targeted older adults, (2) Studies that used virtual reality to mediate dual tasks related to balance and cognitive tasks, (3) Papers written in Korean or English, and (4) Studies for which the full text is available. The exclusion criteria were: (1) Studies that did not use VR technology as an intervention, (2) Studies that used head-mounted display (HMD) devices for mediation, (3) Studies that targeted older adult patients with central nervous system disorders or chronic diseases, (4) Systematic reviews and meta-analyses, and (5) Thesis studies and protocol studies.

2.3 Method of Results Analysis

For the selected studies, we analyzed the types of dual tasks combining balance and cognitive tasks that elderly individuals perform using VR devices. First, we divided the types of balance and cognitive tasks performed during dual-task interventions using VR and compiled them into a table. Second, we analyzed the assessment tools used to evaluate the effectiveness of dual-task interventions using VR and compiled the results into a table.

3 Results

3.1 Selection of Studies

A total of 3983 studies were retrieved from the initial search of 10 databases. After removing duplicates (n = 421) using EndNote and manual review, we assessed the titles and abstracts of the remaining papers for relevance to Virtual Reality, dual-task, and balance, and excluded irrelevant papers, such as review and meta-analysis papers, papers without full texts, papers with inappropriate study designs, and papers with participants not relevant to the research topic. After the first screening, we collected 137 studies and further excluded irrelevant papers by checking the full texts, resulting in the final selection of 18 papers (Fig. 1).

3.2 Level of Evidence

The evaluation of the level of evidence for the final selection of 18 studies revealed that 10 studies were classified as level 1, accounting for 55.6% of the total. Three studies each were classified as level 2 and level 3, accounting for 16.7% each. Additionally, there were two studies (11.0% in total) classified as level 5 in the evidence level, which included one case report and one qualitative study (Table 1).

3.3 Types of Balance and Cognitive Tasks in Dual-Task Interventions

The analysis of the dual-task intervention using VR, divided into balance task types and cognitive task types, showed that the balance task type had the highest number of tasks in the standing position, with 15 tasks (83.3%). Two tasks (11.1%) were performed in the seated position, and one task (5.6%) included both standing and seated balance tasks. For the cognitive tasks, attention had the highest number of tasks with 18 (32.1%), followed by memory with 16 (28.6%), and executive function with 14 (25.0%). Planning tasks accounted for 4 (7.1%), and calculation and inhibition/interference control each accounted for 2 (3.6%) (Table 2).

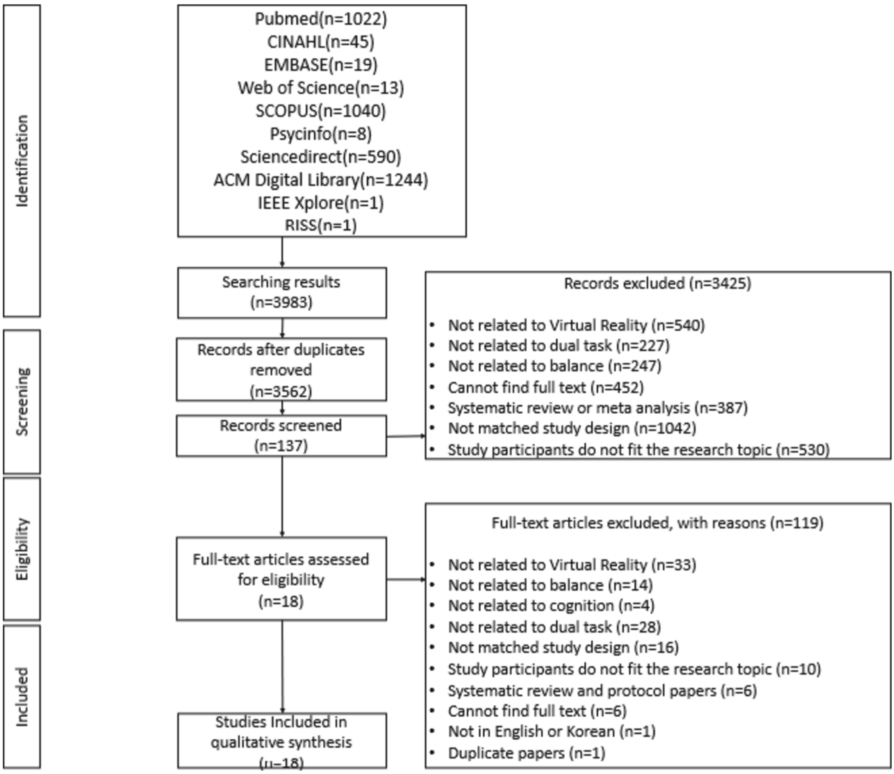

Fig. 1. Flow Diagram of the Literature Selection Process

Table 1. Level of Quality of Each Study

Evidence level	Definition	Frequency, n (%)
1	Randomized controlled trials	10 (55.6)
2	Two groups non-randomized studies	3 (16.7)
3	One groups non-randomized studies	3 (16.7)
4	Single subject designs	0 (0.0)
	Surveys	
5	Case reports	2 (11.0)
	Narrative literature reviews	
	Qualitative researches	
	Total	18 (100.0)

Table 2. Classification of Balance Types and Cognitive Types of Double Tasks

Dual task Intervention		n (%)	Total
Types	Details		
Balance types	Standing Balance (Static Balance, Dynamic Balance)	15 (83.3)	18 (100.0)
	Sitting Balance (Static Balance, Dynamic Balance)	2 (11.1)	
	Standing, Sitting Balance (Static Balance, Dynamic Balance)	1 (5.6)	
Cognition types	Attention	18 (32.1)	56 (100.0)
	Memory	16 (28.6)	
	Executive Function	14 (25.0)	
	Planning	4 (7.1)	
	Calculation	2 (3.6)	
	Inhibition/Interference Control	2 (3.6)	

3.4 Analysis of Evaluation Tools for Assessing the Effects of VR-Based Dual-Task Interventions

Through the selected studies, a total of 30 evaluation tools were identified for measuring the effects of VR-based dual-task interventions on physical functions of older adults, including 26 for balance assessment and 4 for motor function evaluation. Among the balance assessment tools, Mini-BESTest and TUG were the most frequently used, with 3 studies (10.0%) each. Motor function evaluation was conducted with 4 tools, including fNIRS. A total of 42 evaluation tools were used for cognitive function assessment, which was further categorized into executive function, memory, attention, MCI screening test, and overall cognitive function assessment tools. TMT was the most commonly used tool (8 studies, 19.0%) for executive function assessment, while WMS-R was the most frequently used tool (3 studies, 7.1%) for memory assessment. All 5 studies (11.9%) assessing attention utilized Stroop. MoCA was the most frequently used tool (6 studies, 14.3%) for MCI screening. For overall cognitive function assessment, fNIRS and VFT were the most commonly used tools, each in 2 studies (4.8%) (Table 3).

Table 3. Measured Dependent Variables and Outcomes

Dependent variable		Outcomes	n (%)	Total
Types	Details			
Physical (n = 30)	Balance (n = 26)	Mini-BESTest	3 (10.0)	26 (86.7)
		TUG	3 (10.0)	
		FGA	2 (6.7)	
		FSST	2 (6.7)	
		SFT	2 (6.7)	
		SPPB	2 (6.7)	
		10MWT	2 (6.7)	
		BBS	1 (3.3)	
		BIORescue	1 (3.3)	
		EEG	1 (3.3)	
		FES-I	1 (3.3)	
		Five Times Sit to Stand test	1 (3.3)	
		GUG	1 (3.3)	
		Incident Rate of Falls	1 (3.3)	
		LoS	1 (3.3)	
		The Community Balance and Mobility Scale	1 (3.3)	
		YBT	1 (3.3)	
	Motor Function (n = 4)	fNIRS	1 (3.3)	4 (13.3)
		ten-point Borg scale	1 (3.3)	
		Wasps hit	1 (3.3)	
		30 s Sit-to-Stand Test	1 (3.3)	
Cognition (n = 42)	Executive Function (n = 11)	TMT-A, TMT-B	8 (19.0)	11 (26.2)
		VST	2 (4.8)	
		EXIT-25	1 (2.4)	
	Memory (n = 7)	WMS-R	3 (7.1)	7 (16.7)
		ADAS	1 (2.4)	
		CCVLT	1 (2.4)	
		DST	1 (2.4)	

(*continued*)

Table 3. (*continued*)

Dependent variable		Outcomes	n (%)	Total
Types	Details			
		The spatial n-back task test	1 (2.4)	
	Attention (n = 5)	Stroop	2 (4.8)	5 (11.9)
		CWT	1 (2.4)	
		Simple stroop word color test	1 (2.4)	
		TOVA	1 (2.4)	
	Screened as MCI (n = 8)	MoCA	6 (14.3)	8 (19.0)
		K-MMSE	1 (2.4)	
		MMSE	1 (2.4)	
	Overall Cognitive Function (n = 11)	fNIRS	2 (4.8)	11 (26.2)
		VFT	2 (4.8)	
		CNT40	1 (2.4)	
		DSST	1 (2.4)	
		EEG	1 (2.4)	
		RBANS	1 (2.4)	
		Self-Reported Cognitive Function	1 (2.4)	
		WAIS-R	1 (2.4)	
		WAIS-4	1 (2.4)	

ADAS: Alzheimer's Disease Assessment Scale, BBS: Berg Balance Scale, CCVLT: The Chinese version of the California Verbal Learning Test, CNT40: Computerized nerocognitive function test, CWT: The Chinese version of the Stroop Colour and Word Test, DSST: Digit Symbol Substitution Task, DST: Digit Span Test, EEG: Electroencephalogram, EXIT-25: The Executive Interview 25, FES-I: The Falls efficacy scale, FGA: Fuctional Gait Assessment, fNIRS: Functional NIRS, FSST: Four Square Step Test, GUG: Get-up-and-go Test, HbO2: Oxygenated Hemoglobin, LoS: Limits of Stability Scores, MBT: Mind-Body Trainer, K-MMSE: Korea-Mini Mental State Exam, Mini BESTest: Mini Balance Evaluation Systems Test, MMSE: Mini Mental State Exam, MoCA: Montreal Cognitive Assessment, RBANS: the Repeatable Battery for the Neuropsychological Status, SFT: Senior Fitness Test, SPPB: Short Physical Performance Battery, TMT-A: Trail making test-A, TMT-B: Trail making test-B, TOVA: Test of Variables of Attention, TUG: Timed Up and Go, VFT: Verbal Fluency Test, VST: Victoria Stroop Test, WAIS-R: Wechsler Adult Intelligence Scale-Revised, WAIS-4: Wechsler Adult Intelligence Scale-4, WMS-R: Wechsler Memory Scale-Revised, YBT: Y-Balance Test, 10MWT: 10m Walking Test.

4 Conclusion

In this study, we examined research that provided dual-task interventions combining balance and cognitive tasks using VR. We analyzed the types of balance and cognitive tasks used to provide dual-task performance through VR, evaluation tools for analyzing the effects of dual-task performance using VR on the elderly, and the physical, cognitive, and emotional effects, fall prevention rates, and usability of dual-task performance with VR technology. VR dual-task interventions for elderly individuals may have positive effects on their physical balance and cognition. However, it is important to select appropriate challenging tasks based on their cognitive abilities and to create diverse content that can stimulate their interest. Furthermore, it has been observed that while there are numerous existing assessment tools for evaluating physical and cognitive performance separately in the literature review of previous studies, there is a lack of assessment tools specifically designed to evaluate dual-task performance itself. VR technology facilitates the integration of physical and cognitive tasks in dual-task paradigms. Therefore, there is a need for research on the reliability and validity of assessment tools that can evaluate dual-task performance using VR technology.

References

1. Woollacott, M., Shumway-Cook, A.: Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture **16**(1), 1–14 (2002)
2. Hwang, J.-H., Park, M.-S.: Effect of a dual-task virtual reality program for seniors with mild cognitive impairment. Korean J. Clin. Lab. Sci. **50**(4), 492–500 (2018)
3. Pedroli, E., et al.: Characteristics, usability, and users experience of a system combining cognitive and physical therapy in a virtual environment: positive bike. Sensors **18**(7), 2343 (2018)
4. Thalmann, M., et al.: Usability study of a multicomponent exergame training for older adults with mobility limitations. Int. J. Environ. Res. Public Health **18**(24), 13422 (2021)
5. Byun, H., Park, C.W.: Introduction of cybersickness. Korean J. Otorhinolaryngol. Head Neck Surg. **62**(10), 545–553 (2019)
6. Tuena, C., et al.: Usability issues of clinical and research applications of virtual reality in older people: a systematic review. Front. Hum. Neurosci. **14**, 93 (2020)
7. Buhler, H., Misztal, S., Schild, J.: Reducing VR sickness through peripheral visual effects. In: 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR). IEEE (2018)
8. Chang, E., et al.: An integrated model of cybersickness: understanding user's discomfort in virtual reality. J. KIISE **45**(3), 251–279 (2018)
9. Moher, D., et al.: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann. Intern. Med. **151**(4), 264–269 (2009)
10. Bevilacqua, R., et al.: Non-immersive virtual reality for rehabilitation of the older people: a systematic review into efficacy and effectiveness. J. Clin. Med. **8**(11), 1882 (2019)
11. Dermody, G., et al.: The role of virtual reality in improving health outcomes for community-dwelling older adults: systematic review. J. Med. Internet Res. **22**(6), e17331 (2020)