JGG 2024;72:173-184
doi: 10.36150/2499-6564-N762

Effect of vestibular therapy as an adjunct to cognitive therapy to improve cognition in elderly with mild cognitive impairment (MCI): a randomized controlled trial

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Background and aims. The rate of population aging is drastically accelerating globally, having significant social, economic, and health repercussions. The prevalence of aging-related illnesses, such as mild cognitive impairment (MCI), will rise in elderly population as they get older, highlighting necessity of developing new treatment methods to stop MCI. This study aimed to determine effect of vestibular therapy as an adjunct to cognitive therapy to improve cognition in elderly with MCI.

Methods. This was a three-armed, randomized controlled trial. The study was conducted with an estimated sample size of 36. After eligibility screening, participants were randomly assigned to vestibular therapy as an adjunct to cognitive therapy (VT+CT), cognitive therapy (CT) alone, and a control group. Participants in VT+CT group received vestibular therapy and computerized brain program. The CT alone group received a computerized brain program only. Primary outcome measures were ERP-P300, and Digit Symbol Substitution Test (DSST), and secondary outcomes included Stroop Color Word Test (SCWT) and Trail Making Test. Data was collected at baseline, 8th week, and 2 weeks after intervention.

Results. VT+CT resulted in greater improvement in measures of cognition including ERP-P300 latency ($p < 0.03$) and its amplitude ($p < 0.04$), DSST ($p < 0.00$), and TMT-B ($p < 0.00$) as compared to CT alone, and control group.

Conclusions. Given the superior effects in favor of VT+CT, It could reliably be argued that incorporating vestibular therapy in intervention regimen may yield greater improvements in cognition as evident in present study on measures of cognition like ERP-P300, DSST, and TMT-B in elderly with MCI.

Key words: vestibular therapy, cognitive therapy, vestibular-cognitive interactions, cognition

Received: June 17, 2024
Accepted: September 9, 2024
Published online: November 15, 2024

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How to cite this article: Goswami A, Sehgal CA, Noohu MM, et al. Effect of vestibular therapy as an adjunct to cognitive therapy to improve cognition in elderly with mild cognitive impairment (MCI): a randomized controlled trial. Journal of Gerontology and Geriatrics 2024;72:173-184. https://doi.org/10.36150/2499-6564-N762

INTRODUCTION

The likelihood of aging-related illnesses, such as mild MCI rates rising quickly is expected to coincide with life expectancy becoming longer at older ages. The global prevalence of MCI in the population aged ≥ 60 years is up to 38.6% [1], however, it is roughly 36% among the elderly in

rural part of North India [2]. MCI is a concept initially introduced to identify individuals between normal cognitive aging and dementia [3]. MCI is a transitional phase that exists between normal cognitive function and dementia, without obvious functional limitations [4], as a result, this condition is frequently overlooked. MCI is commonly diagnosed by reviewing the patient's medical history, with confirmation from informant accounts, and conducting cognitive screening assessments [5]. MCI is a risk factor for dementia and is found to progress (4-31%) to Alzheimer's disease (AD) [6]. To promote targeted therapies, it has been more crucial in the field of gerontology and geriatrics during the past few decades to identify the characteristics that predict cognitive decline as researchers believe that early interventions for those who are at risk for cognitive decline and their implementation may be more successful in protecting cognitive functions [7]. Computerized cognitive therapy significantly enhances cognitive areas such as memory, attention, executive functions, and the ability to perform functional activities [8].

Numerous anatomical links between the vestibular system and cognitive regions, such as the hippocampus, have been demonstrated in earlier research. Additionally, through head direction and place cells in the hippocampus, the vestibular system plays a crucial role in spatial learning and navigation by sending information about spatial representation to the hippocampus [9]. The vestibular cortical network is so widely distributed that it could, in principle, impact multiple neurocognitive functions in health and disease [10]. Vestibular system impairments were found in patients with AD and its preclinical stage, MCI in studies, utilizing cervical [11], and ocular methods [12]. The vestibular system plays a crucial role in cognition, and abnormalities in this system observed in MCI patients can lead to issues with spatial cognition [13]. Furthermore, vestibular loss may contribute to AD, first characterized by the degradation of cholinergic networks in the posterior cingulate, middle temporal, and posterior-parietal-temporal areas [14]. Interventions involving the vestibular system may therefore enhance these individuals' cognitive abilities in addition to their vestibular functions. Vestibular rehabilitation (VR), an exercise-focused method for addressing vestibular disorders, aims to improve central nervous system compensation at the vestibular nucleus level and other parts of the vestibular pathways [15]. A study including patients with intractable dizziness who used vestibular rehabilitation (VR) three times a day for one to four months demonstrated improvements in their executive functions, attention, processing velocity, and visuospatial ability [16]. A different study found that conducting repeated 20-minute sessions of galvanic vestibular stimulation led to improved cognitive performance in healthy older adults [17]. Exercises for vestibular rehabilitation were proposed by Cawthorne and Cooksey in the 1940s. These exercises involve lying down, sitting, standing, and moving with the eyes open and closed as well as repetitive motions of the head, trunk, and eyes [18]. Results from a recent RCT suggested that a combination of vestibular rehabilitation exercises and GVS significantly improved verbal and spatial memory in amnestic MCI patients [19]. The incremental effects of the addition of vestibular therapy to cognitive therapy are inconclusive in the literature. This study endeavors to create a treatment plan that enhances cognitive function in elderly with MCI. Consequently, it offers a significant understanding of the clinical association between the cognitive and vestibular systems.

METHODS

This clinical trial was registered in Clinical Trial Registry-India (CTRI) with registration number CTRI/2024/01/061113.

Study design and setting

This was a single-blinded, three-armed randomized controlled trial. The researcher who undertook data collection was not blinded, but the subjects involved in the intervention were blinded. The subjects were recruited from the Centre for Physiotherapy and Rehabilitation Sciences Clinic, M.A. Healthcare Centre, Jamia Millia Islamia University, and referred cases from the community to maximize the generalizability effect of this program. The present study was conducted according to the principles indicated in the Declaration of Helsinki.

Participants and recruitment strategy, and randomization

The inclusion criteria of this program were as follows: (1) being aged 60 or above, (2) both males and females, (3) having basic knowledge of primary education, (4) diagnosed with MCI, (5) Addenbrooke's cognitive examination-III scale score of 84/100 [20], (6) Mini-Mental Status Examination (MMSE) score of < 26/30 [21], and (7) with a score of < 7/28 on short-falls efficacy scale, indicating little to no risk of falls [22], and (6) no prior history of neurological diseases and falling which could contribute to balance instability [23]. The participants were not eligible if they were: (1) taking medications affecting consciousness or indirectly cognitive system, (2) having a history of other neurological conditions that may alter cognition, (3) any significantly diagnosed visual and auditory impairment, (4) already engaged in other programs, and (5) medical contraindications for making the necessary head movements during vestibular rehabilitation (eg. Severe cervical disorder).

The CONSORT guidelines were followed while conducting the randomized controlled trial [24]. The identification of individuals who meet the inclusion criteria was facilitated by the patients' register maintained at the Centre for Physiotherapy and Rehabilitation Sciences Clinic and M.A. Health Care Centre. A set of protocols, comprising information on the study and guidelines for making phone calls, was given to all clinic staff members who were participating in the recruitment. The potential subjects who met the criteria were invited to participate in the study and those who agreed were made to sign a consent form. The block randomization was done using computer-generated software and allocation concealment was done using a "sealed envelope" when block randomization occurred, the group assignments were placed in sealed envelopes and revealed one at a time. A schematic overview of the study design has been shown in Figure 1. Efforts were made to ensure the blinding of each participant and unblinding may only be permitted in cases where participants' adherence to the protocol is challenged due to low motivation or if adverse events are reported. The trial was commenced on 17th January and completed by 3rd April, 2024.

Intervention group 0

VT+ CT group: This group of participants received vestibular therapy as an adjunct to cognitive therapy (VT+CT): (1) Vestibular therapy was administered using Cawthrone and Cooksey's vestibular rehabilitation exercises and, (2) Cognitive therapy was given with a computerized brain program game software from Lumosity Inc. The intervention lasted for 45-60 minutes a day, 3 days a week for a total of 8 weeks. Previous studies have shown that 4-8 weeks is an adequate dose to bring about a change [19,25]. The Multimodal Cawthrone and Cooksey's protocol for vestibular rehabilitation add flexibility, cognition, sensory engagement, and muscle strength components to the exercises [18]. The protocol was composed of four progressive stages including specific exercises performed while lying down and sitting (1 week each) and, subsequently, standing and walking (3 weeks each). Cognitive therapy, beginning with 30 minutes on the first day and increasing to 45 minutes in the seventh and eighth weeks, was given in an incremental regimen. The Six major cognitive areas of Divided attention, selective attention, Information processing speed, Memory, Logical reasoning, and Spatial reasoning were the focus of the study. The difficulty level for each participant was kept the same at the outset. When a predetermined performance standard was met during each exercise the level of difficulty was raised [26].

Intervention group 1

CT alone group: This group of participants only received computerized cognitive therapy procured from Lumosity Inc. for (30-45) minutes a day, 3 days a week for a total of 8 weeks. Beginning with 30 minutes on the first day and increasing to 45 minutes in the seventh and eighth weeks, it was an incremental regimen. The study focused on the six major cognitive areas of divided attention, selective attention, information processing speed, Memory, Logical reasoning, and Spatial reasoning. The difficulty level for each participant was kept the same at the outset. When a predetermined performance standard was met during each exercise, the level of difficulty was raised [26].

Group 2

Control group: this group of participants was instructed to continue with their usual care activities and were given targeted therapy after the conclusion of this study. The key features of the interventions for the 3 groups are summarized in Table I.

Data collection

Data was collected at three time points – at baseline before intervention (T1), at 8 weeks (T2) when the program was completed, and at 2 weeks (T3) after the program was completed to test the sustained intervention effect.

Outcome measures

There were 3 sets of outcome measures: demographics, measures related to cognition, and quality of life measures.

Primary outcome

The primary outcome is the measures related to cognition in the elderly with MCI. Cognitive domains of attention, information processing speed, executive functions, memory, logical reasoning, and spatial reasoning were assessed using ERP-P300, and Digit Symbol Substitution Test (DSST). The measure of P300 has been demonstrated to be impacted by brain disorders that may impair the major cognitive functions of attention allocation and immediate memory by decreasing amplitude and/or increasing latency (fair to good internal consistency and poor to good test-retest reliability) [27]. The DSST measures a range of cognitive operations, good performance on the DSST requires intact motor speed, attention, and visuoperceptual functions, including scanning and the ability to write or draw (specificity and sensitivity of 85.7 and 65.2 respectively with PPV 0.59 and NPV 0.92) [28].

Secondary outcome

The secondary outcomes included measures related to

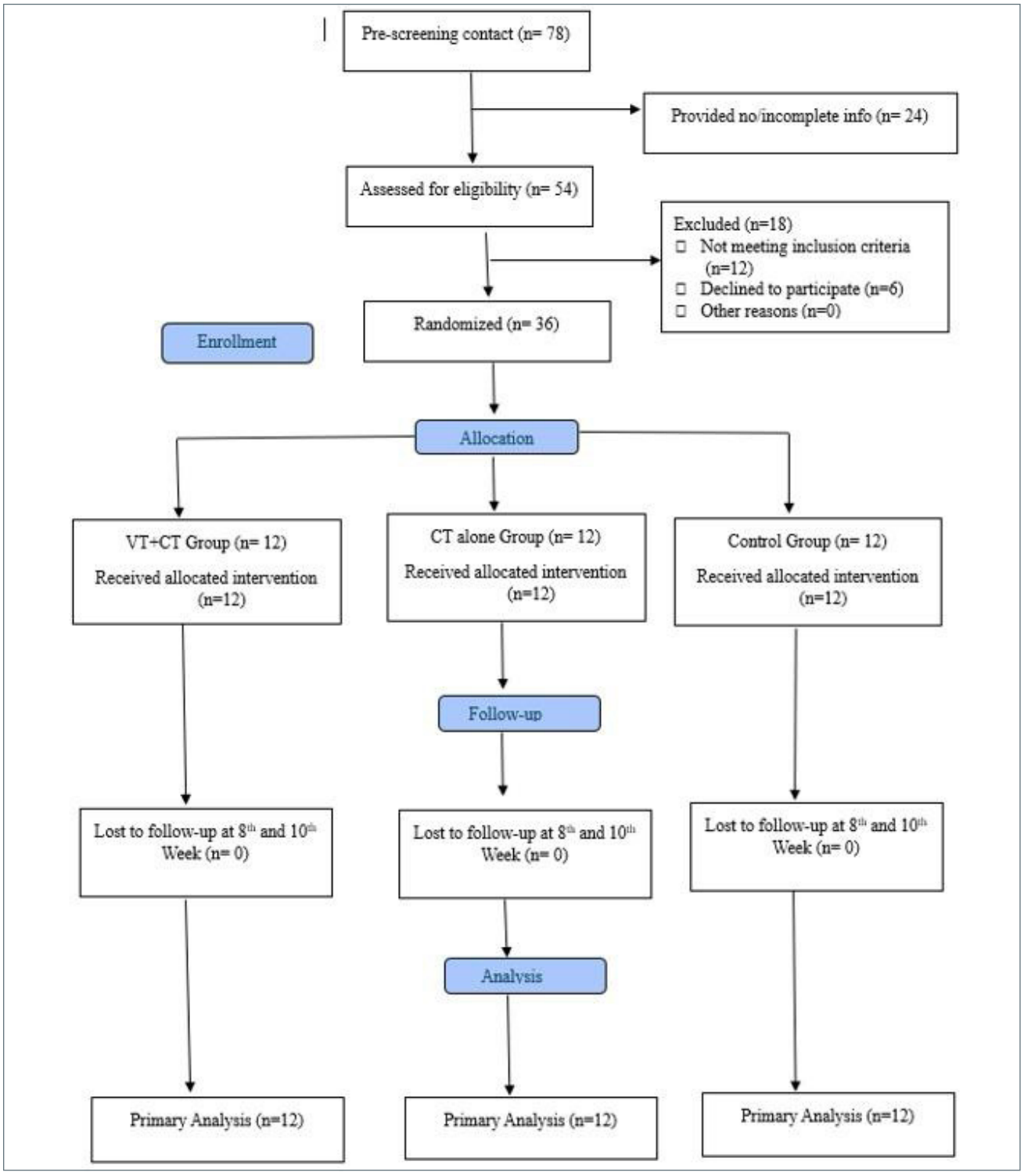

Figure 1. Schematic overview of study design.

cognition. The Stroop color-word test assesses selective attention and inhibition, a valid and reliable measure for the assessment of processing speed and executive functions in older adults with low formal education (with a split-half coefficient of reliability showed high internal consistency > 0.900) [29]. Trail Making Test (TMT-A and

Table I. Description of Intervention for three groups.

Groups	Features	Details
Vestibular therapy + cognitive therapy	Proactive case management with vestibular therapy as an adjunct to cognitive therapy	Multimodal Cawthrone and Cooksey protocol for Vestibular rehabilitation was used in four progressive stages including: Exercise set 1 – In bed or sitting: (Initial 1st week) Eye movement – Head immobile, looking up and down, left and right, and convergence exercises. Head movement – move with eyes open and then eyes closed, bending alternatively, forward and backward, left and right, and roll head and body. Exercise set 2 – Sitting position: (2nd week) Arm and body movements – shrugging and rotating shoulders, bending forward and picking objects from floor, throwing and catching a ball, and turning the head and trunk left to right alternatively. Exercise set – 3 Standing position: (3rd, 4th, and 5th week) Switching from sitting to standing with eyes open and then closed, sitting to standing and then turning around in between, throwing a ball from one hand to the other and following with eyes. Exercise set – 4 Walking position: (6th, 7th, and 8th week) Throwing and catching a ball while walking, climbing stairs up and down with head turned left and right, and up and down slopes. A computerized brain program was used to deliver cognitive therapy beginning with 30 minutes on the first day to 45 minutes in the last week, it was an incremental regimen.
Cognitive therapy alone	A computerized brain program by Lumosity Inc.	Cognitive training was given as enumerated above. The training software was procured from Lumosity Inc. The six major cognitive areas of divided attention, selective attention, information processing speed, memory, and logical and spatial reasoning were the focus of study.
Control group	Usual care group	Participants continued with their usual day activities and will be given targeted therapies after the conclusion of this study

TMT-B) was used to assess executive function and attentional abilities. Part A of TMT evaluates the information processing speed, while part B assesses cognitive flexibility or switching [30]. In part A, the task consisted of connecting numbers (from 1 to 25) with straight lines as fast as possible. In part B, participants had to alternate between letters in alphabetical order and numbers in ascending order (1-A-2-B-3C, etc.) as fast as possible. The total times in seconds for Parts A and B represent the TMT-A and TMT-B direct scores. All outcome measures have been shown in Table II.

Background demographic data

The demographic data, age, gender, marital status, education, accommodation, financial status, family members living in the same household, and caretaking support will be collected at baseline.

Sample size

Power analysis forms the basis for determining sample size [31]. Assuming a 2-tailed α of 0.05, a statistical power (1-β) of 80%, and an effect size of 0.264 after calculating for the same primary outcome measure (Digit symbol substitution test) from the results of previous research studies that provided [32], 11 participants are required per group. Concerning the 10-15% attrition reported in previous programs for community-dwelling older adults, we assume a 10% dropout rate in this study, thus the total sample size needed is 12 participants per group, that is, a total of 36 participants.

Data processing and analysis

The data was coded and presented in numeric form and restricted to the Principal investigator and researcher to ensure confidentiality before, during, and after the

Table II. Outcome measures of the study.

Outcome measures	Tools	Collection time	Methods of data collection
Functions, information, processing speed	ERP-P300	T1, T2, T3	Specific brainwaveforms activities next to a stimulus were recorded using non-invasive P 300 electrodes
Visuoperceptual, functions, attention	Digit Symbol Substitution Test (DSST)	T1, T2, T3	Data was extracted from a pen paper cognitive test presented on a single sheet of paper that requires subjects match symbols to numbers
Selective attention	Stroop Color Word Test (SCWT)	T1, T2, T3	Data was extraxted from a cognitive test sheet having conflicting tasks to test inhibition ability to the irrelevent stimulus
Cognitive flexibility, attention, executive functions	Trail Making Test (TMT A & TMT B)	T1 ,T2,T3	Data scores was extracted from a cognitive test sheet having alphabets and numbers that requires subjects to connect them in a given time

T1: at baseline before intervention; T2: at 8 weeks when the program is completed, T3: at 2 weeks after the program is completed.

trial. Data from the P300, DSST, SCWT, and TMT A & TMT B were entered into the SPSS software (version 26.0, IBM). Each of the variables in the data set was screened by descriptive statistics to detect potential outliers. The normal distribution of data was checked using the Shapiro-Wilk test. To meet the normality criteria, a log transformation of the data was done; thereby meeting the assumption for parametric analysis. One-way Analysis of Variance ANOVA statistics was done to test for non-significant differences in the baseline characteristics of the participants. The sphericity assumptions were checked through Mauchly's test of sphericity. The degree of freedom was adjusted using greenhouse-Geisser correction to meet the sphericity assumptions in case of violation of sphericity. A 3*3 Mixed Model Analysis of variance ANOVA statistics with repeated measures was used to find between-group effects, the within-group (time) effects, and the interaction effects (group*time). A significant result was indicated when the *p*-value (level of significance) was < 0.05 for a 2-tailed test. A Post Hoc analysis with Bonferroni correction was done for pairwise comparisons between the groups.

Data management

One researcher entered the data into an Excel spreadsheet. The entered data was double-checked for any errors. Paper materials related to each participant's assessment and intervention were stored in a binder. The binders were kept inside a lockable shelf at the Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia.

Data monitoring

An independent research advisory committee, which was comprised of the study supervisor, co-supervisor, and three research team members part of the study, got a six-monthly progress report on the status of the study from the researchers at all the stages of the data collection process i.e., screening, subject recruitment, before the intervention, evaluating the intervention, after the intervention and at follow up session.

Data availability

On reasonable request, the corresponding author will make the data related to the paper available, while they are not publicly accessible.

RESULTS

54 subjects were assessed for the eligibility criteria. Out of these 12 subjects didn't meet the inclusion criteria and 6 refused to participate. 36 subjects (Demographic Characteristics given in Table III) were selected to participate in the study and after randomization, they were assigned to either of the three training groups. 12 subjects were allocated to the VT+CT, CT alone, and control groups each. All subjects completed the study and there were no dropouts. There were no adverse events associated with participation in the study. Participants at baseline showed no significant difference between groups in terms of age, weight, height, BMI, MMSE scores, ACE-III scores, S-FES scores, P300 latency, P300 amplitude, SCWT TI, SCWT EI, and TMT-A, TMT-B. However, significant differences at baseline were found in the DSST scores ($p = 0.036$) between the groups (Baseline characteristics are shown in Table IV). There was a significant difference observed in the main effect of group for both, P300 latency ($F = 3.581$, $p = 0.039$, $\eta^2 = 0.178$) and P300 amplitude ($F = 3.445$, $p = 0.044$, $\eta^2 = 0.173$). Furthermore, a significant

difference was observed in the main effect of the group in the measure of DSST (F = 10.819, p = 0.000, η^2 = 0.396). Results are shown in Table V.

A significant difference was found in pairwise comparisons for the P300 latency between group 0 *vs* group 1 (p = 0.047), but not between group 1 *vs* group 2 (p = 0.169) and group 0 *vs* group 2 (p = 0.169). Also, no significant difference was observed for the P300 amplitude between group 0 *vs* group 1 (p = 0.089), group 1 *vs* group 2 (p = 1.000), and group 0 *vs* group 2 (p = 1.000). There was a significant difference noted for the DSST between group 0 *vs* group 1 (p = 0.000), but not between group 1 *vs* group 2 (p = 1.000) and group 0 *vs* group 2 (p = 1.000). Results are shown in Table VI.

However, there was no significant difference in the measure of SCWT error interference in the main effect of group (F = 1.267. p = 0.295, η^2 = 0.071). There was no significant difference observed in the measure of time interference main effect of group (F = 0.060, p = 0.942, η^2 = 0.004). Similarly, there was no significant difference found in measure of TMT-A in the main effect of group (F = 2.716, p = 0.081, η^2 = 0.141). However, there was though significant difference observed in the measure of TMT-B in the main effect of group (F = 6.273, p = 0.005, η^2 = 0.275). Results for all the secondary outcome measures are depicted in Table VII.

A significant difference was found for the TMT-B in pairwise comparisons between group 0 *vs* group 1 (p = 0.004), but not between group 1 *vs* group 2 (p = 0.227) and group 0 *vs* group 2 (p = 0.227).

DISCUSSION

This study examined the effects of VT+CT on cognition in elderly with MCI. Additionally, it explored cognitive-vestibular interactions to inform treatment approaches for MCI. The VT+CT group exhibited a statistically significant reduction in P300 wave latency and a significant increase in P300 amplitude compared to the CT group and the control group. Additionally, significant time effects were observed for the VT+CT group. In line with the present study, Zhao et al. reported reduced latency and higher reaction times in participants engaged in creative expression programs [33]. The VT+CT intervention may enhance cognitive function through several mechanisms. It could trigger persistent endogenous cognitive neurobiological responses and promote self-compensation for cognitive damage. Exercise-induced changes in the hippocampus, such as neurogenesis

Table III. Demographic characteristics of participants.

Variables	N = 36
Age (yrs)	63.47 ± 2.077
Height (m)	1.63 ± 0.077
Weight (kg)	62.67 ± 6.150
BMI (kg/m^2)	23.615 ± 2.262
MMSE score	21.36 ± 1.376
ACE-III score	80.56 ± 2.235
Short-FES score	7.31 ± 0.467

Values presented as Mean ± SD

Table IV. Baseline characteristics of participants.

Variable	Group 0	Group 1	Group 2	F-value	p-value
	N = 12	N = 12	N = 12		
Age (yrs)	63.5 ± 1.83	63.67 ± 2.34	63.25 ± 2.17	0.116	0.891
Height (m)	1.63 ± 0.07	1.61 ± 0.06	1.64 ± 0.09	0.322	0.727
Weight (kg)	63.50 ± 6.45	63.58 ± 6.25	60.91 ± 5.86	0.717	0.495
BMI (kg/m^2)	23.84 ± 1.62	24.26 ± 2.37	22.59±2.51	1.870	0.170
MMSE score	21.25 ± 1.28	21.91 ± 1.16	20.91 ± 1.56	1.709	0.197
ACE-III score	80.75 ± 2.13	80.66 ± 2.01	80.25 ± 2.66	0.164	0.849
S-FES scale	7.33 ± 0.49	7.33 ± 0.49	7.25 ± 0.45	0.121	0.887
ERP-P300					
Pre P300 L	292.99 ± 11.80	298.94 ± 15.43	294.53 ± 19.17	0.460	0.635
Pre P300 A	3.25 ± 1.03	3.98 ± 0.81	3.57 ± 1.19	1.540	0.229
Pre DSST	59.75 ± 2.52	59.58 ± 3.77	59.58 ± 3.77	3.683	0.036*
Pre SCWT TI	13.41 ± 4.63	11.45 ± 3.56	10.04 ± 3.24	2.312	0.115
Pre SCWT EI	0.95 ± 0.39	0.75 ± 0.39	1.08 ± 0.82	1.031	0.368
Pre TMT-A	91.41 ± 4.92	91.25 ± 4.84	88.08 ± 3.94	2.007	0.150
Pre TMT-B	201.33 ± 7.91	202.83 ± 9.25	208.16 ± 15.04	1.240	0.303

MMSE: Mini-Mental Status Examination Scale; ACE-III: Addenbrooke's Cognitive Examination-III Scale; S-FES Scale: Short-Falls Efficacy Scale; ERP-P300: Event-Related Potential P300; DSST: Digit Symbol Substitution Test; SCWT TI: Stroop Color Word Test Time Interference; SCWT EI: Stroop Color Word Test Error Interference; TMT-A: Trail Making Test-A; TMT-B: Trail Making Test-B; Values are presented as Mean ± SD, F-value, p-value.

Table V. Results primary outcome measures.

Dependent variable		F-value	p-value	η^2
ERP-P300				
P300 L	Time	14.766	0.000*	0.309
	Group	3.581	0.039*	0.178
	Time*group	4.563	0.009*	0.217
P300 A	Time	3.609	0.043*	0.099
	Group	3.445	0.044*	0.173
	Time*group	7.088	0.000*	0.301
DSST	Time	24.613	0.000*	0.427
	Group	10.819	0.000*	0.396
	Time*group	3.764	0.017*	0.186

ERP-P300: Event Related Potential-P300; DSST: Digit Symbol Substitution Test; Values are presented as F-values; p-values; η^2.

Table VI. Results post-hoc analysis for Pairwise comparisons.

Variable	Pairwise comparison	Mean difference	Confidence Interval	p-value
ERP-P300				
P300 L	Group 0 *vs* group 1	-8.3147	-16.5386; -0.909	0.047*
	Group 1 *vs* group 2	6.4492	-1.7747; 14.6730	0.169
	Group 0 *vs* group 2	-6.4492	-14.6730; 1.7747	0.169
P300 A	Group 0 *vs* group 1	-0.6156	-1.2984; 0.0673	0.089
	Group 1 *vs* group 2	0.0003	-0.6826; 0.6831	1.000
	Group 0 *vs* group 2	-0.0003	-0.6831; 0.6826	1.000
DSST	Group 0 *vs* group 1	-5.7500	-9.0350; -2.4650	0.000*
	Group 1 *vs* group 2	1.2222	-2.0628; 4.5072	1.000
	Group 0 *vs* group 2	-1.2222	-4.5072; 2.0628	1.000
TMT-B	Group 0 *vs* group 1	15.5556	4.4763; 26.6349	0.004*
	Group 1 *vs* group 2	-8.0556	-19.1349; 3.0237	0.227
	Group 0 *vs* group 2	8.0556	-3.0237; 19.1349	0.227

ERP-P300: Event-Related Potential P300; P300 L: P300 Latency; P300 A: P300 Amplitude; DSST: Digit Symbol Substitution Test; TMT-B: Trail making Test-B; values are presented as mean difference, confidence interval, p-value.

and cell proliferation [34], are likely contributors. Physical activities can reduce oxidative stress and neuroinflammation, increase brain-derived neurotrophic factor (BDNF) expression, enhance calcium messenger RNA levels, and stimulate neuroplasticity [34,35]. These changes support cell growth, survival, memory enhancement, and improved neural transmissions. The broad distribution of the vestibular system includes a distinctive pathway from the semicircular canals to the medial temporal cortex, encompassing the parahippocampal gyrus and hippocampal region [14,36]. it is anticipated that using Cawthorne-Cooksey exercises as a vestibular intervention could enhance memory performance in individuals with aMCI. Statistically significant improvements were noted in DSST scores for the VT+CT group compared to the CT and control groups, with notable time effects for VT+CT. Good DSST performance is linked to sustained attention and visuospatial ability. Lack of peripheral vestibular input can shrink cortical vestibular network regions, including "head direction cells" in the thalamus, subiculum, and entorhinal cortex, and "place cells" in the hippocampus [37]. Spatial working memory centers are located in the hippocampus and basal ganglia, with growing recognition of vestibular-striatal connections [38]. Thus, vestibular therapy likely contributed to synergistic improvements in spatial memory and sustained attention. Additionally, the cognitive game Masterpiece, which targets spatial abilities, may have further enhanced these cognitive domains [26].

The present study showed improvement in all groups in the measure of SCWT (effect of time) with no statistically significant difference observed in favor of VT+CT (no main effect of the group). The results are consistent with the findings reported by Sung et al., wherein they examined the effects of multidomain cognitive function training on cognition in elderly with MCI [39]. The lack of significant improvements in MCI patients from VT+CT may be due to the fact that SCWT assessing selective response to

Table VII. Results secondary outcome measures.

Dependent variable		F-value	p-value	η^2
SCWT TI	Time	21.704	0.000*	0.397
	Group	1.267	0.295	0.071
	Time*group	2.854	0.030*	0.147
SCWT EI	Time	0.683	0.468	0.020
	Group	0.060	0.942	0.004
	Time*group	1.227	0.310	0.069
TMT-A	Time	150.221	0.000*	0.820
	Group	2.716	0.081	0.141
	Time*group	19.370	0.000*	0.540
TMT-B	Time	105.664	0.000*	0.762
	Group	6.273	0.005*	0.275
	Time*group	9.700	0.000*	0.370

SCWT TI: Stroop Color Word test Time Interference; SCWT EI: Stroop Color Word Test Error Interference; TMT-A: Trail Making test-A; TMT-B: Trail making Test-B; values are presented as F-value; p-value, η^2.

stimuli. While cognitive game training improved this domain, VT mainly targets spatial abilities, so the synergistic effects didn't enhance selective attention and inhibition control. Additionally, participants in both groups improved at tasks involving multiple stimuli, with repeated practice reducing interference from new stimuli, as shown by SCWT results. In the present study, participants in the VT+CT group showed enhancements in selective attention, visual-spatial ability, and divided attention over time as measured with TMT-A and TMT-B scores. These findings align with Yang et al. who reported improvements in attentional functions in elderly with MCI following training. Significant differences were observed within and between groups on the TMT-B, indicating improved executive functions in the VT+CT group (main effect of group) [40]. The synergistic effects of virtual reality (VR) and cognitive therapy may have contributed to these enhancements. Game-based training is known to enhance neuroplasticity and motivation for learning in older adults. The VT+CT training, based on activities of daily living (IADLs), effectively promoted complex executive functions, particularly visual attention, through repetitive functional tasks during the 8-week intervention [41]. For instance, games like Familiar Faces trained working memory and task switching, while the Assist Ants game trained divided attention. The enhanced vestibular stimulation and engaging features of the computerized games likely increased motivation and resulted in more substantial training effects on executive function in the VT+CT group compared to traditional combined physical and cognitive training. In contrast, the traditional cognitive program may have lacked these motivating characteristics [41].

Strengths & limitations

Strengths of the study include a stringent and rigorous methodology that ensures robust findings. The follow-up assessments allow for the evaluation of sustained effects post-intervention and identify predictors of treatment response. Objective measure like ERP-P300 accurately reflect changes in cognitive domains. The absence of dropouts enhances the generalizability and adherence to the protocol. However, the study has limitations. The small sample size restricts generalizability and reduces the ability to detect significant differences between groups. Participant homogeneity limits the applicability of findings to diverse populations, impacting external validity. Additionally, the short follow-up period may not capture long-lasting effects, if present.

Clinical implications & future recommendations

Future research should recruit larger and more diverse samples, including individuals with moderate to severe cognitive impairments like dementia and Alzheimer's, to explore the effectiveness of VT+CT therapy. Longitudinal studies with extended follow-up periods are needed to capture long-term effects. Incorporating sensitive multimodal assessment techniques, such as fMRI and clinical biomarkers like BDNF, would provide more reliable results. Further investigations should focus on specific cognitive domains, such as visuospatial abilities, and consider various covariates like gender and co-morbidities such as hypertension and diabetes.

CONCLUSIONS

The present study demonstrates improvements in various cognitive domains, including selective attention, divided attention, working memory, visuospatial abilities, and information processing speed among elderly with MCI after an 8-week intervention (effect of time) with VT+CT (effect of group). These training effects were still evident

at a 2-week follow-up (time interaction effect), indicating the retention of beneficial effects over time. However, the VT+CT was not found to be superior to cognitive therapy alone in enhancing selective attention, sustained attention. Since superior effects in favor of VT+CT have been observed in this study, It could reliably be argued that incorporating vestibular therapy in the intervention regimen may yield greater improvements in cognition as evident in the present study on the measures of cognition like ERP-P300 DSST, TMT-B in the elderly with MCI. The VT+CT could be advised to be utilized in the elderly with MCI as these exercises are utilized with them as evidenced by the no dropouts reported and consequently good adherence to the treatment regimen.

Acknowledgments
We would like to thank the Centre for Physiotherapy and Rehabilitation Sciences clinic and M.A. Health Care Centre for their collaboration with the research team.

Conflict of interest statement
All authors declare no conflict of interest.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions
AG, CAS: conceived the idea and developed the original study plan; MMN: supported the development and implementation of the interventions; SP, MA: verified the analytical methods; AG: wrote the content of the manuscript; CAS: supervised the development of the manuscript. All authors critically revised the draft manuscript and approved the final manuscript.

Ethical consideration
The present study was approved by the Ethics Committee of the University (Proposal reference No.: 19/6/456/JMI/IEC/2023) and written informed consent was obtained from the participants before the commencement of the program.

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