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Executive functioning as a cognitive-motor bridge in older adults at risk of cognitive decline: Design and baseline findings of the MOVE study

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ABSTRACT

Background: The MOVE (Maintaining Overall cognitiVE and physical functioning in at-risk older adults) study is a randomized controlled trial investigating whether executive function and motor training can promote cognitive functioning and mobility in older adults at risk of cognitive decline. This study aimed to characterize the relationships among executive functioning, prospective memory, mobility, and brain structure in the study cohort. **Methods**: Ninety adults aged ≥60 years with subjective cognitive decline, early mild cognitive impairment, or both were enrolled in the MOVE randomized controlled trial. Before intervention, participants underwent cognitive, affective, prospective memory, and sensor-based motor assessments, including gait, Timed Up and Go, and postural sway. Structural MRI was available for 32 participants. Baseline profiles were compared among participants stratified according to their level of executive functioning, and associations between executive functioning, motor performance, prospective memory, and regional brain volumes were examined. **Results**: Higher executive functioning was associated with better prospective memory, lower fall risk, and more efficient gait and functional mobility. Hippocampal volume was consistently related to prospective memory performance although right cerebellar cortex was involved in remembering to perform an intended action at a specific time. Regional brain volumes across cerebellar, hippocampal, striatal, and parietal regions were associated with gait and functional mobility. Executive functioning significantly mediated the associations between bilateral cerebellar and right striatal volumes and motor performance. **Conclusions:** Executive functioning emerged as a potential link between prospective memory, mobility, and cerebellar integrity, providing a framework for the longitudinal evaluation of cognitive and motor training effects.

KEYWORDS: Ageing, Prevention, Subjective Cognitive Decline, Executive Functioning, Motor Functioning

KEYPOINTS:

1. The MOVE study explores links between cognition, mobility, and brain integrity in older adults at risk of cognitive decline.
2. Better executive functioning is associated with better prospective memory and more efficient mobility.
3. Executive functioning mediates associations between cerebellar and striatal volumes and mobility.
4. Executive functioning may link prospective memory, mobility, and cerebellar integrity.

BACKGROUND

The progressive ageing of the population has made dementia prevention one of the major public health priorities worldwide (1). As the neuropathological processes underlying Alzheimer's disease begin years, if not decades, before the onset of clinical symptoms, increasing attention has shifted from treating established dementia to promoting brain health during the preclinical stages of disease (2,3). Individuals with Subjective Cognitive Decline (SCD), who report persistent cognitive complaints despite preserved objective cognitive performance, and those with early Mild Cognitive Impairment (eMCI) represent particularly relevant targets for preventive interventions because they are at increased risk of progression to dementia (4–8). This preventive approach is further supported by the Brain Health Services recommendations and by the 2024 Lancet Commission (3), which estimated that nearly 45% of dementia cases could potentially be prevented or delayed through modification of risk factors across the lifespan, emphasizing the importance of interventions before objective cognitive impairment becomes evident (2,3).

Growing evidence suggests that cognitive and motor functions are closely interconnected rather than representing independent domains. Executive processes, including inhibitory control, working memory, cognitive flexibility, and attentional control, support goal-directed behavior and are closely linked to mobility (9). Consistent evidence indicates that poorer executive functioning is associated with slower and more variable gait, impaired balance, and an increased risk of future

falls, even among cognitively healthy older adults, suggesting that executive dysfunction may represent an early marker of mobility decline (10,11). These relationships likely reflect shared neural substrates involving fronto-subcortical executive networks together with posterior regions responsible for spatial orientation and sensorimotor integration (12–14).

The close relationship between cognition and mobility is further supported by intervention studies demonstrating bidirectional transfer between the two domains. Physical exercise has consistently been shown to improve executive functions, including inhibitory control, working memory, and cognitive flexibility (15,16). Conversely, executive-based cognitive training improves mobility outcomes, particularly under cognitively demanding walking conditions, and may reduce fall risk (17,18). Together, these findings support the existence of a shared cognitive-motor network in ageing, whereby interventions targeting one domain may induce beneficial changes in the other.

One higher-order cognitive function that may be relevant in this context is prospective memory (PM), defined as the ability to remember to execute intended actions at the appropriate moment in the future (19). PM is essential for everyday functioning because it supports activities such as remembering medications, appointments, or other intended actions while engaged in ongoing tasks (20). Successful PM relies on the coordinated contribution of retrospective memory together with executive processes responsible for intention monitoring, cue detection, attentional switching, and inhibition (21). Accordingly, PM declines with ageing, largely owing to age-related executive dysfunction, and represents one of the most common sources of everyday memory complaints (19,22–24). Importantly, PM predicts functional independence beyond conventional neuropsychological measures and its decline has recently been associated with an increased risk of subsequent cognitive decline, highlighting its ecological and clinical relevance (20,21). Despite the well-established links among executive functioning, mobility, and prospective memory, these research areas have largely developed independently and to date, no studies have directly investigated whether executive-based or motor training improves PM in older adults at risk of cognitive decline. To address these questions, the MOVE (Maintaining Overall cognitiVE and physical functioning in at-risk older adults) project was designed as a randomized controlled trial comparing an executive-function cognitive training program, a motor training intervention,

and a waiting-list control condition in older adults with SCD or eMCI. Our specific and preliminary aims are to evaluate if different levels of executive functioning are associated with changes in PM and motor performance in older adults at increased risk of cognitive decline and assess whether these alterations are reflected in specific neural correlates.

METHODS

Participants

The present study is focused on the baseline cross-sectional characterization of participants enrolled in the MOVE project, a single-center, randomized controlled trial designed to investigate the effects of cognitive and motor training on cognitive, motor, and neuroimaging outcomes in older adults at increased risk of cognitive decline. The MOVE project was prospectively registered on the Open Science Framework (OSF; registration ID: 7dp3e-v1; [2026-03-05]). The preregistration also includes the sample size calculation (25). Between April 2025 and December 2025, 90 community-dwelling older adults at increased risk of cognitive decline were recruited at the Neurocognitive Rehabilitation Centre (CeRiN) of the Center for Mind/Brain Sciences (University of Trento).

To be included, participants had to be aged ≥60 years and meet at least one of the following criteria: (i) early Mild Cognitive Impairment (eMCI), defined as borderline performance on one or more neuropsychological tests according to Italian normative data or a global Clinical Dementia Rating (CDR) score of 0.5 without objective neuropsychological impairment (26) or (ii) SCD according to SCDplus criteria (27) and/or the presence of memory complaints as rated by the Everyday Memory Questionnaire (28). SCD was operationalized following previous studies (29). Individuals were excluded if they had a current or previous history of neuropsychiatric disorders, current or previous substance abuse, or objective cognitive impairment at neuropsychological evaluation.

Phone screening was initially conducted to determine participants' preliminary eligibility, including willingness to participate, age requirements and the absence of major exclusion criteria. Individuals meeting the preliminary eligibility criteria were invited to undergo an in-person extensive neuropsychological assessment. During this visit, a comprehensive medical history

interview and cognitive screening were performed to verify all inclusion and exclusion criteria. Ninety participants (64 females; mean age=71 years; SD=7; maximum sample age= 87; minimum sample age= 60), that met the eligibility criteria, subsequently underwent a further evaluation to assess prospective memory and motor measures. A subset of thirty-two participants underwent an MRI scanning session (23 females; mean age = 71 years, SD = 6; maximum sample age= 83; minimum sample age= 62).

All participants provided informed consent for the study, which was conducted following the ethical guidelines of the local ethics committee (University of Trento Research Ethics Committee, protocol 2025-002) and the Declaration of Helsinki (30).

Baseline neuropsychological assessment

Global cognitive functioning was assessed using the Montreal Cognitive Assessment (MoCA; (31). Attention was assessed using the Symbol Digit Modalities Test (SDMT; (32) and Trail Making Test Part A (TMT-A; (33); executive functioning using the Trail Making Test Part B (TMT-B (33); the TMT B–A difference score (33), the Stroop Test (34), the Paced Auditory Serial Addition Test - 3 seconds (PASAT; (35), phonemic verbal fluency (36), and the Tower of London (ToL; (37), language using semantic verbal fluency (38) and naming tasks (39); memory using Digit Span forward and backward (40), the Corsi Block-Tapping Test (40), the Rey Auditory Verbal Learning Test (RAVLT; (41), and delayed recall of the Rey–Osterrieth Complex Figure (ROCF; (34); social cognition using the Ekman Facial Emotion Recognition Test (42) and the Face Test (43); visuospatial abilities using the Benton Judgment of Line Orientation (44) and ROCF copy (34).

Affective functioning was assessed using self-report measures of anxiety and depression (Hospital Anxiety and Depression Scale, HAD; (45); apathy (Starkstein Apathy Scale, SAS (46), and perceived loneliness (Italian Social and Emotional Loneliness Scale, ISELS; (47)).

Outcome measures

Cognitive scores

Global cognitive functioning was assessed using the Montreal Cognitive Assessment (MoCA; (31)). In addition, participants underwent a comprehensive neuropsychological battery assessing

multiple cognitive domains, including attention, executive functioning, memory, language, social cognition, and visuospatial abilities. For each cognitive test, raw scores were standardized into *z*-scores. For measures in which higher values reflected poorer performance (i.e., time-based variables), *z*-scores were reversed so that higher scores consistently indicated better cognitive performance across all measures. Composite *z*-scores for each cognitive domain were then calculated by averaging the standardized scores of the tests assigned to attention, executive functioning, memory, language, social cognition, and visuospatial abilities.

Prospective memory outcomes

Prospective memory was assessed using PRO-MEMO, a new ecological prospective memory test currently undergoing normative standardization (48). It includes six prospective memory intentions embedded within ongoing attention-demanding paper-and-pencil tasks, thereby minimizing active rehearsal of the intentions. The six tasks include both time-based (n = 3) and event-based (n = 3) intentions. Performance is scored separately for the WHEN component (i.e., successful self-initiated retrieval of the intention at the appropriate time or event) and the WHAT component (i.e., correct recall of the intended action), allowing the distinction between failures of intention retrieval and failures of content recall.

Following completion of the prospective memory task, three complementary questionnaires assessed retrospective memory for the encoded intentions. These included a free-recall questionnaire (Q1), a recognition questionnaire (Q2), and an incidental memory questionnaire (Q3) assessing memory for information encountered during the ongoing attentional activities.

The outcome measures included the WHEN component score, the WHAT component score, the total score (given by the sum of WHEN and WHAT components), time-based and event-based components, and scores on the three memory questionnaires (Q1, free recall; Q2, recognition; Q3, incidental memory).

Motor outcomes

Motor performance was assessed using the mHealth system (mHealth Technologies, Bologna, Italy). The system consists of wearable inertial sensors that provide quantitative measures of gait,

functional mobility, and postural sway. Participants completed three standardized motor tasks: a 12-m walk test (GAIT), a 3-m Timed Up and Go (TUG) test including sit-to-walk, turning, and turn-to-sit phases, and a static balance assessment (SWAY) under different conditions (bipedal stance with eyes open and closed). For the aims of the current work, spatio-temporal and turning parameters were derived from both GAIT and TUG based on previous evidence (49,50), as well as SWAY parameters (51). The mHealth system also generated a composite fall risk index (52), integrating gait performance with demographic, clinical, cognitive, psychological, and fall history information to provide an overall estimate of fall risk.

MRI acquisition and processing

A subset of participants underwent MRI scanning on a 3T Siemens scanner (MAGNETOM Prisma, Siemens Healthineers, Forchheim, Germany) equipped with a 64-channel head receiving coil. High-resolution structural T1-weighted images were acquired using a research-application compressed-sensing Magnetization-Prepared Rapid Gradient Echo (csMPRAGE) sequence (TR = 2300 ms, TE = 2.88 ms, flip angle = 9°, voxel size = 1 × 1 × 1 mm, acquisition time = 1:14, mmPAT = 5.0) (53). Four to six T1-weighted images acquired during the same scanning session were averaged to generate a robust anatomical image prior to preprocessing (54,55).

Structural images were converted from DICOM to NIfTI format using dcm2niix (56) and processed with FreeSurfer 7.4.1. Cortical reconstruction and volumetric segmentation were performed using the *recon-all* pipeline (57). Cortical and subcortical brain volumes were extracted according to the Desikan–Killiany atlas (58). All structural images underwent visual quality control before statistical analyses. Bilateral cortical and subcortical regions of interest (ROIs) were selected based on their involvement in executive functioning, motor control, and sensorimotor integration according to previous literature (13,14,63).

Statistical analyses

To evaluate the effect of executive functioning on PM and motor outcomes, participants were stratified according to their baseline executive functioning composite score: those scoring below the 25th percentile of the sample distribution were classified as the LOWef executive functioning

group, whereas those scoring at or above the 25th percentile were classified as the HIGHef executive functioning group.

Given the inherent variability and potential measurement noise associated with sensor-derived motor data, an outlier removal procedure was applied to the motor measures to reduce the influence of extreme and potentially artefactual trial responses on subsequent analyses. Outliers were identified separately for each motor parameter using the interquartile range (IQR) method. Group differences in PM, motor performance, fall risk, and regional brain volumes were examined using one-way analyses of variance (ANOVAs), with executive-function group as the between-subject factor. For PRO-MEMO outcomes, baseline memory composite score was added as a covariate to control for individual differences in retrospective memory performance. For variables showing significant differences, associations between regional brain volumes and PM or motor outcomes were examined using Spearman correlation coefficients. Mediation analyses were subsequently conducted for the significant brain–motor and brain-prospective memory associations to determine whether executive functioning accounted for these relationships. Regional brain volume was entered as the predictor, executive functioning as the mediator, and the cognitive or motor variable as the outcome. For PRO-MEMO outcomes the total score was considered, while for motor performance gait speed during the GAIT assessment and TUG total duration were selected as summary measures of gait and functional mobility, respectively. Direct, indirect, and total effects were estimated using maximum likelihood estimation and are reported as unstandardized coefficients with 95% confidence intervals. All tests were two-tailed, with statistical significance set at $p < .05$.

Statistical analyses were performed using Jamovi 2.6.44 (64) with a significance level <0.05. Homogeneity of variances was assessed using Levene's test. Depending on whether the assumption of homogeneity was met, either Fisher or Welch's ANOVA was applied. Pairwise group comparisons were subsequently performed using the appropriate post-hoc procedure for each analysis (Tukey's following Fisher's ANOVA and Games–Howell following Welch's ANOVA).

RESULTS

When taking into consideration executive functioning (HIGHef vs LOWef functioning), a significant

difference emerged on the total PRO-MEMO score ($F(1, 87) = 9.37$, $p = .003$), the WHEN component ($F(1, 87) = 11.29$, $p = .001$), the WHAT component ($F(1, 87) = 4.11$, $p = .046$), and the time-based component ($F(1, 87) = 6.85$, $p = .010$), with the HIGHef group showing higher performance compared to the LOWef group (*Table 1*). No significant group differences were observed for the event-based component nor for the retrospective questionnaires.

	LOWef	**HIGHef**	***F***	***p***	**Direction (post-hoc)**
WHEN	3.43 (1.16)	4.67 (1.01)	11.29	**.001**	HIGHef > LOWef, $p = .001$
WHAT	3.70 (1.46)	4.61 (1.03)	4.11	**.046**	HIGHef > LOWef, $p = .046$
Event-based	3.48 (1.61)	4.56 (1.29)	3.40	.069	—
Time-based	3.65 (1.27)	4.72 (1.25)	6.85	**.010**	HIGHef > LOWef, $p = .010$
Total	7.13 (2.28)	9.28 (1.78)	9.37	**.003**	HIGHef > LOWef, $p = .003$
Q1	5.24 (2.37)	6.83 (2.14)	2.08	.153	—
Q2	12.35 (2.15)	13.69 (1.79)	1.97	.164	—
Q3	7.09 (0.85)	7.52 (0.68)	2.28	.135	—

Table 1. Comparison between LOWef vs HIGHef on PRO-MEMO variables. Values are reported as unadjusted means and standard deviations (in parentheses). ANCOVAs were conducted with executive functioning group (LOWef vs. HIGHef) as the between-subject factor and memory performance (composite memory z-score) as a covariate. *F* and *p* values refer to the adjusted group effect. Only significant pairwise comparisons are reported. $p < .05$ was considered statistically significant.

Participants with HIGHef executive functioning also showed significantly lower fall risk scores than those with LOWef executive functioning ($F(1, 88) = 6.04$, $p = .016$). Additionally, participants with HIGHef executive functioning showed more efficient GAIT performance, characterized by longer strides, faster gait speed, shorter stride duration, a longer swing phase, and reduced double-support time. They also performed better on the TUG, completing the task more rapidly, walking faster and with longer steps, and showing higher mean and peak turning velocities. Regarding postural SWAY, the HIGHef group exhibited lower anteroposterior sway velocity under the open-eyes condition, indicating greater postural stability (see *Table 2* for results on specific motor variables).

		HIGHef	LOWef	F	p	Direction
GAIT Spatiotemporal parameters	Variability (s)	1.57 (0.46)	1.60 (0.52)	0.08	.78	—
	Cadence (steps/min)	133.50 (11)	129.46 (10.02)	2.39	.13	—
	Stride Length (m)	1.58 (0.17)	1.44 (0.17)	10.77	<.01	HIGHef > LOWef
	Gait Speed (m/s)	1.76 (0.20)	1.56 (0.22)	15.95	<.01	HIGHef > LOWef
	Stride Duration (s)	0.90 (0.08)	0.93 (0.07)	4.20	.04	HIGHef < LOWef
	Swing Time (%)	43.14 (1.40)	42.32 (1.59)	4.96	.03	HIGHef > LOWef
	Double Support (%)	13.61 (2.77)	15.43 (2.73)	6.41	.01	HIGHef < LOWef
TUG						
Spatiotemporal parameters	Total Duration (s)	9.94 (1.62)	11.06 (1.40)	8.74	<.01	HIGHef < LOWef
	Gait Speed (m/s)	1.38 (0.27)	1.17 (0.19)	12.01	<.01	HIGHef > LOWef
	Cadence (steps/min)	110.19 (13.20)	109.02 (7.91)	0.24†	.62	—
	Mean Step Length (m)	0.79 (0.12)	0.70 (0.11)	8.28	<.01	HIGHef > LOWef
	Mean Step Duration (s)	0.56 (0.06)	0.57 (0.05)	2.03	.16	—
	Standard Deviation of Step Duration (s)	0.08 (0.04)	0.09 (0.04)	0.72	.40	—
Turning parameters	Turn 1 Average Velocity (°/s)	115.39 (21.83)	105.64 (20.23)	3.54	.06	—
	Turn 1 Peak/Max Velocity (°/s)	200.41 (38.13)	180.63 (33.15)	4.91	.03	HIGHef > LOWef
	Turn 2 Average Velocity (°/s)	126.38 (24.27)	110.60 (22.09)	7.56	<.01	HIGHef > LOWef
	Turn 2 Peak/Max Velocity (°/s)	214.19 (33.34)	195.09 (35.98)	5.40	.02	HIGHef > LOWef
SWAY						
Eyes open	Mean anteroposterior sway velocity (mm/s)	3.81 (0.99)	4.30 (1.03)	4.13	.04	HIGHef < LOWef

		HIGHef	LOWef	F	p	Direction
	Mean mediolateral sway velocity (mm/s)	2.58 (0.77)	2.71 (0.86)	0.42	.52	—
	Total sway area (mm^2/s)	14.52 (8.32)	16.85 (8.93)	1.14	.29	—
	Total horizontal sway path length (mm)	192.64 (47.99)	210.51 (55.86)	2.15	.15	—
Eyes closed	Mean anteroposterior sway velocity (mm/s)	5.09 (1.60)	5.33 (1.69)	0.34	.56	—
	Mean mediolateral sway velocity (mm/s)	3.13 (1.43)	3.27 (1.50)	0.16	.69	—
	Total sway area (mm^2/s)	21.09 (13.20)	23.23 (13.38)	0.44	.51	—
	Total horizontal sway path length (mm)	248.10 (76.53)	260.74 (83.98)	0.44	.51	—

Table 2. Comparison between HIGHef and LOWef performance at TUG, GAIT and SWAY.
Note. Values are reported as mean (SD). † Welch's ANOVA is reported because Levene's test indicated heterogeneity of variances; Fisher's ANOVA was used for all other variables. Only significant post-hoc comparisons are reported.

Participants of the HIGHef group showed significantly larger regional brain volumes than those with lower executive functioning in the right inferior parietal cortex (F = 6.20, p = .018), posterior cingulate cortex (F = 5.36, p = .028), superior parietal cortex (F = 4.50, p = .042), insula (F = 4.55, p = .041), and accumbens (F = 5.92, p = .021), as well as in the bilateral cerebellar cortex (Fs = 4.81–5.89, ps = .036–.021, left-right), putamen (Fs = 7.84–6.82, ps = .009–.014, left-right), and hippocampus (Fs = 4.63–6.02, ps = .040–.020, left-right). Significantly larger volumes were also observed in the left rostral middle frontal cortex (Welch's F = 5.61, p = .024). No other significant differences emerged (see *Supplementary Table S1*). When considering PRO-MEMO performance, hippocampal volume showed the most consistent associations across outcomes. Bilateral hippocampal volumes were positively associated with the WHEN sub-score (left: ρ = .540, p = .001; right: ρ = .438, p = .012), while left hippocampal volume was also positively associated with the Time-based sub-score (ρ = .554, p = .001) and total PRO-MEMO score (ρ = .425, p = .015). Additional associations emerged between the WHEN sub-score and right putamen volume (ρ = .374, p = .035), and between the Time-based sub-score and right cerebellar cortical volume (ρ =

.356, p = .046). Considering the motor variables, larger regional brain volumes were associated with better motor performance, as reflected by longer strides, faster gait speed, shorter TUG duration, and higher angular velocities (see *Supplementary Table S2*).

Bilateral cerebellar and hippocampal volumes were significantly associated with several GAIT (i.e., stride length and gait speed) and TUG parameters (i.e., total duration, gait speed, and angular velocity measures). Additional brain–motor associations involved the right putamen, nucleus accumbens, and inferior parietal cortex, which were related to both GAIT and TUG parameters, while associations with the right superior parietal and posterior cingulate cortices were specific to TUG performance. Mediation analyses further examined whether executive functioning accounted for the associations between regional brain volumes and outcomes, using gait speed and TUG total duration as representative measures of gait and functional mobility, respectively. Significant indirect effects through executive functioning were observed for several brain–motor associations. Executive functioning mediated the association between right putamen volume and both gait speed (indirect effect: $b = 1.04 \times 10^{-4}$, p = .039) and TUG total duration ($b = -7.22 \times 10^{-4}$, p = .016), as well as between right accumbens volume and TUG total duration ($b = -3.40 \times 10^{-3}$, p = .036). Executive functioning also mediated the association between bilateral cerebellar cortical volumes and TUG total duration [left: indirect effect, $b = -6.28 \times 10^{-5}$, p = .039; right: $b = -6.61 \times 10^{-5}$, p = .032]. No significant effect was found for PRO-MEMO total score. See figure 1.

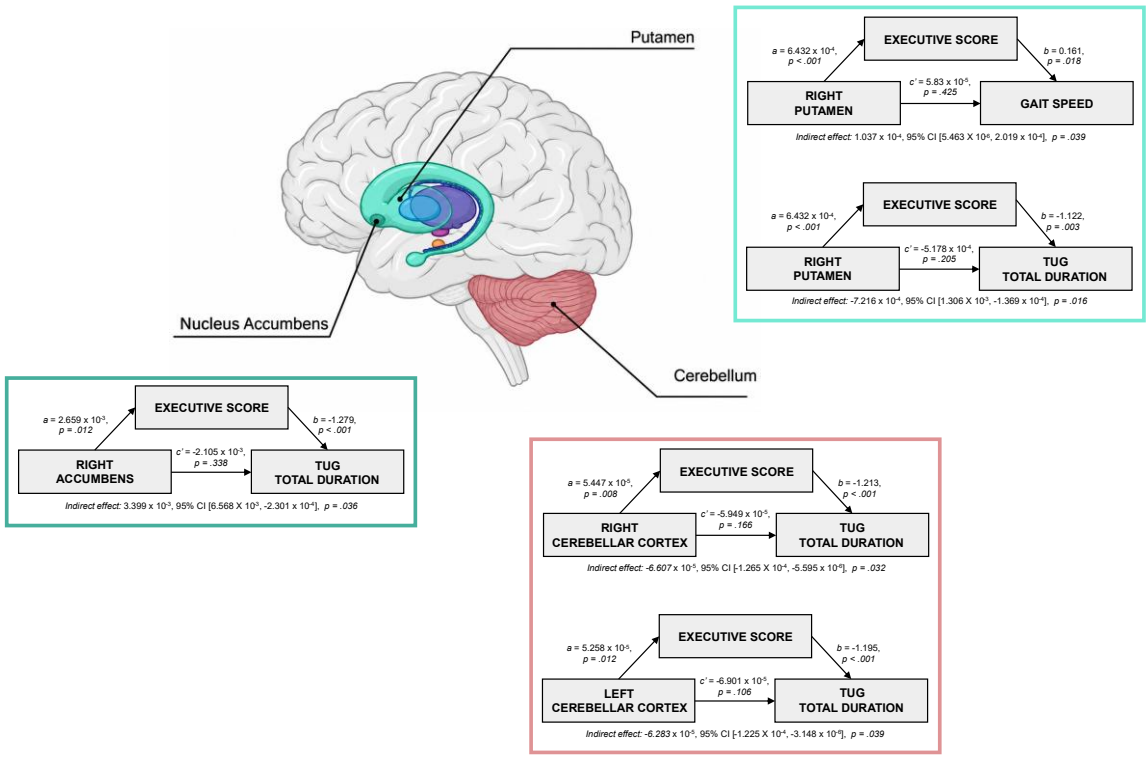

Figure 1. Mediation models linking brain volumes, executive functioning, and motor performance.

DISCUSSION

The MOVE project aims to investigate cognitive and motor functioning in older adults with SCD or eMCI, with a particular focus on the interplay between these domains and their potential relevance for interventions. Within this framework, the present study investigated how executive functioning, PM, and mobility are related in this population. By stratifying participants according to their level of executive functioning, we examined whether lower and higher executive functioning were associated with differences in PM and motor performance, and explored the neural correlates of these relationships. These baseline findings thus provide the foundation for evaluating whether and how cognitive and motor interventions within the MOVE trial modify these interconnected cognitive, motor, and neural processes over time.

Consistently with previous literature on older healthy adults, higher executive functioning was associated with better PM performance (21) and a more efficient motor profile (65–68), including lower fall risk and better gait, functional mobility, and postural stability.

A central finding was the consistent association between executive functioning and PM. Participants with higher executive functioning achieved better overall PRO-MEMO performance, with differences involving both the prospective (WHEN) and retrospective/content (WHAT) components of the task. The association was particularly evident for time-based PM, whereas no significant differences emerged for event-based intentions or for the retrospective memory questionnaires. This pattern is consistent with previous accounts emphasizing the contribution of executive control to the self-initiated retrieval of delayed intentions (69,70). The present findings therefore suggest that individual differences in executive efficiency may already translate into differences in an ecologically relevant cognitive ability in older adults who are still largely functionally independent.

At the neuroanatomical level, better PM performance was primarily associated with larger hippocampal volumes, with additional associations involving the putamen and cerebellum in the prospective and time-based components. These findings are in line with evidence suggesting complementary contributions of the hippocampus, basal ganglia, and cerebellum to temporal processing, with the hippocampus supporting temporal memory and striatal–cerebellar circuits possibly contributing to timing and appropriately timed actions (71,72).

The relevance of executive functioning extended beyond PM to the motor domain. Participants with higher executive functioning showed a more efficient motor profile, characterized by faster gait, longer strides, better functional mobility, and lower fall risk. This finding is consistent with previous evidence indicating that mobility increasingly relies on executive resources in older age, particularly for the planning, monitoring, and adaptive regulation of goal-directed movements (9,73).

The close relationship between executive functioning and mobility was further supported by the neuroimaging findings. Larger regional brain volumes were associated with better motor performance, with bilateral cerebellar and hippocampal volumes showing the most consistent associations across gait and TUG measures. Additional associations involving the putamen,

nucleus accumbens, and parietal regions further suggest that mobility relies on a distributed network encompassing motor, cognitive, and integrative systems.

Importantly, the mediation analyses provided further insight into these brain–behavior relationships, showing that executive functioning significantly mediated the associations between bilateral cerebellar volume and TUG duration, as well as between striatal volumes and motor performance. This pattern supports a distributed cognitive-motor framework in which mobility relies on the interaction between executive-control processes and subcortical motor systems. Interestingly, recent functional neuroimaging evidence further indicates that the cerebellum and basal ganglia, including the putamen and nucleus accumbens, participate in distributed networks supporting higher-order cognitive operations such as working-memory manipulation and action planning (74). These findings reinforce a systems-level view in which cerebellar and striatal structures contribute to both cognitive and motor control rather than operating as exclusively motor substrates.

Within the striatum, the putamen contributes to the selection and regulation of goal-directed movement, whereas the nucleus accumbens may support mobility through the integration of cognitive, motivational, and motor information, with greater accumbens volume previously associated with better gait performance in older adults (75).

Cerebellar integrity has also been associated with gait speed and overall mobility and may contribute to locomotion through the coordination and adaptive regulation of movement (76,77). Importantly, evidence from functional neuroimaging further suggests that the contribution of the cerebellum to motor control changes with ageing, with a greater cerebellar recruitment in older adults, possibly reflecting reduced motor automaticity. In this context, our findings may complement the reduced-automaticity account proposed by Zapparoli and colleagues (78), suggesting that when motor behavior becomes less automatic, the relationship between cerebellar integrity and efficient mobility may increasingly involve executive-control resources.

Overall, the convergence of cerebellar and striatal mediation effects suggests that executive functioning may represent a functional bridge between the integrity of distributed cognitive-motor circuits and mobility. However, given the cross-sectional design, these indirect effects should not be interpreted as evidence of causal pathways.

Taken together, these converging behavioral and neuroimaging findings position executive functioning at the intersection of cognition, brain integrity, and mobility, supporting its potential role as a functional bridge within distributed cognitive-motor networks. These findings also provide the baseline framework for evaluating whether the cognitive and motor interventions implemented within MOVE can modify these relationships over time.

Some limitations should be acknowledged. First, the relatively small clinical subgroups and MRI subsample may have limited statistical power, in this context the neuroimaging findings should therefore be considered exploratory. Second, the single-center recruitment of a selected population with SCD and/or subtle cognitive impairment may limit the generalizability of the findings. Despite these limitations, the present results highlight the close interplay between cognitive, motor, and neural functioning in older adults at increased risk of cognitive decline.

CONCLUSIONS

The present study highlights the close interplay between executive functioning, prospective memory, mobility, and brain structure in older adults at increased risk of cognitive decline. Higher executive functioning was associated with better prospective memory and more efficient motor performance, while cerebellar and striatal volumes showed associations with mobility partly accounted for by executive functioning. These findings support the role of executive functioning as a potential functional link within distributed cognitive-motor networks. Longitudinal analyses of the MOVE trial will help determine whether cognitive and motor interventions can modify these relationships and translate into functional benefits.

ADDITIONAL FILE

Additional file (DOCX). This file contains *Supplementary Tables S1–S2*, reporting additional analyses of MRI-derived brain volumes: (*S1*) Comparison between LOWef and HIGHef groups on MRI variables, and (*S2*) Correlations between motor and MRI variables.

LIST OF ABBREVIATIONS

ANOVA: Analysis of variance

CDR: Clinical Dementia Rating

eMCI: Early mild cognitive impairment

fMRI: Functional magnetic resonance imaging

GAIT: 12-m walk test

HAD: Hospital Anxiety and Depression Scale

HIGHef: Higher executive functioning group

IQR: Interquartile range

ISELS: Italian Social and Emotional Loneliness Scale

LOWef: Lower executive functioning group

MoCA: Montreal Cognitive Assessment

MRI: Magnetic resonance imaging

PM: Prospective memory

RAVLT: Rey Auditory Verbal Learning Test

ROCF: Rey–Osterrieth Complex Figure

ROI: Region of interest

SAS: Starkstein Apathy Scale

SCD: Subjective cognitive decline

SD: Standard Deviation

SDMT: Symbol Digit Modalities Test

SWAY: Static balance assessment

TMT: Trail Making Test

ToL: Tower of London

TUG: Timed Up and Go

DECLARATIONS

Ethics approval and consent to participate

The study was approved by the University of Trento Research Ethics Committee (protocol number 2025-002). All participants provided written informed consent before participation. The study was conducted in accordance with the Declaration of Helsinki.

Clinical trial number

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request, subject to applicable ethical and institutional requirements.

Competing interests

The authors declare that they have no competing interests.

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