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Original Article

Physiotherapy Section

Effect of Dual Task Training and Virtual Reality on Cognitive Motor Interference in Patients with Parkinson's Disease: A Randomised Clinical Pilot Study

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ABSTRACT

Introduction: Rehabilitation plays a vital role in managing Parkinson's Disease (PD), particularly in addressing both motor and cognitive impairments. Dual Task Training (DTT) improves motor symptoms and cognitive performance, while Virtual Reality (VR) enhances motor function compared to conventional therapy. However, limited evidence exists on the combined effects on Cognitive-Motor Interference (CMI) in individuals with PD.

Aim: To evaluate the effects of DTT and VR individually and in combination on CMI in patients with PD.

Materials and Methods: The present study was a three-arm, single-blinded randomised clinical pilot trial involving 36 participants with PD aged 50-80 years. The participants were randomly allocated into three groups, using sequentially numbered, opaque, sealed envelopes. For five days a week for four weeks, experimental Group 1 received VR treatment, Group 2 received DTT, and Group 3 received a combined treatment of Group 1 and Group 2. Outcome measures, such as the Montreal Cognitive Assessment (MoCA), Movement Disorder Society-Unified Parkinson's disease Rating Scale (MDS-UPDRS) and the Timed Up and Go test (TUG), were used to assess the subject preintervention and postintervention. Normality was assessed using the Shapiro-Wilk test. As the data were normally distributed, a paired t-test was used for pre and post-comparisons, and one-way Analysis of Variance (ANOVA) was used to assess intervention effects.

Results: Participants demonstrated significant improvements in MoCA, MDS-UPDRS, and TUG Scores (p-value <0.001). The VR+DTT group showed the most improvements in MoCA (18.75±1.91 to 26.33±3.22), MDS-UPDRS (62.50±6.98 to 50.25±9.31), and TUG (24.33±3.17 to 17.17±3.97). A significant difference was found between groups in MoCA (p-value <0.001) and TUG (p-value=0.001), but not in MDS-UPDRS (p-value=0.232).

Conclusion: This study concluded that combining DTT with VR may be a promising approach to improve CMI in patients with PD.

Keywords: Cognition, Cognitive dysfunction, Outcome assessment

INTRODUCTION

The PD is a progressive neurodegenerative condition characterised by motor symptoms such as bradykinesia, tremor, rigidity, and postural instability, along with a range of non motor symptoms, including cognitive impairment, mood disturbances, and autonomic dysfunction. As the world population ages, the incidence of PD continues to rise, affecting up to 9% of individuals aged 80 to 84 years [1]. Cognitive decline, particularly Mild Cognitive Impairment (PD-MCI), is common in PD, with prevalence estimates ranging widely from 20-70% depending on the diagnostic criteria and study population [2].

Rehabilitation has emerged as a promising non pharmacological approach to manage the motor and cognitive symptoms of PD [3]. Conventional physiotherapy in PD focuses on improving gait, posture, balance, transfers, upper limb function, and overall physical capacity [4]. Additionally, evidence-based strategies such as the Lee Silverman Voice Treatment (LSVT-BIG), cueing techniques, and cognitive movement strategies have been employed to maintain independence and quality of life [5-8]. CMI is a phenomenon where simultaneous cognitive and motor task performance results in decreased efficiency in one or both domains [9] and is particularly relevant in PD due to impaired automaticity and attentional control [10].

The DTT improves motor and cognitive tasks by enhancing executive function and divided attention [11,12]. VR has gained popularity as an immersive rehabilitation tool, allowing patients to interact with computer-generated environments in real time, offering multisensory feedback that enhances motor learning and motivation [13], with studies showing improvements in gait, balance, and stride parameters following VR-based interventions in individuals with PD [11,14].

Although DTT and VR independently show benefits in improving cognitive and motor functions in PD [12,13], limited research has examined their combined effects on CMI [15]. Addressing this gap is essential, as targeting both motor and cognitive deficits concurrently may yield synergistic outcomes. Therefore, this study intended to evaluate the individual and combined effects of DTT and VR on CMI in patients with PD.

Null Hypothesis (H0)-There is no significant difference among VR, DTT, and combined VR+DTT on CMI in patients with PD and Alternative Hypothesis (H1)- There is a significant difference between VR, DTT and combined VR+DTT in terms of CMI in patients with PD

MATERIALS AND METHODS

This was a three-arm, single-blind randomised clinical pilot trial conducted in a community-based setting and tertiary healthcare hospital's Outpatient Department (OPD) in Mullana, Ambala, Haryana, India between December 2024 and December 2025. The study protocol was approved by the Institutional Ethical Committee (IEC) of a tertiary healthcare hospital (IEC-3117). The Clinical Trials Registry (CTRI) registration number was obtained (CTRI/2025/06/088932). The study complies with the ethical guidelines of the Declaration of Helsinki (2013 revision). After receiving ethical approval, patients who volunteered and met the eligibility criteria for the study attended the assessments and exercise treatment. All participants received information about the study protocols and signed a written consent form.

Inclusion criteria: 1) Diagnosed cases of PD; 2) Age 50 to 80 years; 3) Hoehn and Yahr (H&Y) stage- ≥2 [16]; 4) MDS-UPDRS score for categories mild to moderate (only Part 1 to Part-III will be considered) able to walk independently [17]; 5) MoCA score- 10 to 22 [18]; 6) TUG Test- Between 12 to 30 sec [19]; 7) Both males and females included.

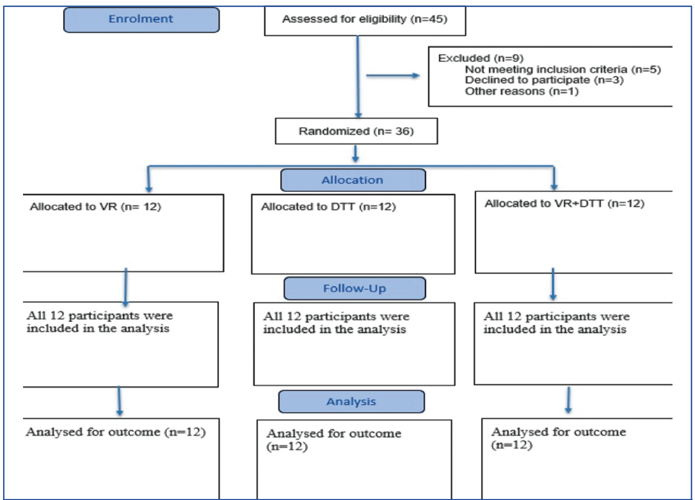
Exclusion criteria: 1) Patient suffering from other neurological conditions like stroke, traumatic brain injury, etc.,; 2) Musculoskeletal conditions that would restrict walking activity; 3) Cardiopulmonary conditions; 4) Surgical procedures for PD, including deep brain stimulation or focused ultrasound; 5) Psychological illness, like dementia.

Sample size estimation: The sample size in the present study was determined based on recommendations for pilot studies. According to the guideline proposed by Julious SA, a minimum of 12 participants per group was considered appropriate for pilot studies to estimate parameters and assess feasibility [20]. Accordingly, 12 participants were included in each group in the present study.

Study Procedure

Thirty-six participants were included from a community-based setting using convenience sampling. According to the rule of conducting a pilot study, 12 samples in each group were included [Table/Fig-1] [20]. All subjects were informed about the study process and treatment in their native language, and written informed consent was obtained from all the participants. Then, participants were randomly assigned by Randomised Allocation Software Version 2.0140 into one of three groups: VR group, DTT group, and combined group.

The therapist provided patients and their caregivers with an information sheet that explained the study protocol as well as the potential risks and benefits. Participants' basic demographic data were collected at baseline, including age, gender, and Body Mass Index (BMI). The protocols ensured that each group had a similar intervention schedule on duration (i.e., 60 minutes per session), frequency (i.e., five times per week), and training structure (i.e., a 5-10-min warm-up, a 45-50-min core activity session, and a 5-min cooldown). As this was a single-blinded study, all participants were blinded to the group allocation. All outcomes were evaluated before intervention and after completing the intervention by the same assessor. Primary outcomes included an MoCA, MDS-UPDRS, and a secondary outcome included TUG.



[Table/Fig-1]: CONSORT flow diagram showing participant recruitment, allocation, follow-up, and analysis across the VR, DTT, and VR+DTT groups.

Outcome measures: Outcome measures included were: MoCA, MDS-UPDRS and TUG. The pre- and postintervention assessments were conducted on Day 1 (baseline) and at the end of the 4th week (postintervention). Demographic and baseline clinical data were collected using a structured data collection form.

Primary outcomes:

- The MDS-UPDRS Parts I-III was used to assess non motor experiences of daily living (Part-I), motor experiences of daily living (Part-II), and motor examination (Part-III). Part-I consists of 13 items, Part-II of 13 items, and Part-III of 18 items with each item scored on a 5-point scale (0-4), where higher scores indicate greater disease severity. The MDS-UPDRS has demonstrated high internal consistency (Cronbach's alpha = 0.79-0.93 across parts) and validity in patients with PD. In the present study, participants with scores representing mild-to-moderate disease severity suitable for participation in the intervention program were included. Part-IV was not included as it assesses motor complications related to pharmacological treatment, which were beyond the scope of this rehabilitation-focused study [17,21].
- The MoCA was used to evaluate cognitive function, including attention, executive function, memory, language, visuospatial ability, abstraction, and orientation. It is a 30-point screening tool, with higher scores indicating better cognitive function. A score below 26 suggests cognitive impairment. The MoCA is a reliable and valid screening tool for detecting mild cognitive impairment [18]. The MoCA score range of 10-22 was selected to represent participants with mild to moderate cognitive deficits, ensuring that they had sufficient cognitive ability to understand and follow instructions while still demonstrating measurable cognitive impairment. Scores below 10 were excluded to avoid severe cognitive impairment. Scores above 22 were excluded to avoid near-normal cognitive functioning.

Secondary outcome: The TUG test was used to assess functional mobility and dynamic balance. It measures the time (in seconds) taken by a participant to stand up from a chair, walk three meters, turn, return, and sit down. Longer completion times indicate poorer functional mobility. The TUG Assessment of Biomechanical Strategies (TUG-ABS) has demonstrated excellent test-retest reliability in individuals with PD (ICC = 0.96) [22]. In the present study, participants with TUG scores ranging from 12 to 30 seconds, indicating mild-to-moderate balance impairment, were included.

Intervention protocol: Each intervention session lasted 60 minutes, conducted five days per week for four weeks. Outcome measures were assessed at baseline (Day 1) and immediately after completion of the 4-week intervention period.

Group 1 {Virtual Reality (VR)}

Patients were engaged in rehabilitation using various VR-based games like "Balance: VR brain training game," "In Mind VR," "Roller Coaster VR," and "VR Tunnel Race". These games were delivered through a VR headset (Manufacture: Careflection, China, Item type name: VR QUEST, HD Video Headset Box for 4-6" Screen Smart Glasses, GOLDEN) and were designed to improve gait, postural control, and balance. They included target-based stepping games, obstacle navigation, rhythmic stepping exercises, and balance board activities [23-25].

Group 2 {Dual-task Training (DTT)}

The DTT group underwent a rehabilitation program that combines gait training with cognitive tasks simultaneously. This included motor exercises alongside tasks that required cognitive engagement. The training was structured to increase progressively in difficulty, starting with simpler tasks like cognitive tasks, which included recalling letter sequences, answering yes/no questions while walking, and motor tasks involved walking forward and backwards on a predetermined path and advancing to more complex dual-task scenarios [15,26,27]. Patients in motor and cognitive tasks were listed in [Table/Fig-2].

Intervention	Procedure	Intensity
Walking with cognitive challenges	Motor Task: Walk at a natural, comfortable speed. Cognitive Tasks: • Count backward from 100. • List animals or fruits that begin with a given letter. • Alternate between saying a number and a letter in sequence (e.g., "1, A, 2, B...").	3-4 times per week
Obstacle navigation with attention tasks	Motor Task: Walk while stepping over obstacles or weaving through cones. Cognitive Tasks: • Solve basic math problems out loud. • Recognise and name colours or shapes shown on cards by the therapist. • React to specific auditory cues, such as clapping when a certain word is heard.	3-4 times per week
Balancing with memory tasks	Motor Task: Balance on one leg or stand on an uneven surface. Cognitive Tasks: • Recite a shopping list backward. • Recall recent events or specific details from a story just read aloud.	3-4 times per week
Marching or dancing with rhythmic counting	Motor task: March in place, dance, or move in rhythm with a beat. cognitive tasks: • Count the steps while avoiding specific numbers, such as divisible by 4. • Respond to verbal commands like "turn left" or "step back."	3-4 times per week
Throwing/ catching with verbal fluency	Motor task: Play catch by tossing a ball to a partner. Cognitive Tasks: • Name items from a specific category (e.g., countries, sports) with each toss. • Provide synonyms or antonyms for words given by the partner.	3-4 times per week
Tandem walking with visual scanning	Motor Task: Walk straight, placing one foot directly in front of the other (heel-to-toe). Cognitive Tasks: • Search for specific objects or colours around you. • Solve a word puzzle displayed on a nearby board.	3-4 times per week

[Table/Fig-2]: Intervention protocol for dual task training [26,27].

Group 3 {Dual-task Training (DTT) +Virtual Reality (VR)}

Patients in this group participated in a rehabilitation program that uses a variety of VR-based games to combine walking workouts and cognitive difficulties. Each session lasted 60 minutes, including a 45-50- minute core training phase. Participants engaged in VR motor tasks while concurrently performing cognitive tasks such as counting backwards, word generation, and responding to verbal cues. This intervention integrates features from both the VR and DTT regimens to simultaneously improve motor function and cognitive performance. As the components were delivered simultaneously, separate time durations for DTT and VR were not assigned. This integrated approach was used to stimulate real-life dual-task conditions and to target CMI in patients with PD effectively.

STATISTICAL ANALYSIS

Statistical Package for the Social Sciences (SPSS) version 26.0 was used for data analysis. Normality of continuous variables was evaluated using the Shapiro-Wilk test. The data were normally distributed, and a paired-samples t-test was used to compare pre- and post-test effects. One-way ANOVA was carried out to detect the intervention effects on the outcome measures. Continuous outcome variables are reported as Mean (M)±Standard Deviation (SD). All tests were two-tailed, with statistical significance set at p-value <0.05.

RESULTS

A total of 36 participants with PD were included in the study, comprising 22 males and 14 females. Participants were randomly allocated into three groups: VR (n=12), DTT (n=12), and combined VR+DTT (n=12). The baseline demographic and clinical characteristics of the participants were comparable among the three groups and are presented in [Table/Fig-3].

Variables	VR (N=12) Mean±SD	DTT (N=12) Mean±SD	VR+DTT (N=12) Mean±SD	p-value
Age (years)	66.75±3.36	69.33±4.75	67.50±3.96	0.21*
Height (cm)	162.72±6.71	163.33±5.56	164.22±10.09	0.87*
Weight (kg)	61.50±7.15	64.91±8.45	56.62±6.49	0.18*
BMI (kg/m²)	23.92±3.44	24.50±2.89	21.35±3.61	0.12*
MoCA score	17.66±2.14	18.58±2.46	18.75±1.91	0.42*
MDS-UPDRS score	61.66±7.17	60.25±7.68	62.50±6.98	0.71*
TUG (sec)	24.50±2.61	24.41±2.93	24.33±3.17	0.98*

[Table/Fig-3]: Demographics of participants.
Values expressed as mean±SD. *Not statistically significant (p-value >0.05) BMI: Body mass index; MoCA: Montreal cognitive assessment scale, MDS-UPDRS: Movement Disorder Society-Unified Parkinson's disease Rating Scale; TUG: Time up and go test
The Shapiro-Wilk test was indicated that data were normally distributed p-value <0.05; therefore, parametric statistical tests were applied.

Within-group analysis: Demonstrated a statistically significant improvement in all outcome measures across the three intervention groups following the four-week intervention. MoCA and MDS-UPDRS measured significant improvement in cognitive function and in functional mobility, as assessed by the TUG test (p-value <0.05). In the VR group, significant improvements were observed in MoCA scores (p-value <0.001), along with significant reductions in MDS-UPDRS scores (p-value <0.001) and TUG completion time (p-value <0.001). Similarly, the DTT group demonstrated significant improvements in cognitive performance (p-value <0.001), motor function (p-value <0.001), and mobility (p-value <0.001), following the intervention. The combined VR+DTT group also showed significant improvements in all outcome measures (p-value <0.001), with the greatest magnitude of improvement observed among the three groups. These findings indicate that all interventions were effective in improving cognitive function, motor symptoms, and functional mobility in individuals with PD (p-value <0.05) in [Table/Fig-4].

Between-group analysis: One-way ANOVA indicated significant differences across the intervention groups in postintervention MoCA (F=11.505, p-value <0.001) and TUG performance (F=8.750, p-value=0.001). However, no statistically significant differences were observed among the groups MDS-UPDRS (F=1.526, p-value =0.232 in [Table/Fig-5].

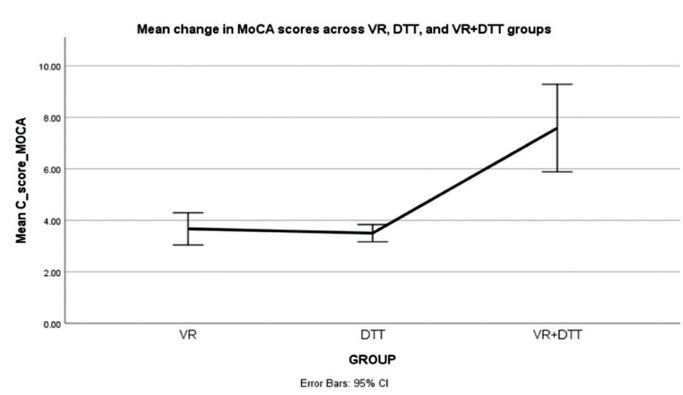
[Table/Fig-6-8] illustrates the mean change in MoCA, MDS-UPDRS, and TUG scores across all three groups. The VR+DTT group showed the greatest improvements compared to the VR and DTT groups in mean scores of MoCA and the greatest reduction in TUG time. In MDS-UPDRS, although the group demonstrated a greater reduction

Group	Group	Outcome	Preintervention Mean ±SD	Postintervention Mean±SD	p-value
Group 1	VR	MoCA	17.66±2.14	21.33±2.42	<0.001*
	VR	MDS-UPDRS	61.66±7.17	56.33±8.31	<0.001*
	VR	TUG (sec)	24.50±2.61	22.25±2.56	<0.001*
Group 2	DTT	MoCA	18.58±2.46	22.08±2.53	<0.001*
	DTT	MDS-UPDRS	60.25±7.68	53.83±8.04	<0.001*
	DTT	TUG (sec)	24.41±2.93	19.00±2.21	<0.001*
Group 3	VR+DTT	MoCA	18.75±1.91	26.33±3.22	<0.001*
	VR+DTT	MDS-UPDRS	62.50±6.98	50.25±9.31	<0.001*
	VR+DTT	TUG (sec)	24.33±3.17	17.17±3.97	<0.001*

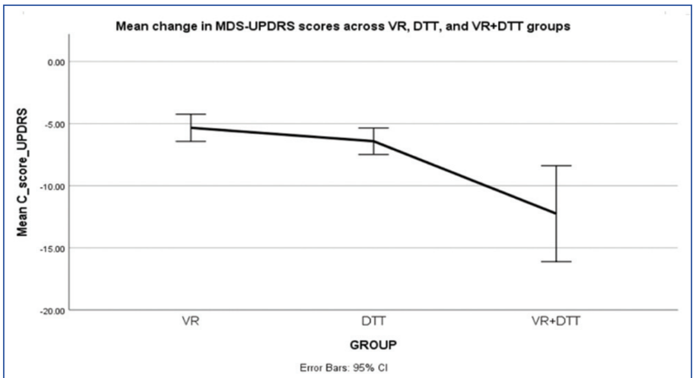
[Table/Fig-4]: Within-group comparison of outcome measures.
Values are presented as Mean±Standard Deviation. Within-group comparisons were performed using paired t-tests. *Statistical significance was set at p<0.05.

Outcome variable	Group	Preintervention Mean±SD	Postintervention Mean±SD	Mean difference	F value	p-value
MoCA	VR	17.66±2.14	21.33±2.42	+3.67	11.505	<0.001*
	DTT	18.58±2.46	22.08±2.54	+3.50		
	VR+DTT	18.75±1.91	26.33±3.23	+7.58		
MDS-UPDRS	VR	61.66±7.17	56.33±8.32	-5.33	1.526	0.232
	DTT	60.25±7.68	53.83±8.04	-6.42		
	VR+DTT	62.50±6.98	50.25±9.31	-12.25		
TUG	VR	24.50±2.61	22.25±2.56	-2.25	8.750	0.001*
	DTT	24.41±2.93	19.00±2.22	-5.41		
	VR+DTT	24.33±3.17	17.17±3.97	-7.16		

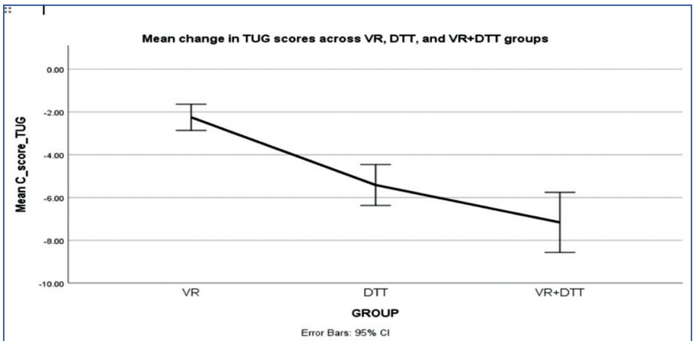
[Table/Fig-5]: Between-group comparison of outcome measures.
*Statistical significance was set at p<0.05.



[Table/Fig-6]: Line graph illustrating the change in mean MoCA scores from preintervention to postintervention among the VR, DTT, and VR+DTT groups. Error bars represent 95% confidence intervals.



[Table/Fig-7]: Line graph illustrating the change in mean MDS-UPDRS scores from preintervention to postintervention among the VR, DTT, and VR+DTT groups. Error bars represent 95% confidence intervals.



[Table/Fig-8]: Line graph illustrating the change in mean TUG scores from preintervention to postintervention among the VR, DTT, and VR+DTT groups. Error bars represent 95% confidence intervals.

in scores, indicating improved motor function, the differences of between-group were not statistically significant (p-value=0.232).

Post-hoc Bonferroni comparisons indicated that the combined VR+DTT group demonstrated significantly greater improvement in cognitive function (MoCA) compared with the VR group and DTT groups (p-value <0.05). There were no significant differences seen between the VR and DTT groups in [Table/Fig-9].

Outcome	Comparison	Mean difference	p-value
MoCA	VR vs DTT	-0.75	0.784
	VR vs VR+DTT	-5.00	0.001*
	DTT vs VR+DTT	-4.25	0.002*
TUG	VR vs DTT	3.25	0.033*
	VR vs VR+DTT	5.08	0.001*
	DTT vs VR+DTT	1.83	0.309

[Table/Fig-9]: Post-hoc Bonferroni comparison between intervention groups.
*Significant at p<0.05

DISCUSSION

This pilot study investigated a unique, integrated rehabilitation method that combines DTT and VR to reduce CMI in individuals with PD. No trial has explicitly investigated the synergistic effects of VR and DTT on balance, cognition, and gait; this investigation might make a substantial contribution to the PD rehabilitation literature. Following the analysis of the results, it can be noted that all the outcomes showed significant changes in the between-group and within-group analysis of all three outcomes except for between group analysis of MDS-UPDRS. Consequently, the study rejects the null hypothesis.

There was a considerable increase in cognitive function (MoCA) in the combined intervention group. Cognition in PD is predominantly caused by front-striatal circuit disruption, which affects attention, executive function, and working memory. VR training promotes cognitive engagement and neuroplasticity by providing multimodal stimulation, task-specific training, and real- time feedback. Pompeu JE et al., and Barboza NM et al., have shown that VR can enhance cognitive function and everyday activities in individuals with PD [28,29]. Furthermore, DTT controls attention and executive function by requiring concurrent cognitive and motor processing, which improves cognitive flexibility and task switching ability [30]. The significant improvement in combined VR+DTT might be attributed to enhanced cortical activation and integration of cognitive and motor pathways, leading to improved cognitive outcomes [27].

The significant improvements in functional mobility (TUG) were seen in all three groups, with a significant improvement in the combined group. VR intervention gives the multisensory feedback, which can help with motor learning, coordination, and postural stability. Similarly, DTT enhances gait performance by improving cognitive load. Previous neuroimaging research [27] suggests that when persons with PD undertake dual-task tasks, there is increased activity in areas such as the anterior cingulate cortex, cerebellar vermis, and precuneus. These activations are believed to be compensatory mechanisms for basal ganglia impairment. These findings indicate that DTT may help increase functional connectivity among brain regions involved in both motor control and cognitive processing, which is especially important for minimising CMI [13,25]. Some research has found that exercise- and task-based therapies enhance mobility, balance, and gait performance in PD [5]. The combination intervention was likely more effective since it addressed motor control, attentional demand, and environmental adaptation simultaneously, resulting in improved functional mobility [31].

Although all groups showed improvements in motor symptoms (MDS-UPDRS), but no significant difference between the groups. Motor symptoms in PD are largely caused by dopaminergic neuron loss and basal ganglia dysfunction. Exercise and rehabilitation therapies can enhance motor performance by improving motor learning, strength, and coordination; the effects may be comparable across different intervention groups [32]. Previous studies have shown that physiotherapy and exercise-based therapies alleviate motor symptoms, although the differences across intervention modalities are frequently minor, which might explain why all groups improved, but no significant between-group difference were seen [33,34].

The results of the current study are consistent with earlier research [27], suggesting that combined cognitive and motor training may offer additional benefits than a single intervention in individuals with PD by increasing neuroplasticity, enhancing sensory integration, and better motor-cognitive coordination. This multimodal strategy has the potential to improve not just individual motor or cognitive results, but also integrated capabilities required for everyday activities and functional independence in PD by improving neural efficiency, motor learning and cognitive processing in individuals with PD [35].

This study's key strength is its novel mix of VR and DTT, which treats both motor and cognitive impairment at the same time. In addition, the inclusion of well-validated clinical tests such as the MoCA, MDS-UPDRS, and TUG test assures the reliability and clinical relevance of outcome measures. The study is further strengthened by a defined intervention timeframe and thorough adherence monitoring measures. Importantly, including a group that received both DTT and VR enables the evaluation of potential interaction or synergistic effects, which might influence more holistic rehabilitation treatments.

Limitation(s)

Despite its potential benefits, numerous limits must be recognised. First, the small sample size may restrict the generalisability of the findings. Second, the relatively short intervention impedes understanding of the long-term efficacy of treatment effects. Third, follow-up assessments were not done to evaluate the sustainability of the intervention effects. These limitations underline the need for cautious interpretation and emphasise the necessity of future investigations with bigger, more varied populations and longer follow-up periods.

CONCLUSION(S)

The present pilot study showed that VR, DTT and combined intervention enhance cognitive function, motor symptoms and functional mobility in individuals with PD. The combined VR+DTT group resulted in greater improvement in cognition and functional mobility as compared to the VR and DTT groups. However, no significant between-group differences were observed for motor symptoms (MDS-UPDRS). These findings suggest that this approach may provide enhanced rehabilitation benefits in individuals with PD.

Data availability statements: Data sharing does not apply to this article as no datasets were generated or analysed during the current study.

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