

Virtual reality-based cognitive training for MCI in the elderly: A feasibility randomised pilot study

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Dear Editor,

Mild cognitive impairment (MCI) is an at-risk state for progression to dementia where cognitive functions are objectively impaired but functional abilities remain preserved. Current prevalence of MCI among Singaporean Chinese older adults aged 60 and above stands at 12.5%, but this estimate is projected to rise with population ageing.¹ Significant efforts are taken to delay the conversion of MCI to dementia, given the tremendous healthcare and socioeconomic costs associated with disability and dependency in dementia. With the lack of disease-modifying pharmacotherapy to treat neurocognitive disorders, recent attention has been placed on non-pharmacological interventions including computerised cognitive training to prevent cognitive decline in MCI.²

Cognitive training involves guided repetitive practice of standardised tasks designed to target specific cognitive skills or processes, with the aim of improving cognition via reinforcement of neural pathways and neuroplastic mechanisms.³ Virtual reality (VR) technology presents as a novel application for cognitive training where its wrap-around display screens offer a multisensory and immersive environment that enhances ecological validity over that of traditional computerised interfaces.⁴ VR cognitive training (VRCT) used in the context of rehabilitation for traumatic brain injury, stroke and Parkinson's disease has brought about changes in brain structural and functional connectivity.⁵ A recent systematic review of VRCT on MCI found only 4 randomised controlled studies comparing VRCT to traditional cognitive interventions, with the majority utilising only cognitive screening measures to assess for cognition; and only 1 study had investigated the effectiveness of fully immersive VRCT.⁶ Immersion levels, training modality and the cultural theme of computerised environment are important training design factors as they moderate cognitive outcomes.⁷ This study seeks to contribute

to the dearth in literature on immersive VR training by examining the feasibility and therapeutic efficacy of a fully immersive multi-domain VRCT programme on the attention, memory and executive function of older adults with MCI.

This cross-sectional pilot study employed a randomised controlled design with participants recruited from an outpatient memory clinic in Changi General Hospital, Singapore. Participants were aged between 65 and 85 years, had a diagnosis of MCI by a clinician in accordance with Petersen's criteria, and Mini Mental Status Examination ≥ 23 . Exclusion criteria included severe visual or auditory impairment, major psychiatric disorders and serious medical illnesses. The study was approved by the SingHealth Centralised Institutional Review Board (2020/2239).

Randomly generated intervention allocations sealed in opaque envelopes were provided by a biostatistician to psychologists conducting the interventions. Participants who were assigned to the VRCT intervention group underwent hourly VRCT sessions over a 10-week period conducted in outpatient settings. The VR experiences were administered through a head-mounted Oculus Go Screen V7 (Meta Platforms, Inc, Menlo Park, CA, US) with a 5.5-inch display that weighed 468 grams. The software application used was MindGym (DancingMind Pte Ltd, Singapore) that features visual stimuli reflecting familiar localised environments. The present VRCT programme included applications that involved tasks of memory retention, escaping mazes, listening conversations and interference control. Participants who were assigned to the active control group were reviewed monthly and provided treatment-as-usual, which included weekly homework tasks from a cognitive stimulation booklet.

Feasibility of the VRCT programme was assessed across 4 domains: acceptability based on perceived ease of use and usefulness of VRCT, safety, adherence

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to VRCT sessions and preliminary efficacy. Comprehensive neuropsychological battery was administered by blinded assessors pre- and post-intervention to evaluate the cognitive outcomes of interest, including the Montreal cognitive assessment (MoCA), the frontal assessment battery (FAB), and the repeatable battery for the assessment of neuropsychological status (RBANS).

Data were analysed using SPSS Statistics software version 26.0 (IBM Corp, Armonk, NY, US). Continuous variables were presented as mean and standard deviation or median and interquartile range where appropriate, while categorical variables were presented as frequencies and percentages. A 1-way analysis of variance was conducted to assess the between-group difference of the intervention's effect over time for each outcome measurement. The significance level was established at $P < 0.05$. Cohen's d effect size (ES) was reported alongside the P values. Thresholds of 0.2 for small, 0.5 for moderate and 0.8 for large effects were employed as guiding benchmarks.

Of 33 participants who were screened for eligibility, 11 were randomly allocated to the VRCT group and 11

to the control group. Participants in the VRCT group were older and had poorer MoCA baseline scores. All participants in the VRCT group completed the full 10 weekly sessions with no dropouts. Two controls withdrew from the study due to concerns of visiting the hospital amid COVID-19. No adverse events related to VR usage such as dizziness, headache or fatigue were reported. Most participants reported high levels of comfort while using the interface. About 91% of participants found the VRCT programme useful in enhancing their subjective memory and attention. The VRCT participants exhibited significant favourable changes in the RBANS figure copy ($P = 0.01$) and FAB go/no-go ($P = 0.04$) subdomains over time as compared to the control group (Table 1). While not statistically significant, moderate to large ES favouring the VRCT group were observed in RBANS list recall ($ES = 0.7$) and RBANS figure recall ($ES = 0.8$) over time. Conversely, moderate to large ES favouring the control group was found for RBANS list learning ($ES = 0.6$).

To our knowledge, this is the first fully immersive VRCT programme conducted for older adults with MCI in Singapore. Our study supports the safety

Table 1. Changes in cognitive outcomes between groups at baseline and after 10 weeks.

		n	Baseline	Post	Mean difference (between groups)	Cohen's d	Between groups
			Mean (SD)	Mean (SD)	Mean (95% CI)		P value
MoCA	VR	11	20.8 (3.6)	20.3 (3.7)	-0.7 (-3.5 to 2.2)	0.2	0.64
	CG	9	23.4 (2.9)	23.6 (1.3)			
RBANS							
Figure copy	VR	11	16.7 (2.5)	18.0 (1.5)	3.2 (0.7–5.6)	1.2	0.01 ^a
	CG	9	18.6 (1.2)	16.7 (3.0)			
List recall	VR	11	0.4 (0.9)	1.4 (1.7)	1.1 (-0.4 to 2.6)	0.7	0.14
	CG	9	3.1 (3.1)	3.0 (3.3)			
Figure recall	VR	11	5.5 (3.2)	7.4 (3.9)	2.4 (-0.4 to 5.1)	0.8	0.09
	CG	9	7.2 (6.2)	6.8 (5.3)			
FAB	VR	11	14.4 (2.2)	15.8 (1.7)	0.6 (-1.0 to 2.1)	0.3	0.45
	CG	9	15.8 (1.6)	16.7 (1.2)			
Conflicting instructions	VR	11	2.6 (0.9)	3.0 (0.0)	0.3 (-0.4 to 0.9)	0.3	0.45
	CG	9	2.9 (0.3)	3.0 (0.0)			
Go/no-go	VR	11	2.3 (0.8)	2.6 (0.7)	0.6 (0.04–1.1)	1.0	0.04 ^a
	CG	9	2.9 (0.3)	2.7 (0.5)			

CG: control group; CI: confidence interval; FAB: frontal assessment battery; MoCA: Montreal cognitive assessment; RBANS: repeatable battery for the assessment of neuropsychological status; SD: standard deviation; VR: Virtual reality group

Mean difference (between groups): Change over time in VR – change over time in CG.

^a Significant at the $P < 0.05$ level.

and tolerability of VRCT. Factors that facilitated its acceptability included gradation of training duration and task difficulty that prevented side effects of VR usage and enabled older participants to gain familiarity and confidence in the VR system. Consistent adherence and satisfaction throughout the 10 weekly programme were indicative of sustained motivation and enjoyment levels, key in ensuring longer-term intervention adherence among participants.⁸ Improvements in verbal memory, visual memory and aspects of executive function (specifically response inhibition) were found for the VRCT intervention group. Repetitive practice on prescribed VRCT tasks appeared to have contributed to near transfer effects on immediate neuropsychological testing.² No improvement in attention was found and may be due to insufficient training frequency and intensity to bring about potential benefits.⁹

Due to the study's small sample size and lack of a priori power analysis, which limits statistical validity, our findings need to be interpreted with caution. Larger multicentre randomised controlled trials with higher training frequency and longer follow-up are needed to verify the maintenance of intervention effects on cognitive outcomes. We are unable to explain mechanistic changes in cognitive outcomes due to the lack of pathophysiological markers to understand how VRCT may counter neurodegeneration. To enhance the scalability of VRCT, future studies can also examine the utility of this programme in group-based community settings to meet the cognitive care needs of an ageing population.

Ethics statement

This study was approved by the SingHealth Centralised Institutional Review Board (2020/2239).

Declaration

The authors declare no conflict of interest and have no affiliations or financial involvement with any commercial organisation with a direct financial interest in the subject or materials discussed in the manuscript.

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Keywords: *cognitive impairment, cognitive rehabilitation, cognitive stimulation, cognitive training, dementia, mild cognitive impairment, virtual reality*

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